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February 12, 2026

Via E-Mail and Online Submission

Orange County Board of Supervisors
400 Civic Center Drive
Santa Ana, CA 92701

Re: Justification of Appeal of Planning Commission Approval of Saddleback Meadows Use Permit No. PA23-0119 (January 28, 2026 Planning Commission Meeting)

Dear Members of the Board of Supervisors:

On behalf of the Saddleback Canyons Conservancy and the Rural Canyons Conservation Fund, we respectfully submit this appeal of the Planning Commission's approval of the Use Permit for the Saddleback Meadows Project ("Project"). As detailed below, and in our two prior letters to the Board of Supervisors and the Planning Commission (Exhibit A), and the separate January 26, 2026 letter from Tiffany Yap, D.Env/PhD, of the Center for Biological Diversity to the Planning Commission (Exhibit B, "CBD Letter"), which are all attached hereto and fully incorporated by reference as providing additional bases for this appeal, the Project violates the County's zoning ordinance, is inconsistent with the Foothill/Trabuco Specific Plan, fails to comply with the California Environmental Quality Act (CEQA), and poses significant threats to public safety and the environment. Each of these flaws mandate denying the Use Permit. For these reasons, as further discussed below, the Planning Commission's approval was improper and should be reversed so that the Use Permit is denied.

I. The Project Threatens Public Safety.

The Project would place 181 new residential units in a Very High Fire Hazard Severity Zone, as identified by the State Fire Marshal, with constrained evacuation routes. The County's prior EIR is nearly 25 years old, and provides no evacuation modeling, no assessment of roadway capacity to accommodate simultaneous project and community evacuation with emergency access, no traffic modeling under emergency conditions, and no evaluation of impacts on existing evacuation plans and existing conditions with hundreds of new homes that now surround the project site. *See* Draft Revised Subsequent Environmental Impact Report, EIR 566 (April 2002) ("2002 RSEIR"). Adding new development in the wildland-urban interface without adequate evacuation analysis and planning endangers both new residents and existing community members who share the same limited evacuation routes.

Notably, since the Project's original approvals, thousands of new homes have been built in nearby areas (e.g., Iron Ridge, Sky Ridge, Saddle Crest), significantly increasing traffic on El Toro and Santiago Canyon Roads. The County must examine the capacity of current infrastructure to handle the cumulative traffic from these new developments during wildfire evacuation conditions before approving any further development. Notably, the Planning Commission staff report did not describe what, if any, evacuation studies have been completed to ensure that the Hidden Ridge community can safely evacuate along with the portion of the new 181 homes that would exit the Project site or address the ingress and egress of emergency vehicles to the new neighborhood via Valley Vista Way during a wildfire evacuation. The Planning Commission should have denied this Project based on these serious public safety concerns, which were repeatedly voiced during public comments at the January 26, 2026 Planning Commission hearing.

II. The Project is Inconsistent with the County's Zoning Code and Foothill/Trabuco Specific Plan.

The Project violates the County's zoning code and the Foothill/Trabuco Specific Plan's (F/TSP) standards and cannot be approved as designed. The F/TSP designates the property as Residential Estates (RE) with a Planned Development (PD) combining district, which requires compliance with the RE base district standards modified only as permitted under the PD regulations. The RE zone requires a minimum building site area of 20,000 square feet per unit. *See* Orange County Code § 7-9-31.3. Although the PD combining district allows flexibility on individual lot sizes and setbacks, it mandates that "the net development area shall have an average land area per unit no less than the minimum area per unit required by the base district." *Id.* § 7-9-48.6(c). This means that, if approved, a project could have lots that are less than 20,000 square feet, but those smaller lots need to be balanced out by larger ones so that the lot sizes – when averaged out – can still meet the minimum 20,000 square foot requirement. The Project fails to meet this requirement. The Project proposes an average lot size of 6,062 square feet per unit—far below the 20,000 square foot minimum required by the RE zoning district. *See* Saddleback Meadows Area Plan at 2. This means the Project crams too many homes onto too little land, which is in direct violation of the development standards the County established to preserve the rural character of the F/TSP area.

The Planning Commission's staff report failed to address this fundamental zoning violation, and the Planning Commission did not meaningfully address this issue either. Rather than demonstrate how the Project satisfies the mandatory net development area requirement to meeting the district zoning standards, the Planning Commission's decision focuses on setbacks, building heights, and architectural projections—details that matter only if the Project can otherwise lawfully proceed. The Planning Commission staff report never calculated the net development area or explained how 181 units can fit on this site in a manner that complies with the zoning code. Thus, the Planning Commission erred when it determined that the Project complies with the zoning code and the F/TSP.

Indeed, the Project is inconsistent with the overall goals and objectives of the F/TSP, including the goal of preserving the rural character of the planning area and provide a buffer between urban development and the Cleveland National Forest (Goal 1.0-a) and to preserve significant landform, biological, and scenic resources (Goal 1.0-b). *See* F/TSP at I-5. The Foothill/Trabuco Specific Plan Review Board itself observed that the Project creates a "significant risk of negatively impacting the rural nature of the canyon." *See* Hyperlink/Attachment to Exhibit A, Oct. 11, 2023 Meeting Minutes, Foothill/Trabuco Specific Plan Review Board. Yet, the Review Board was never consulted when the County administratively approved an Area Plan and Tentative Tract Map for the Project, and the Planning Commission did not consider any of the Review Board's recommended modifications to the Use Permit, which were intended to lessen the Project's glaring inconsistencies with the F/TSP:

- Side setbacks to maintain 15 feet on each side of a parcel
- Front setback to maintain 20 feet
- Rear setback to maintain 20 feet
- Maximum Building height of 30 feet

The County cannot approve a project that violates its own code and is inconsistent with the F/TSP, which is designed to preserve the rural character of Trabuco Canyon. The subdivision's lot sizes (some as small as 4,000 sq. ft.) and reduced setbacks are inconsistent with these goals. The developer must reduce the number of units to comply with the applicable zoning and the F/TSP.

III. The Project Relies on Outdated Environmental Analysis and Fails to Comply with CEQA.

The Project's most recent certified environmental review document, the 2002 "RSEIR," is significantly outdated and the County's recent addendum was not provided to the public for review and comment, nor was it certified by this Body or the Planning Commission. Since the last certified environmental document, in 2002, substantial changes in circumstances and new information, in addition to changes to the project itself, have emerged that trigger the requirement for a subsequent or supplemental EIR. These changes including new scientific information and changed circumstances regarding the Project's environmental impacts, relevant regulatory changes, and new related significance thresholds in CEQA Guidelines, Appendix G, and other amendments to the CEQA Guidelines. As described below, these changes and new information will create new significant impacts that were not previously analyzed or mitigated in the 2002 RSEIR. Significantly, the 2002 RSEIR did not consider cumulative greenhouse gas (GHG) emissions or wildfire risk impacts at all. Even if the 2002 RSEIR was determined to be adequate at that time, the new information and changed circumstances described below require a supplemental EIR under CEQA Guidelines section 15162(a), which provides that:

> When an EIR has been certified . . . for a project, no subsequent EIR shall be prepared for that project unless the lead agency determines, on the basis of substantial evidence in the light of the whole record, one or more of the following:
>
> (1) *Substantial changes are proposed in the project* which will require major revisions of the previous EIR or negative declaration due to the involvement of *new significant environmental effects* or a substantial increase in the severity of previously identified significant effects
>
> (2) *Substantial changes occur with respect to the circumstances under which the project is undertaken* which will require major revisions of the previous EIR or negative declaration due to the involvement of *new significant environmental effects or a substantial increase in the severity of previously identified significant effects*.
>
> (3) *New information of substantial importance*, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous EIR was certified as complete or the negative declaration was adopted, shows any of the following:
>
> > (A) *The project will have one or more significant effects not discussed in the previous EIR or negative declaration*;

As discussed below, each of these standards is met here. As the next agency issuing a discretionary approval for the Project, the County is required to address these issues in a subsequent EIR before it may approve the Use Permit and may not approve the permit until it does so. CEQA Guidelines § 15162(c). The Planning Commission's decision to approve the Use Permit prior to performing subsequent environmental review violates CEQA.

A. Changed Circumstances and New Information Necessitate Analyzing the Project's Significant Impacts to Wildfire Risk and Evacuation Impacts.

The 2002 EIR does not and could not have addressed California's "new normal" of catastrophic wildfire in the wildland-urban interface driven by climate change and poor development planning. California's climatic conditions have become warmer and drier since 2002. California is experiencing record-high temperatures: summers are 2.5 degrees warmer than they were several decades ago, and they are likely to get even hotter. *See* Exhibit C (Rust). These high temperatures remove moisture from plants and soils, increasing fire danger and adding combustible fuel to the landscape. *Id.* "Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation," according to UCLA climate scientist Daniel Swain. *See* Exhibit D (Mulkern). One result is that the wildfire risk in areas adjacent to wildlands continues to increase. According to CalFire, the 2020 wildfire season burned over 4.2 million acres—over 4% of the State—in nearly 10,000 incidents; 33 people died; and over 10,000 structures were damaged and destroyed. *See* Exhibit E (CAL FIRE). The years 2020 and 2021 collectively brought nine of the 20 largest wildfires in California's history, and 18 of the 20 largest California wildfires have happened since 2002. *See* Exhibit F (CAL FIRE). In

2024, the Airport Fire burned just three miles from the Project site.[1] And last year, Los Angeles County experienced the devastating Palisades and Altadena fires.

These fires demonstrate that wildfire season in the western United States, including California, has lengthened from a previous average of between five and seven months to a year-round occurrence. The number of large wildfires that burn more than 1,000 acres has increased throughout the western United States. This is occurring as average annual temperature in the western regions of the United States have risen by nearly two degrees Fahrenheit since the 1970s and the winter snowpack has declined. *See* Exhibit G (Keeley). Expected changes in precipitation will continue to result in decreased fuel moisture and increased fire risk. *See* Exhibits H (UCS Infographic), I (Westerling), and J (Cayan).

The state's worsening fire seasons underscore the substantial changed circumstances surrounding wildfire risk assessment and the new information about wildfires in California that has been developed over the last 24 years since the original EIR was certified. California now requires comprehensive wildfire risk evaluations for projects in high fire hazard severity zones, like the proposed Project. In 2022, in response to the growing threat of catastrophic wildfire, the California Attorney General and Governor's Office of Planning and Research published guidance requiring agencies to analyze evacuation capacity, emergency access, traffic modeling under emergency conditions, and timing for evacuation. *See* OAG Guidance Hyperlink/Attachment to Exhibit A. None of these issues were anticipated when the County certified the 2002 RSEIR, and the Project's environmental review contains no analysis of the Project's evacuation impacts, despite being located in a Very High Fire Hazard Severity Zone where the Project would add significant new residents and traffic burden to existing evacuation routes and impair emergency response. *See* Section I, supra.

Indeed, the Project will significantly increase the fire risk at the Project site and in surrounding areas. The Project will develop land within the Wildland Urban Interface (WUI), and numerous studies have found that development at the urban-wildland border results in more human ignitions. *See* Exhibit K (Qiu, "WUI expansions have also increased fire ignitions risks from human activities"); Exhibit L (Tang, "In WUI, there are more human ignitions compared to wildland"); Exhibit M (Radeloff, "growth of the [] wildland-urban interface raises wildfire risk"). The CBD Letter provides additional evidence on how and why development in high fire-prone areas increases ignition risk and puts more people in harm's way. *See* CBD Letter at 8. Recent legislation including SB 901 (2018) and AB 38 (2019) established the requirements for wildfire mitigation, and in 2018, CEQA's Appendix G was updated to add new wildfire significance thresholds that did not exist in 2002. These thresholds include whether the Project would exacerbate wildfire risks and thereby expose project occupants to pollutant concentrations from a wildfire, increase the uncontrolled spread of a wildfire, or substantially impair an adopted

[1] The County recently approved a $33-million settlement of claims stemming from the Airport Fire:
https://laist.com/news/orange-county-supervisors-approve-33-million-airport-fire-settlement

emergency response plan or emergency evacuation plan. CEQA Guidelines, Appendix G, § XX. Due to the growing significance of wildfire risk throughout the state, courts have also recognized that "[d]eveloping new homes and stores in a very high fire hazard area risks exacerbating the hazard" related to wildfires (*League to Save Lake Tahoe Mountain v. County of Placer* (2022) 75 Cal.App.5th 63, 136), and that the "need for [an EIR's] disclosure of the potentially substantial adverse risk of human-caused wildfire is uncontroversial" (*People ex rel. Bonta v. County of Lake* (2024) 105 Cal.App.5th 1222, 1231). Thus, an EIR must "reasonably describe the 'additional wildfire risk factors as compared to existing conditions' that the project would 'introduce' to the area." *County of Lake*, 105 Cal.App.5th 1222 at 1233. The County has never performed any such analysis for the Project, and should not turn a blind eye to this pressing issue.

Based on the evidence discussed above regarding the dramatic increase in wildfire activity in California—and in the F/TSP area—in recent years and the increased ignition risk that wildland-adjacent development presents, the Project will exacerbate wildfire risks and impair evacuation. These changed circumstances and new information require major revisions to the RSEIR to address these new significant impacts. The County must prepare a wildfire risk analysis consistent with current CEQA Guidelines and state guidance before approving the Project.

B. There Is New Information and Changed Circumstances that Necessitate Analysis and Quantification of GHG Emissions.

The 2002 RSEIR did not evaluate climate change impacts. Although other air quality-related impacts from the Project were assessed, the 2002 RSEIR did not separately consider how the Project's construction or operation would generate greenhouse gases (GHG), much less consider how to mitigate those emissions. Information regarding the need to reduce GHG emissions was not widely referenced in 2002 and related data at the state, regional, and local level was not readily available in 2002. The CEQA Guidelines Appendix G checklist used in 2002 did not reference GHG emissions or study Vehicle Miles Traveled (VMT) as a substantial contributor to GHG emissions.

The role of GHG emissions in driving climate change and global warming has become an issue of critical importance to the State of California over the last twenty years. With the adoption of Assembly Bill 32 in 2006, the Legislature first recognized that "[G]lobal warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems." Health & Safety Code § 38501(a). AB 32 further established state policy "design emissions reduction measures to meet the statewide emissions limits for greenhouse gases." *Id.* § 38501(h).

Numerous subsequent laws and regulations mandate efforts to reduce GHG emissions. As directed by AB 32, the California Air Resources Board adopted its first Scoping Plan in 2008. The document has been updated several times since. The current "2022 Scoping Plan for Achieving Carbon Neutrality" is intended achieve targets for carbon neutrality and reduce GHG emissions by 85 percent below 1990 levels no later than 2045 (as directed by Assembly Bill 1279). Current state statutes and the Scoping Plan embody "an ambitious and aggressive approach to decarbonize every sector of the economy, setting us on course for a more equitable and sustainable future in the face of humanity's greatest existential threat, and ensuring that those who benefit from this transformation include communities hardest hit by climate impacts and the ongoing pollution from the use of fossil fuels." *See* CARB 2022 Scoping Plan at 1 (Hyperlink/Attachment to Exhibit A).

Locally, Orange County has prepared a Preliminary Climate Action Plan (CAP) that covers the Unincorporated County Communities. Released in 2024, the CAP recognizes that "[A]s Orange County's popularity grows, developing strategies to address climate change and maintain the pristine natural resources and make the region unique has become more critical than ever." *See* CAP at 1.[2] The CAP further acknowledges the need for action to address severe air quality conditions in the area:

> "Orange County is part of the South Coast Air Basin which, under the Clean Air Act, is in extreme non- attainment for ozone and serious non-attainment for PM 2.5. These pollutants, ozone and black carbon, a form of fine particulate matter, also contribute to the formation of GHG emissions. Consequently, Orange County residents are breathing some of the worst air quality in the nation."

CAP at 10. The CAP identifies the need to address environmental pollution and improve public health overall. This new policy direction is based on new information learned since the time the 2002 RSEIR was certified, none of which has been accounted for in the design or planning of the Project.

The CEQA Guidelines have likewise been amended to include the requirement to quantify GHG emissions; assess consistency with applicable plans, including the Scoping Plan, Regional Sustainable Communities Strategies/Regional Transportation Plans, and local Climate Action Plans; measure projects against threshold of significance analysis using current methodologies; and include VMT in the GHG emissions analysis. *See* CEQA Guidelines § 15164.4, Appendix G. The Guidelines further state that an "agency's analysis must reasonably reflect evolving scientific knowledge and state regulatory schemes" regarding greenhouse gas emissions and climate change. CEQA Guidelines § 15164.4(b). The County must update its environmental analysis to account for the current state of climate science and state policies that prioritize the reduction of GHG emissions.

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[2] Draft Climate Action Plan: https://www.oclandfills.com/sites/ocwr/files/2024-08/Draft_PreliminaryCAP_OrangeCounty_08012024.pdf

For instance, the more recent (2022) Ranch Hills DEIR,[3] which analyzed the impacts of a 37-unit residential development where the County was the lead agency, used the South Coast Air Quality Management District (SCAQMD) GHG emissions threshold of 3,000 MTCO2e/year for determining whether a project may have significant GHG emissions impacts. The results of the Ranch Hills GHG analysis indicate that the 37-unit project would generate 434 MTCO2e/year. *See* Ranch Hills DEIR at 4.7-16. However, that project is in a completely urbanized location on a site that is being redeveloped from another existing use. The proposed Saddleback Mountain project will have substantial amounts of site grading – with construction emissions from grading equipment and heavy-duty haul trucks – and will also have a higher VMT due to being located in an area further out from services, schools, workplaces, and other daily-trip destinations. The Ranch Hills example provides further evidence that the Project is likely to generate annual GHG emissions that are above the SCAQMD threshold, creating a new significant impact that will need to be mitigated.

C. There Is New Information and Changed Circumstances Regarding the Project's Impacts to Mountain Lions and Maintaining Habitat Connectivity.

The 2002 EIR contains no analysis of the Project's impacts to mountain lions and a limited discussion of impacts to wildlife corridors. As detailed in the CBD Letter, mountain lions in the Project area are part of the Santa Ana Mountains population, which has declined significantly in recent years and received "candidacy status" in April 2020 under CESA, such that they are afforded the same protections as other CESA-listed species. On December 10, 2025, the California Department of Fish and Wildlife ("CDFW") released their status review recommending listing all six of the petitioned mountain lion populations as a threatened Southern California and Central Coast mountain lion distinct population segment (DPS) under CESA. (The California Fish and Game Commission is expected to act on the listing petition in February 2026.)

The 2002 RSEIR assessed the impacts of the Project on biological resources and determined that a significant impact would occur if the Project resulted in, among other things, a "substantial effect on a species or native plant or animal," "substantial effect on the movement of a migratory fish, bird, or animal species," or "project-specific conflict with an adopted resource management plan or policy." See RSEIR at 4.8-17. Under these thresholds, the RSEIR concluded that direct and indirect impacts would occur with the implementation of the proposed Project, but that the impacts would be less than significant with the project design features, standard conditions of approval, and the three mitigation measures. The RSEIR also concluded that cumulative impacts would be less than significant because "all identified related projects in the region would have to mitigate biological impacts to less than significant." *See Id* at 4.8-22.

The 2002 RSEIR did not assess impacts to mountain lion populations in the Project's vicinity, and could not account for the significant decline in the population since 2002. The

[3] Ranch Hills DEIR: https://files.ceqanet.lci.ca.gov/270826-2/attachment/LVJf_Bj_rY-fRc00-pVaSd4QQof1zp6chHpY6kLTlQzMs5S4uMMuSmLO3tWyn456bEztzXWo5l6zwnid0

population has declined to the point of being listed as a threatened species. The CBD Letter highlights the numerous studies undertaken from 2015 to 2023 that highlight the impacts of human activities and development in the Urban-Wildland Interface on mountain lions, from vehicle strikes to human activities that cause changes to mountain lions' behavior and avoidance of areas with higher development densities. *See* CBD letter at 4. The letter further describes how the local "[T]he Santa Ana Mountains puma population is [] small, isolated, and geographically limited, which suggests that further encroachment into remaining habitat and connectivity areas could drive the population closer to extirpation. This highlights the need to reduce human-caused mortalities, in part, by protecting existing intact habitats and improving connectivity within and between subpopulations." *Id*.

All of the recent studies and findings regarding the mountain lion populations' decline represent substantial changed circumstances and new information of substantial importance, which was not known and could not have been known at the time the 2002 RSEIR was certified. The studies show how the Project would significantly impact a species or native plant or animal and the movement of a migratory fish, bird, or animal species, both of which would be significant effects that were not discussed in the 2002 RSEIR. CEQA also requires a "mandatory finding of significance" when a project has the potential to impact a CESA-listed species. CEQA Guidelines § 15065(a)(1); *Endangered Habitats League, Inc. v. County of Orange* (2005) 131 Cal.App.4th 777, 792, fn. 12. And such a finding triggers a duty to consider and adopt all feasible alternatives or mitigation measures to reduce such impacts. Pub. Resources Code § 21002. Moreover, under CESA, the County may not approve projects that could jeopardize the continued existence of this population or result in destruction of essential habitat (Fish & Game Code § 2053(a)) and the County must require that mitigation measures be implemented for projects that could destroy mountain lion habitat or impair connectivity (Fish & Game Code § 2054). These impacts need to be studied in a subsequent or supplemental EIR.

The Project would degrade wildlife connectivity generally. The 2002 RSEIR cited Figure 4.8.4 (Proposed Wildlife Movement Corridors) to illustrate the Primary Wildlife Corridors that exist through and around the site, contending that the Project poses a less than significant impact to "the movement of a migratory fish, bird, or animal species" by maintaining these corridors. There is a Wildlife Movement Corridor that bisects the Project site and connects to open space both to the east and west of the Project site. *See* Exhibit N. However, the eastern terminus of the corridor has since been developed with a residential neighborhood and is now home to the "Oaks at Portola Hills" subdivision, which diminishes its value for enabling safe wildlife movement, leaving the Proposed Wildlife Movement Corridor through the Project site as deficient.

In their original letter on the 2002 RSEIR, the US Fish and Wildlife Service and the California Department of Fish and Game noted that "the proposed project poses significant unmitigated impacts to future Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP) reserve design for the Southern Subregion of Orange County," among other concerns. *See* Exhibit O at 1. This concern has only worsened with the construction of other development projects in the area, further impeding wildlife movement and degrading existing habitat. In light of these changed circumstances, the Project will have a significant impact on the

connectivity of habitat and the movement of wildlife through the area, and this impact needs to be addressed in a subsequent or supplemental EIR and mitigated.

D. The Project Lacks a Reliable Water Supply.

Fundamental details about the Project's water supply remain unknown and have not been evaluated in the County's environmental documents. The 2002 RSEIR and the recent 2022 Addendum stated that the Trabuco Canyon Water District would provide the Project water service from its existing or future facilities. RSEIR at 2-18. That is no longer true. In March 2025, the Water District made clear it would not supply water to the Project from its facilities. Instead, the developer must construct a new 1-million-gallon reservoir and conveyance infrastructure at locations that have not been identified or disclosed to the public. Replacing the planned water supply with a new, unknown supply is a substantial change to the Project that will create new significant impacts, and requires major revisions to the EIR to address these changes and impacts.

CEQA requires that agencies evaluate "the reasonably foreseeable impacts of supplying water to the project," not speculative promises that water will somehow materialize. *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 430-31. Yet the County has provided no information about where this new reservoir will be built, how the infrastructure will be constructed, what environmental damage will result from that construction, or whether use of the water supply itself will create additional environmental impacts. The Project description is now incomplete and inaccurate, and the environmental review is incomplete. The County has ostensibly attempted to pass its CEQA responsibility onto the Trabuco Canyon Water District; but as the next agency issuing a discretionary approval, the County must address the location and design of these facilities, analyze their environmental impacts in a subsequent or supplemental EIR, and show that adequate water supplies actually exist before it may approve this Use Permit. *City of San Jose v. Great Oaks Water Co.* (1987) 192 Cal.App.3d 1005, 1016; CEQA Guidelines § 15162(c).

E. The 2022 Addendum Cannot Satisfy CEQA Analysis Required by CEQA Guidelines Section 15162.

As discussed above, the County has not prepared a subsequent or supplemental EIR to address the significant changes to the Project, new information, and changed circumstances following the certification of the 2002 RSEIR. The County's most recent 2022 Addendum entirely fails to address these issues, and instead incorrectly asserts that because the Project is reducing the number of its residential units, it will not create new significant impacts. But this contention, which was never provided to the public for review and input before the Addendum was finalized, entirely fails to address the issues raised in this letter.

Indeed, even if the Addendum purported to do so, an addendum is not an adequate vehicle to address these new significant impacts. Addenda are only appropriate where "none of the conditions described in [Guidelines] Section 15162 calling for preparation of a subsequent EIR

have occurred." CEQA Guidelines § 15164. Here, Guidelines section 15162 requires the County to compare the Project, its circumstances, and relevant new information to the "previous EIR" that was certified in 2002 following public review to determine whether a subsequent or supplemental EIR is required. The County failed to even attempt to perform this analysis prior to the Planning Commission's approval of the Use Permit. As discussed above, before it may approve the Use Permit, the County must address these issues in a new certified EIR.

IV. The Use Permit's Findings Are Not Supported.

The Planning Commission adopted the following findings in their approval of the Project:

Compatibility – The location, size, design and operating characteristics of the proposed development standards will not create unusual conditions or situations that may be incompatible with other permitted uses in the vicinity because the proposed project is adjacent to residential areas to the west and south and designed to maintain a buffer between urban development and the Cleveland National Forest to the north and east. In addition, the minimum lot size is compatible with other recently approved and under construction residential developments in the vicinity, including single family residential lots as small as 3,200 square feet (Portola Center).

General Welfare – The application will not result in conditions or circumstances contrary to the public health and safety and the general welfare because the proposed project was evaluated under RSEIR No. 566, certified by the Board on November 5, 2002, RSEIR No. 566 Addendum No. 1 administratively approved on August 11, 2004, and RSEIR No. 566 Addendum No. 2, administratively approved on September 26, 2022 and impacts to all environmental resources (except for cumulative air quality impacts) will be less than significant.

Foothill/Trabuco Specific Plan – The proposed project is consistent with the purpose and intent of the Foothill/Trabuco Specific Plan because on November 9, 2002, the Board approved Ordinance No. 02-008 to modify the Bridlewood Residential district of the F/TSP to include "Residential Estates/Planned Development District Regulations" to allow a project to be developed that would keep with the character of the development envisioned by the F/TSP and allowed for site specific development standards to be imposed through a use permit process.

But the project is *not* compatible with either the surrounding area, with public health and safety and the general welfare, nor is it consistent with the site zoning or the F/TSP. The Foothill/Trabuco Specific Plan Review Board (F/TSPRB) reviewed this proposed Planning Application PA23-0119 at their October 11, 2023 meeting. Members of the Board stated that the Project is inconsistent with the F/TSP, and "due to its size and scope it has a significant risk of negatively impacting the rural nature of the canyon." Thus, the above findings, and the Planning Commission's separate findings that the Project does not require additional environmental review, are erroneous and not supported by substantial evidence.

V. The County Is Not Legally Required to Approve the Project.

The Planning Commission was incorrectly led to believe that the Settlement Agreement between the developer and the Vendanta Society compels the County approve the Use Permit. This is not correct. The County is not a party to that agreement, and even if it were, the County could not lawfully commit itself to issue the requested Use Permit in violation of state law and local zoning. *Trancas Property Owners Ass'n v. City of Malibu* (2006) 138 Cal.App.4th 172.

Moreover, the applicant has no vested right to develop this Project. Development rights vest only when all building permits have been issued and the applicant has performed substantial work based on those permits. *Avco Community Developers, Inc. v. South Coast Regional Com.* (1976) 17 Cal.3d 785; *Hafen v. County of Orange* (2005) 128 Cal.App.4th 13. Because the applicant has not received all required discretionary permits and has not started construction, the County retains full discretion to deny the Use Permit. Indeed, as the Lead Agency, the County has broad authority to deny the Use Permit due to the Project's environmental impacts. CEQA Guidelines § 15042.

VI. Conclusion

The Planning Commission erred when it approved a Project that fails to meet basic legal requirements and places residents at risk during the next wildfire evacuation. We respectfully urge the Board of Supervisors to grant this appeal, overturn the Planning Commission's decision, and deny the Use Permit for the Saddleback Meadows Project.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Edward T. Schexnayder

cc: Saddleback Canyons Conservancy
Rural Canyons Conservation Fund
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Exhibits:

A. Shute Mihaly & Weinberger LLP, January 26, 2026 letter to Orange County Planning Commission with June 18, 2025 Board of Supervisors letter attached
B. Center for Biological Diversity, January 26, 2026 letter to Orange County Planning Commission

C. Susanne Rust et al., *How climate change is fueling record-breaking California wildfires, heat and smog*, Los Angeles Times (Sep. 13, 2020)

D. Anne Mulkern, *Fast-Moving California Wildfires Boosted by Climate Change*, Scientific American (Aug. 24, 2020)

E. Cal FIRE, *2020 Wildfire Activity Statistics*

F. Cal FIRE, *20 Largest Wildfires in California History*

G. Jon E. Keely et al., *Nexus Between Wildfire, Climate Change, and Population Growth In California*, Fremontia: Journal of the California Native Plant Society (March 2020)

H. Union of Concerned Scientists, *Infographic: Wildfires and Climate Change – Visualizing the Connection in Five Sets of Photos and Charts* (Updated May 9, 2022)

I. Westerling, A.L., Hidalgo, H.G. Cayan, D.R. and Swetnam, T.W., *Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity*, 313 Science 940 (2006)

J. D. Cayan, A. L. Luers, M. Hanemann, G. Franco, and B. Croes, *Scenarios of Climate Change in California: Overview*, CEC-500-2005-186-SF (2006)

K. Mingha Qiu et al., *The rising threat of wildland-urban interface fires in the era of climate change: The Los Angeles 2025 fires*, The Innovation (February 4, 2025)

L. Wenfu Tang et al., *Global expansion of wildland-urban interface (WUI) and WUI fires: insights from a multiyear worldwide unified database (WUWUI)* 2024 Environ. Res. Lett. 19 044028 (March 19, 2024)

M. Volker C. Radeloff et al., *Rapid Growth of the US wildland-urban interface raises wildfire risk*, PNAS (March 27, 2018)

N. Draft RSEIR Figure 4.8.4, *Proposed Regional Wildlife Movement Corridors map*

O. US Fish and Wildlife Service and California Department of Fish and Game letter to Orange County dated June 26, 2002.

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APPEAL EXHIBIT A

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January 26, 2026

Via E-Mail

Orange County Planning Commission
400 Civic Center Drive
Santa Ana, CA 92701
c/o Scarlet Duggan, Land Use Manager
scarlet.duggan@ocpw.ocgov.com

Re: Saddleback Meadows Use Permit No. PA23-0119 (Item 2, January 28, 2026 Planning Commission Agenda)

Dear Commissioners:

This firm represents the Saddleback Canyons Conservancy, a non-profit association dedicated to protecting and enhancing the environment and quality of life in the Foothill/Trabuco Specific Plan area. The Conservancy's mission is to support and strengthen the Specific Plan and ensure that development maintains the existing rural character of the plan area, minimizes adverse environmental, public health, and aesthetic impacts, and maximizes public safety.

The Conservancy and the Rural Canyons Conservation Fund object to the proposed Use Permit for the Saddleback Meadows Project ("Project"). As detailed in our prior letter to the Board of Supervisors, which is attached and fully incorporated by reference, the Project violates County zoning standards, would create harmful public safety and environmental impacts, and requires additional review under the California Environmental Quality Act. *See* Attachment 2, June 18, 2025 Letter to Board of Supervisors. The most significant concerns with the Project include:

Wildfire Risk – The Project threatens to trap existing foothill residents in a high risk area during a wildfire evacuation. The Project site sits in a designated Very High Fire Hazard Severity Zone, and is just ***three miles from where the Airport Fire burned in 2024***. Yet the County has never addressed how 181 new households and hundreds of new vehicles will affect existing residents' ability to evacuate on El Toro Road—which narrows to two lanes just south of the Project site—during a wildfire event. The County's previous environmental review is silent on whether emergency vehicles can reach the site while residents evacuate, whether Valley Vista Way can handle evacuation traffic from both the new development and the nearly 200 existing homes it serves, and whether adding hundreds of new residents and vehicles to this corridor will delay evacuation for others already living in the area. The existing environmental review also

fails to analyze how 181 new homes will increase ignition risk, despite evidence showing that 95-97% of California wildfires are caused by human sources and that development in wildfire zones directly increases both ignition events and losses of life and structures. The County must answer these critical questions before approving the Project.

Unknown Water Supply – Fundamental details about the Project's water supply remain unknown. The County's 2022 Addendum stated that the Trabuco Canyon Water District would provide water service from its existing or future facilities. That is no longer true. In March 2025, the Water District made clear it would not use its facilities to serve the Project. Instead, the developer must construct a new 1-million-gallon reservoir and conveyance infrastructure at locations that have not been identified or disclosed to the public. CEQA requires that agencies evaluate "the reasonably foreseeable impacts of supplying water to the project," not speculative promises that water will somehow materialize. *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 430-31. The County has provided no information about where this new reservoir will be built, how the infrastructure will be constructed, what environmental damage will result from that construction, or whether use of the water supply itself will create additional environmental impacts. The Project description is now inaccurate, and the environmental review is incomplete. The County must identify the location and design of these facilities, analyze their environmental impacts in a subsequent or supplemental EIR, and show that adequate water supplies actually exist before it approves this Use Permit. *City of San Jose v. Great Oaks Water Co.* (1987) 192 Cal.App.3d 1005, 1016.

Zoning Code Violation –The Project violates the County's zoning code and cannot be approved as designed. The Foothill/Trabuco Specific Plan designates the property as Residential Estates (RE) with a Planned Development (PD) combining district, which requires compliance with the RE base district standards modified only as permitted under the PD regulations. The RE zone requires a minimum building site area of 20,000 square feet per unit. Orange County Code § 7-9-31.3. Although the PD combining district allows flexibility on individual lot sizes and setbacks, it mandates that "the net development area shall have an average land area per unit no less than the minimum area per unit required by the base district." *Id.* § 7-9-48.6(c). The Project fails this test. The Project proposes an average lot size of 6,062 square feet per unit—far below the 20,000 square foot minimum required by the zoning code. *See* Area Plan at 2. This means the Project crams too many homes onto too little land in direct violation of the development standards the County established to preserve the rural character of the FTSP area. For this reason, the Foothill/Trabuco Specific Plan Review Board observed that the Project creates a "significant risk of negatively impacting the rural nature of the canyon." *See* Attachment 1, Oct. 11, 2023 Meeting Minutes, Foothill/Trabuco Specific Plan Review Board. The County cannot approve a project that violates its own code and is inconsistent with the goals of the Specific Plan. The developer must reduce the number of units to comply with the applicable zoning.

The staff report is inexplicably silent on this fundamental zoning violation. Rather than address whether the Project satisfies the mandatory net development area requirement, the staff report focuses on setbacks, building heights, and architectural projections—details that matter only if the Project can otherwise lawfully proceed. The staff report never calculates the net

development area or explains how 181 units can fit on this site in a manner that complies with the zoning code. The Planning Commission cannot find that the Project complies with the zoning code and the Specific Plan when the Project violates a basic requirement of the Planned Development regulations.

The County's previous issuance of a subdivision map and related approvals for the Project do not allow the County to bypass required development standards in the Foothill/Trabuco Specific Plan and the zoning code. *Hafen v. County of Orange* (2005) 128 Cal.App.4th 133 holds that even after a final subdivision map is recorded, the applicant is required to fully comply with the County's zoning code and the Foothill/Trabuco Specific Plan.

The Planning Commission should deny the requested Use Permit. The Project violates the County's zoning code, threatens public safety in a Very High Fire Hazard Severity Zone, relies on a water supply that does not exist, and will have numerous other environmental impacts. For these reasons, there is not substantial evidence to support finding that the Project does not require additional environmental review, or otherwise complies with applicable zoning, General Plan, and Specific Plan regulations. The County cannot approve a project that fails to meet basic legal requirements and places residents at risk during the next wildfire evacuation.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Edward T. Schexnayder

cc: Board of Supervisors

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ATTACHMENT 1

FOOTHILL/TRABUCO SPECIFIC PLAN REVIEW BOARD
Trabuco Canyon, California

Meeting minutes of the regular meeting of the Foothill/Trabuco Specific Plan Review Board held October 11, 2023 at 7:00 P.M.

In attendance were Chairman Dale Weber, Vice-Chairman Jake Reed, Secretary Robert Borland, and member Mike McClanahan. Joining the meeting were members of the public.

Item 1) Call to Order

The meeting was called to order at 7:00 PM by Dale Weber

Item 2) Approval of Minutes

Motion by McClanahan: Approve minutes as presented

Second by Reed

No further discussion

Vote: 4-Ayes

Item 3) Old Business

None

Item 4)

PA23-0119 –

A Use Permit to establish residential development standards (setbacks, building heights, etc.) for the 181-unit Saddleback Meadows development. The zoning on the site permits the applicants to develop as a planned development. – Applicants – California Quartet, L.P., (Recupero & Associates, agents) - Location – vacant 222.2-acre project site located on the eastern side of El Toro Road, adjacent to the former St. Michael's Abbey site and approximately one-half mile south of the intersection of Santiago Canyon Road (El Toro Road) and Live Oak Canyon Road. Third Supervisorial district.

Project Details:

Weber asked the applicants if they would like to present their project. Brian Diaz responded that they had not prepared anything.

Kevin Canning from the county planning department explained the general details of the project.

Following Kevins explanation, the floor was opened up to the public in case they had questions for Kevin.

DRAFT

FOOTHILL/TRABUCO SPECIFIC PLAN REVIEW BOARD
Trabuco Canyon, California

Public Comments:

John asked Kevin if he knew what the approximate time frame was on the project being completed. Kevin responded that there was no way to know, depends how long the process takes.

Dan asked when the EIR was completed. Kevin said he was not sure, but that all documents are re-assessed each step of the process.

Lynn asked about the potential for wildfires in the area, and how this project would impact the evacuation plans and focus of first responders. Kevin said that houses are built to current fire code, and that it is up to the Sheriffs Department to review evacuation plans.

Gloria asked about the existing lawsuit

Anthony stated that he was the general counsel for the existing lawsuit on behalf of the Monastery. Anthony asked Kevin how the county was able to schedule a meeting without notifying the plaintiff (Monastery). He stated that it was a stipulation within the settlement agreement that they would be notified of any meetings related to this project. Kevin stated that no decisions are made tonight, this is only an advisory committee. Anthony responded that he objects to this meeting due to improper notice.

Erin asked about schools, water, traffic, and other impacts of this project on the community. Asked who do we talk to about these issues. Kevin directed to the county supervisors office.

Mike asked about the CEQA study and if it has been reviewed recently as times have changed and additional developments have been built in the area. Kevin responded that he wasn't aware of that specifically, but all required items have been completed thus far on the project.

Dan asked if the addendums to the EIR are open for public discussion. Kevin responded that the county reviews everything.

Bruce asked if in the applicants studies they have figured out that the hill in which this project is supposed to be built is in fact a sand dune. He said 12 engineers have looked at the soil over the years and come to the same conclusion. Kevin responded that he was not aware of any soil issues.

Darin asked how the new homeowners would get fire insurance. Kevin said he wasn't sure.

Irene asked about the emergency exits and evacuation routes for these new homes as well as the existing Hidden Ridge development where she lives. She stated that the only way out for her community is through the street Valley Vista Way. She stated that these new 181 homes would also have their only exit as Valley Vista Way. Kevin responded that all evacuation routes are reviewed by the fire department.

Paul asked if all soil testing has been completed. Kevin responded that some has been completed and some still needs to be done. Paul then asked why we are having a meeting about building setbacks when the soil tests haven't even been completed. Kevin responded that the applicant asked for a meeting on setbacks.

FOOTHILL/TRABUCO SPECIFIC PLAN REVIEW BOARD
Trabuco Canyon, California

Robert asked if there was still an opportunity to do tract map adjustments. Kevin responded that the tract map has not been recorded yet. Robert then asked Kevin, if you were in our shoes and were concerned about this development who would you talk too? Kevin responded, your county supervisor.

Steve stated that evacuation due to fire has always been an issue, and new building standards do not change that. We still have to evacuate even though these new houses are built to current code.

Gloria said that new traffic studies should be required. We need to study the traffic today after all of the new developments that have been completed in the area. This neighborhood needs larger exits, and also the 2007 CEQA guidelines were amended to require studies on greenhouse gas emissions.

Board Discussion:

Borland stated that the Specific Plan was created back in 1991 not to prevent development in the canyon area, but to ensure it is done in a responsible manner while taking into account the wildlife, trees, and surrounding nature. Under the spirit of the plan, a 181-unit development should definitely be subject to the parameters of the specific plan if at all possible. Due to its size and scope it has a significant risk of negatively impacting the rural nature of the canyon.

Page III-4 of the Specific Plan (Exhibit 1) describes the original Bridlewood Residential District (BWR) project as it stood in 1991 when the plan was implemented. You will see that Bridlewood (BWR) was made up of four different developments, Saddleback Meadows, Lyon Ranch, Santiago Ranch, and Zadeh. You will also see that it says that these developments are only exempt from the plan if they stay consistent with the approvals that were made prior to the 1991 creation of the specific plan. Today, Saddleback Meadows has taken over the entire Bridlewood District (BWR), and the other three projects have gone away. This is a material change in prior approvals, as one project got sizably bigger and three disappeared from the Bridlewood Residential District.

On Page III-20 of the Specific Plan (Exhibit 2) you will see the original purpose and intent of the Bridlewood Residential District (BWR). It states that *"While the Board of Supervisors does not believe that these approvals are consistent with the Goals and Objectives of the Specific plan, the property owner has recently declared bankruptcy."* This clearly shows that this project being exempt from the plan was not the intent of the Board of Supervisors, they were stuck with it due to Federal bankruptcy laws. In section 3.2(a) you will see once again that the plan states that this project is only exempt if it stays true to approvals prior to 1991. 3.2(b) states that any deviations from the approved plans will require the project to *"be consistent with all of the provisions of the Specific Plan."*

The original project included four different developments in Bridlewood Residential District (BWR), three were eliminated and rolled into Saddleback Meadows. The original Saddleback Meadows project was 700 mobile homes, it is now 181 single family homes on lots as small as 4000 sq feet. The Specific Plan states that any changes to the prior approvals within the Bridlewood Residential District (BWR) will require the project to be subject to the entire Specific Plan. Significant changes were made, therefore this entire project should be brought before the Foothill Specific Plan Review Board for complete review.

FOOTHILL/TRABUCO SPECIFIC PLAN REVIEW BOARD
Trabuco Canyon, California

Weber stated that on one of the board of supervisor resolutions it states that a minimum of 71% of the land must be donated to the county for open space or easement. This current project shows it using 38% of the land, thus only leaving 62% as open space. He pointed out that this project location is the beginning of the transition from the city into the Cleveland National Forest. Portolla Hills, which is just outside the forest area, has 7000-8000 sq ft lots. This proposed project gets as low as 4000 sq ft. As we move into the forest from the city, lots should get bigger (10,000-15,000 sq ft) and open space should grow. This project shrinks lot size and is looking to almost eliminate open space within the development.

Public Comments:

David stated that 35 foot building heights were ridiculous for this area.

Ray submitted a three page document to the board detailing several issues and questions regarding this project. (Exhibit 3)

Kevin (public) asked if there was someone at the county that would review the soil tests. Kevin (county) responded that licensed engineers will review them.

Bruce stated that he lives next to the development property and it is all sand.

Dan stated that 7.5 million cubic yards of grading within the Specific Plan area is absolutely crazy

Kim asked what the size range was for the setbacks.

Board Discussion:

The board discussed several different variations of setbacks and building heights. Borland stated that the biggest concern here is the lot size, combined with the developers request to be able to build on the entire lot. There will be next to zero open space within the development, this is going to look more like townhomes in Ladera Ranch then something fitting of a forest friendly development. Although we cannot do high enough setbacks to make a 4000 sq ft lot look rural, we need to set them as high as possible to ensure that there is at least some space between the homes.

Motion:

Weber made a motion for 15 foot setbacks on each side, 20 foot setbacks on the front and back, and a maximum building height of 30 feet.

Reed seconded.

Vote: 4 Ayes

FOOTHILL/TRABUCO SPECIFIC PLAN REVIEW BOARD
Trabuco Canyon, California

Item 6) Public Comments

None

Item 7) Administrative Matters

None

McClanahan made a motion to adjourn, Weber seconds. Meeting adjourned at 8:59 PM

ATTACHMENT 2

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June 18, 2025

Via E-Mail

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Re: Saddleback Meadows Final Tract Map No. 15230 (Item 14, June 24, 2025 Board Agenda)

Dear Chair Chaffee and members of the Board of Supervisors:

This firm represents the Saddleback Canyons Conservancy, a non-profit association dedicated to protecting and enhancing the environment and quality of life in the Foothill-Trabuco Specific Plan area. The Conservancy's mission is to support and strengthen the Specific Plan and ensure that any new development maintains the existing rural character of the plan area, minimizes adverse environmental, public health, and aesthetic impacts, and maximizes public safety.

Both the Conservancy and the Rural Canyons Conservation Fund submit this letter to object to the Board's consideration of a final tract map for Saddleback Meadows Project ("Project"). The tentative tract map for the Project was administratively approved in 2022. The tentative map was not subject to review by the review board for the Foothill-Trabuco Specific Plan nor was it subject to adequate public review. Moreover, the Project requires a Conditional Use Permit which we understand is currently under review by the Orange County Planning Department and Planning Commission.

As detailed in this letter, the proposed Use Permit does not comply with applicable County zoning standards, and would create undue public safety and environmental impacts. Most significantly, the Project would add new residents and traffic to a very high fire hazard severity area, burdening existing evacuation routes and impairing emergency response. Unless the Project is redesigned to comply with the County zoning, and all adverse public safety and environmental impacts are fully evaluated and mitigated, the County should deny the proposed Use Permit.

Key details of the Project remain to be resolved through the Use Permit process, including, as further described in this letter, that the required average building site area as

reflected in the final map must be increased. The Conservancy and Rural Canyons Conservation Fund therefore request that the Board pull the proposed final map from the consent agenda and defer action on it until it is corrected and after the Use Permit has been subject to adequate public and environmental review and the Project is redesigned to address its significant public safety and health impacts.

I. The Use Permit Should Be Denied Because It Violates the County's Zoning Ordinance.

All projects must comply with the County's own code and ordinances. *Robison v. City of Oakland* (1968) 268 Cal.App.2d 269, 274. In 2002, the County amended the zoning for the Saddleback Meadows property through Ordinance 02-008.[1] This ordinance establishes multiple development requirements for the property, including setting a maximum number of dwelling units, a minimum open space requirement, and requiring that any future development comply with the site development standards in the County's "Residential Estates (Planned Development) District regulations." Ordinance 02-008, Ex. 1 § 3.3.

The County's Residential Estates or "RE" zone is intended for the "development and maintenance of low-density single-family residential neighborhoods in which large building sites and generous open spaces are featured." Orange County Code ("OCC") § 7-9-31.1(e). The RE zone contains numerous development standards that are intended to fulfill this purpose, including maximum site coverage, minimum building setbacks, and "a minimum building site area per unit," which requires that each building site contains a minimum of 20,000 square feet. *See id*. § 7-9-31.3.

The proposed Project does not meet the Residential Estates zoning standards. The RE zone requires a 40-foot front setback and a 25-rear setback from any street right-of-way (*id*.), but the Project proposes only a 10-ft front and rear setbacks. *See* Saddleback Meadows Use Permit Application (July 13, 2023) ("Application") at 2. Nor does the application provide the minimum 20,000 square-foot site area required for each unit. Instead, the Use Permit application proposes only a 4,000 square foot minimum building site area (*see id*.), and the associated tentative tract map (TTM 15230) shows that none of the proposed lots would exceed 13,000 square feet.

The County's zoning ordinance permits Planned Development projects to deviate from standards in an underlying zoning district (*see* OCC § 7-9-48.2), but the Project does not comply with the Planned Development regulations either. Although Planned Developments need not satisfy basic district setbacks or a minimum land area for any individual building site, a project's "net development area shall have an average land area per unit *no less than the minimum area per unit required by the base [zoning] district*." *Id*. § 7-9-48.6(c) (emphasis added). The proposed Project violates this requirement. It does not meet or exceed an average 20,000 square-feet per unit required for Planned Developments in the RE zone. *Id*. §§ 7-9-31.3, 7-9-48.6(c).

[1] *See* https://ocds.ocpublicworks.com/sites/ocpwocds/files/2023-09/PA23_0119_Att%201_Ordinance_02-008.pdf

Instead, the Project's 78.3-acre development area (Application at 2) yields an average land area per unit less than 20,000 square feet.[2] As a result, the number of units proposed for the Project site exceeds the maximum number of units allowed under the development code. *See* OCC § 7-9-48.6(c), (d). As designed, the Project violates the County's development standards and cannot be approved.

II. Even if the Project Did Satisfy the County's Zoning Code, the Planning Commission Should Exercise Its Discretion to Deny the Application.

Even if the applicant could redesign its Project comply with the Residential Estates and Planned Development zoning requirements, the Planning Commission nonetheless retains the discretion to deny a use permit for the Project. *See* OCC TABLE 7-9-125 (Use Permits are discretionary). Indeed, the applicant lacks any vested right to develop the Project as proposed. *See Avco Community Developers, Inc. v. South Coast Regional Com.* (1976) 17 Cal.3d 785, 793-94; *accord Toigo v. Town of Ross* (1998) 70 Cal.App.4th 309, 321. Development rights vest only when "all final discretionary permits have been authorized and significant 'hard costs' have been expended in reliance on those permits—that is, until substantial construction has occurred in reliance on a building permit." *Hermosa Beach Stop Oil Coalition v. City of Hermosa Beach* (2001) 86 Cal.App.4th 534, 552. Because the applicant has not received all required discretionary permits or begun construction, it has no vested right to complete the development.

Similarly, the Project would not be subject to permit streamlining requirements or to the mandates of the Housing Accountability Act because the Project is inconsistent with County zoning. *See Land Waste Management v. Contra Costa County Bd. of Supervisors* (1990) 222 Cal.App.3d 950, 959; Gov. Code, § 65589.5(j) (restrictions on disapproving housing applicable only where a proposed housing development project complies with applicable general plan and zoning standards "in effect at the time that the application was deemed complete"). The County retains its full discretion to deny the proposed Project and should do so here.

III. The Project Would Harm Public Safety and the Environment.

The most recent Revised Subsequent Environmental Impact Report ("RSEIR") for the Project was certified in 2002. Although the County has processed two RSEIR addenda for the Project since then, these addenda do not address key changed circumstances and new information that has occurred since 2002, which require additional environmental review under CEQA. *See* Pub. Resources Code § 21166; CEQA Guidelines § 15162. Before approving the Project, the County must conduct additional environmental review to address the issues discussed below.

[2] 78.3-acre development area (3,410,748 square feet) ÷ 181 units = 18,843 sf/unit.

A. The County must evaluate how the Project could impair wildfire evacuation and increase the risk of wildfire ignition.

Wildfire danger throughout the State is worsening. California is experiencing record-high temperatures: summers are 2.5 degrees warmer than they were several decades ago, and they are likely to get even hotter. *See* Exhibit A, Susanne Rust et al., *How climate change is fueling record-breaking California wildfires, heat and smog*, Los Angeles Times (Sep. 13, 2020). These high temperatures remove moisture from plants and soils, increasing fire danger and adding combustible fuel to the landscape. *Id.*; *see also* Exhibit B, Anne Mulkern, *Fast-Moving California Wildfires Boosted by Climate Change*, Scientific American (Aug. 24, 2020) ("Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation," according to UCLA climate scientist Daniel Swain). The eight largest wildfires in California's history have all occurred within the last seven years.[3] According to CalFire, the 2020 wildfire season alone burned over 4.2 million acres—over 4% of the State—in nearly 10,000 incidents; 33 people died; and over 10,000 structures were damaged and destroyed. *See* Exhibit C, 2020 Incident Archive, CalFire. As of September 2020, that year had already brought six of the 20 largest wildfires in California's history, which occurred even before the Silverado fire (October 2020) and Bond fire (December 2020) burned ten miles from the project site.[4] *See* Exhibit A, Rust et al. And just last year, the Airport Fire burned nearly 24,000 acres in Orange and Riverside Counties, and ***burning land roughly 3 miles from Project site***.[5]

Growing evidence shows that humans are responsible for most wildfires, with development in the Wildland-Urban Interface particularly likely to be threatened by wildfire and ignite. *See* Exhibit D, Tiffany Yap, et al., Center for Biological Diversity, *Built to Burn: California's Wildlands Developments Are Playing With Fire* (Feb. 2021), at 1 ("Almost all contemporary wildfires in California, 95-97%, are caused by human sources such as power lines, car sparks and electrical equipment. Building new developments in highly fire-prone wildlands increases unintentional ignitions and places more people in danger.").

The County has recognized the risks that wildfires pose to its rural areas, particularly the County's foothills. The County's General Plan discussion of "FIRE HAZARDS" states that the foothill areas of Orange County are considered high to very high fire hazard areas." Orange County General Plan at III-4. Although this status does not preclude development entirely, "future development in these areas must minimize potential fire hazards and adequate fire

[3] *See* https://wfca.com/wildfire-articles/history-of-california-wildfires/#pp-toc-6x9tjk18rl5u-anchor-1
[4] *See* https://www.fire.ca.gov/incidents/2020/10/26/silverado-fire; https://www.fire.ca.gov/incidents/2020/12/2/bond-fire
[5] *See* https://www.fire.ca.gov/incidents/2024/9/9/airport-fire/

protection must be maintained." *Id*. Indeed, the Project site is located in the wildland-urban interface, in a ***designated very high fire hazard severity zone***.[6]

Despite this, the Project's environmental documents do not address whether added traffic from the Project will impair evacuation and emergency response during a wildfire event. The ability to safely evacuate the Project site is imperative. Residents in wildfire prone areas must be prepared to flee oncoming wildfire at any moment. El Toro Road, which reduces to two lanes south of the Project site, provides the sole means of ingress for emergency vehicles and egress for any residents attempting to flee in the event of a wildfire. But the addenda do not address how new traffic from the Project would affect other foothill residents' ability to evacuate, or emergency response vehicles attempting to use El Toro. The Project's emergency access along Valley Vista Way appears particularly dangerous. Valley Vista Way provides the sole means of residents of nearly 200 homes off of Meadow Ridge Drive in addition to the Villas residential complex. It is not clear how Valley Vista (or El Toro) can safely accommodate both safe evacuation of these residents and oncoming emergency response vehicles for the Project site.

Nor has the County addressed how new residents at the Project will increase potential ignition sources in this already fire-prone area, despite the evidence that development in the wildland-urban interface is a substantial cause of new wildfires.

CEQA requires the County to consider these issues. In light of new information concerning the increasing, and increasingly catastrophic, risk of siting new development in wildfire prone areas, the updated CEQA Guidelines include new and/or revised evaluation criteria in Appendix G and Guideline Section 15162.(a).[7] As the California Resources Agency notes, these revisions "clarif[y] that a lead agency should consider not just existing hazards, but the potential for increasing severity of hazards over time. This change is necessary because certain types of hazards are expected to be more severe in the future due to our changing climate. Examples include … more intense wildfires." 2018 CEQA Final Statement of Reasons,[8] p. 39. The Agency also concluded that while wildfire risk already exists in wildland-urban interface areas, "bringing development to those areas makes the risk worse." *Id.* at 87.

The County should also use any revised CEQA analysis as an opportunity to take heed of the State Attorney General's 2022 guidance paper, Best Practices for Analyzing and Mitigating Wildfire Impacts of Development Projects Under the California Environmental Quality Act,

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[6] *See* https://osfm.fire.ca.gov/what-we-do/community-wildfire-preparedness-and-mitigation/fire-hazard-severity-zones

[7] These revisions are identified by the California Natural Resources Agency at https://files.resources.ca.gov/ceqa/docs/2018_CEQA_FINAL_TEXT_122818.pdf

[8] *See* https://files.resources.ca.gov/ceqa/docs/2018_CEQA_Final_Statement_of%20Reasons_111218.pdf.

issued October 10, 2022.[9] That document lays out the importance and threat to the State posed by wildland fire, and states:

> In the last ten years, new legislation passed requiring local jurisdictions to consider wildfire risks in their planning processes. The Governor's Office of Planning and Research (OPR) recently published comprehensive guidance to help local agencies comply with these requirements.

Id. at 5. Adherence to the above referenced OPR guidance will ensure that the County meets the requirements of the new wildfire risk evaluation criteria in conformance with State law. The County should not approve the proposed Use Permit until it prepares a wildfire risk analysis that accounts for these issues and is consistent with the revised CEQA Guidelines.

B. The County must disclose and analyze impacts related to providing a water supply for the Project.

The County's 2022 CEQA Addendum stated that the Project's planned water tank had been eliminated and that the Trabuco Canyon Water District would provide water service for the Project from its existing or future facilities. *See* Addendum No. 2 at 6-32. Recently, however, the Water District has stated that it would not use its own facilities to serve the Project. *See* Exhibit E, Trabuco Canyon Water District March 19, 2025 Meeting Materials. Instead, the Project's developer is required to construct a new 1-million-gallon reservoir and conveyance infrastructure, at undetermined locations, to serve the Project.

"An accurate, stable and finite project description is the sine qua non of an informative and legally sufficient" environmental review under CEQA. *Santiago County Water District v. County of Orange* (1981) 118 Cal.App.3d 818, 830. But here, the 2022 Addendum's description of the Project's water storage and conveyance facilities is no longer accurate, and the public has no information regarding where the new facilities will be located, how they will be designed, or what the impacts associated with their development and maintenance would be.

The County cannot approve the Use Permit without first describing the Project's water supply facilities and disclosing the environmental impacts that would result from supplying the Project with water. CEQA requires that decision makers receive "sufficient facts to evaluate the pros and cons of supplying the amount of water that the [project] will need." *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova*, 40 Cal.4th 412, 430-31 (2007). This information includes describing construction-related impacts from building a new reservoir and water conveyance infrastructure, and analyzing water supplies that "bear a likelihood of actually proving available; speculative sources . . . are insufficient bases for decision making under CEQA." *Id.* at 432.

[9] Available at https://oag.ca.gov/system/files/attachments/press-docs/2022.10.10%20-%20Wildfire%20Guidance.pdf

"The ultimate question under CEQA . . . is not whether an EIR establishes a likely source of water, but whether it adequately addresses the reasonably foreseeable *impacts* of supplying water to the project." *Id*. at 434. Here, the County's environmental documents provide no discussion regarding the reasonably foreseeable impacts related to supplying water to the Project. The location of the Project's water supply is unknown, and unless potential supplies are identified and evaluated, it is impossible for the County to determine how supplying the Project with water will impact the environment. Even when faced with uncertainty regarding a project's water supply, lead agencies "shall conduct an analysis of alternative sources, including at least in general terms the environmental consequences of using those alternative sources." CEQA Guidelines § 15155(f). Until the County performs such an analysis, it cannot approve the Project.

C. The County must evaluate the Project's impacts to mountain lions and other species.

Mountain lions in the Project area are part of the Santa Ana Mountains population, which is facing extinction due to high levels of inbreeding, low genetic diversity, high human-caused mortality rates from car strikes, depredation kills, rodenticide poisoning, poaching, disease, and increased wildfires. As a result, this mountain lion population received "candidacy status" in April 2020 under the California Endangered Species Act ("CESA").[10] This status affords mountain lions the same protections as other CESA-listed species. CEQA requires a "mandatory finding of significance" when a project has the potential to impact a CESA-listed species. CEQA Guidelines § 15065(a)(1); *Endangered Habitats League, Inc. v. County of Orange* (2005) 131 Cal.App.4th 777, 792 fn. 12. This finding triggers a duty to consider and adopt all feasible alternatives or mitigation measures to reduce impacts to listed species. Pub. Resources Code. Code § 21002. Moreover, CESA prohibits the County from approving projects that could jeopardize the continued existence of these populations or cause destruction of essential habitat (Fish & Game Code § 2053(a)) and agencies must require that appropriate mitigation measures be implemented for projects that could destroy mountain lion habitat or impair connectivity (Fish & Game Code § 2054). The 2002 RSEIR does not address these issues or the increasing threat to the Santa Ana Mountain population of mountain lions in the last 20 years.

Indeed, the Project would not only develop potential mountain lion habitat, but it would further constrict a critical habitat linkage between Whiting Ranch Wilderness and O'Neill Regional Park. This corridor is the only remaining lower elevation habitat linkage through the foothills of the Santa Ana Mountains in this area but has been dramatically reduced by development of the Portola Hills community and other projects in the area. The County must assess the Project's cumulative impacts to mountain lions, and other species such as coyotes, bob cats, and deer, that rely on this linkage, and consider feasible mitigation and alternatives to avoid those impacts.

[10] Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=178623&inline and https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=171208&inline

D. The County must evaluate the Project against California's standards for reducing greenhouse gas emissions.

The 2002 RSEIR did not evaluate climate change impacts. Although the RSEIR evaluated other air quality-related impacts from the Project, it did not separately consider how the Project's construction or operation would generate greenhouse gases (GHG), much less consider how to mitigate those emissions. *See* 2002 RSEIR Section 4.6. Indeed, statistics regarding the need to reduce GHG emissions were not widely referenced and data at the state, regional, and local level was not readily available in 2002. The CEQA Appendix G checklist used in 2002 did not reference GHG emissions or study Vehicle Miles Traveled as a substantial contributor to GHG emissions.

In the last 10 to 15 years, the effects of climate change and the need to minimize GHG emissions have increasingly been recognized as issues of life- and health-threatening relevance. Scientific reports regarding climate change released since 2002 are beyond alarming, indicating that the world may hit its "tipping point" for GHG emissions far sooner than previously expected. For example, the World Meteorological Organization's most recent report provides an ominous warning, stating that atmospheric levels of the three main greenhouse gases—carbon dioxide, methane, and nitrous oxide—all reached new record highs in 2023 and are continuing to increase.[11]

In response to the growing economic and environmental threat, reducing the state's greenhouse gas emissions is a now a statewide priority and legislative mandate. This was not the case in 2002 when the County certified the RSEIR. Key legislative milestones since 2002 include:

AB 32 (2006). AB 32 required California to reduce its GHG emissions to 1990 levels by 2020 — a reduction of approximately 15 percent below emissions that were expected under a "business as usual" scenario. AB 32 was the first program in the country to take a comprehensive, long-term approach to addressing climate change.

SB 97 (2007). SB 97 recognized the need to analyze greenhouse gas emissions as a part of the CEQA process. SB 97 required OPR to develop, and the California Natural Resources Agency to adopt, amendments to the CEQA Guidelines addressing the analysis and mitigation of greenhouse gas emissions.

SB 32 (2016). SB 32 expands upon AB 32 and requires California to reduce its GHG emissions to 40% below the 1990 levels by 2030.

AB 1279 (2022). AB 1279 requires the state to achieve ***net zero GHG emissions as soon as possible, but no later than 2045***, and achieve and maintain net negative greenhouse gas emissions thereafter. The bill also requires California to reduce statewide GHG emissions by 85

[11] Available at https://library.wmo.int/viewer/68835/download?file=1347_Global-statement-2023_en.pdf&type=pdf&navigator=1

percent compared to 1990 levels and directs the California Air Resources Board (CARB) to work with relevant state agencies to achieve these goals.

Additionally, as directed by AB 32, CARB adopted its first Scoping Plan in 2008. The document has been updated several times since. The current "2022 Scoping Plan for Achieving Carbon Neutrality" lays out a path to achieve targets for carbon neutrality and reduce GHG emissions by 85 percent below 1990 levels no later than 2045 (as directed by Assembly Bill 1279).

In line with the science and legislation discussed above, the 2022 CARB Scoping Plan is far more aggressive than previous scoping plans, requiring substantially greater efforts to lower greenhouse gas emissions. The County must assess the Project's consistency (or inconsistency) with the new Scoping Plan in an SEIR, and adopt any feasible mitigation measures to reduce the Project's climate change impacts. Some of the Scoping Plan's relevant substantial changes that the County must consider are:

"The major element of" the Scoping Plan's "*unprecedented transformation* is the aggressive reduction of fossil fuels wherever they are currently used in California, building on and accelerating carbon reduction programs that have been in place for a decade and a half. That means rapidly moving to zero-emission transportation; electrifying the cars, buses, trains, and trucks that now constitute California's single largest source of planet-warming pollution." *See* CARB 2022 Scoping Plan at p. 1 (emphasis added).[12]

The Scoping Plan "identifies a technologically feasible and cost-effective path to achieve carbon neutrality by 2045 while also assessing the progress California is making toward reducing its GHG emissions by at least 40 percent below 1990 levels by 2030, as called for in SB 32 and laid out in the 2017 Scoping Plan. The 2030 target is an interim but important step along the critical path to the broader goal of deep decarbonization by 2045. Modeling for this Scoping Plan shows that this decade must be one of transformation "*on a scale never seen before* to set us up for success in 2045." *See* CARB 2022 Scoping Plan at p. 24 (emphasis added).

"The Scoping Plan Scenario achieves the AB 1279 target of 85 percent below 1990 levels by 2045 and *identifies a need to accelerate the 2030 target* to 48 percent below 1990 levels." *See* CARB 2022 Scoping Plan at p. 71.

Significantly, the 2022 Scoping Plan states that the residential sector generated 8% of the total GHG emissions throughout California in 2020. Additionally, 38% of GHG emissions were generated by the transportation sector, which includes private passenger vehicles like those that will serve the proposed Project. *See* Exhibit F [greenhouse gas inventory]. To reduce these emissions, Scoping Plan "Appendix D (Local Actions) provides suggestions for prioritizing the various types of mitigation, starting with on-site GHG-reducing design features and mitigation measures, such as methods to reduce VMT and support building decarbonization, access to

[12] https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp.pdf

shared mobility services or transit, and EV charging. After exhausting all the onsite GHG mitigation measures, CARB recommends prioritizing local, off-site GHG mitigation measures, including both direct investment and voluntary GHG reduction or sequestration projects, in the neighborhoods impacted by the project. This could include, for example, development of a neighborhood green space, investment in street trees, or expansion of transit services." *See* CARB 2022 Scoping Plan at p. 270.

Despite the worsening trend in greenhouse gas emissions and California's recent legislative and executive actions to curb emissions in the state, the most recent CEQA addendum for the Project argues that it need not consider greenhouse gas impacts at all because scientists were generally aware of the potential for climate change before the initial RSEIR was certified. *See* Addendum No. 2 at 6-12. However, it was impossible to anticipate the current severity of climate change, or to predict the state's more recent goals for reducing greenhouse gas emissions in response to the climate change.

Indeed, in 2018, the CEQA Guidelines were updated to ***require*** the analysis of greenhouse gas emissions. *See* CEQA Guidelines § 15064.4(a) (agencies "shall make a good faith effort, based to the extent possible on scientific and factual data, to describe, calculate or estimate the amount of greenhouse gas emissions resulting from a project"). CEQA Guidelines Appendix G lists Greenhouse Gas Emissions as a stand-alone impact analysis section and that implementation of the project would result in a significant GHG impact if it would:

- Generate GHG emissions, either directly or indirectly, that may have a significant impact on the environment.

- Fundamentally conflict with an applicable plan, policy, or regulation adopted for the purposes of reducing the emissions of GHGs.

In light of these changes to the CEQA Guidelines, and the increasingly stringent state standards for reducing GHG emissions, the County must evaluate and mitigate the Project's GHG emissions before it approves the proposed Use Permit.

IV. Conclusion

The Saddleback Meadows Project cannot be approved in its current form. It conflicts with the County's zoning code and would create significant safety and environmental impacts that have not been adequately considered. The Board should refrain from approving the final tract map for the Project and should defer any action on it until the Planning Commission has conducted adequate public and environmental review of the Use Permit application and resolved these issues.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Edward T. Schexnayder

cc: Marissa Leahy, Orange County Planning Commission
Pamela Passow, Orange County Parks Director

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EXHIBIT A

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CALIFORNIA

How climate change is fueling record-breaking California wildfires, heat and smog

Smoke and haze from wildfires hovered Thursday over San Francisco, as much of California was blanketed in smoke from a siege of wildfires and poor air quality. (Eric Risberg / Associated Press)

By SUSANNE RUST, TONY BARBOZA

SEP. 13, 2020 6 AM PT

In 2001, a team of international scientists projected that during the next 100 years, the planet's inhabitants would witness higher maximum temperatures, more hot days and heat waves, an increase in the risk of forest fires and "substantially degraded air quality" in large metropolitan areas as a result of climate change.

In just the past month, nearly two decades after the third United Nations Intergovernmental Panel on Climate Change report was issued, heat records were busted across California, more than 3 million acres of land burned , and in major metropolitan areas, such as Los Angeles and San Francisco, air pollution has skyrocketed.

"This shouldn't come as a surprise to anyone," said Michael Gerrard, director of the Sabin Center for Climate Change Law at Columbia University. "Maybe we underestimated the magnitude and speed" at which these events would occur, he said, but "we've seen this long freight train barreling down on us for decades, and now the locomotive is on top of us, with no caboose in sight."

In a matter of weeks, California has experienced six of the 20 largest wildfires in modern history and toppled all-time temperature records from the desert to the coast. Millions are suffering from some of the worst air quality in years due to heat-triggered smog and fire smoke. A sooty plume has blanketed most of the West Coast, blotting out the sun and threatening people's lungs during a deadly pandemic.

California is being pushed to extremes. And the record heat, fires and pollution all have one thing in common: They were made worse by climate change. Their convergence is perhaps the strongest signal yet that the calamity climate scientists have warned of for years isn't far off in the future; it is here today and can no longer be ignored.

"What we've been seeing in California are some of the clearest events where we can say this is climate change — that climate change has clearly made this worse," said Zeke Hausfather, a climate scientist at the Breakthrough Institute, an Oakland-based think tank. "People who have lived in California for 30, 40 years are saying this is unprecedented, it has never been this hot, it has never been this smoky in all the years I've lived here."

CALIFORNIA

Los Angeles suffers worst smog in almost 30 years

Sep. 10, 2020

Unprecedented, yes. But not unexpected.

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Since the 1980s, government and oil industry scientists have been anticipating the events that have transpired across the state this past month.

As one 1988 internal Shell Oil Co. document noted, "by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation."

"I'm only sorry that in 1989, I could not get an audience for what I wanted to communicate," said Jim Hansen, a retired NASA researcher and early climate change scientist, of testimony he made to Congress about the issue.

Record temperatures

Each of the extremes Californians are living through right now is fueled, at least in part, by the gradual warming of the planet, which is accelerating as greenhouse gas emissions continue to rise.

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California summers are 2.5 degrees warmer than they were in the 1970s and are on track to heat up an additional 4.5 degrees by the end of the century if the world's current emissions trajectory continues, said Hausfather.

While precise attribution studies on the extreme heat waves in California in recent weeks will take time to complete, he said, they are clear examples of how climate change compounds natural weather variability to increase the likelihood of what once would have been a rare event.

"In a world without climate change, it still would have been a hot August; we still would have had some fires. But it's clear that climate change has made things notably worse," he said. "An extreme heat event that would have been 100 degrees is now 102.5 or 103 degrees, and that is actually a pretty big difference in terms of the impacts on people."

Attachment A

During the mid-August heat wave, Death Valley soared to 130 degrees, one of the hottest temperatures ever recorded on Earth.

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Another ferocious heat wave over the Labor Day weekend brought Death Valley-like heat to other areas. Los Angeles County had its hottest temperature on record when Woodland Hills hit 121 degrees Sept. 6. At Cal Poly San Luis Obispo, it reached 120 degrees, the highest reading since record-keeping began in 1869, in an area that is less than 10 miles from the Pacific Ocean.

CALIFORNIA

A sizzling summer: Hottest August on record in California

Sep. 10, 2020

John Lindsey, a marine meteorologist with Pacific Gas and Electric, said the mercury rose to unprecedented levels in San Luis Obispo due to hot, downslope winds blowing from the northeast. They are known locally as Santa Lucia winds and can increase temperatures by 5.5 degrees for every 1,000 feet they descend.

“It was just rip-roaring hot,” said Lindsey, who has forecast weather along the Central Coast since 1991. “You just don’t expect Death Valley temperatures along coastal California.”

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Lindsey, who acknowledges that he was a bit of a climate skeptic in the past, said seeing the increase in seawater temperatures, in particular, over many years "was a real epiphany or wake-up call."

"By now, there's no doubt in most people's minds that the atmosphere is warming and the ocean is warming," he said. "With the way greenhouse gases are increasing, in my mind, there's no doubt that we're causing this. It's human activity that's causing this. So I'm concerned about the future. And that's somebody who's very skeptical."

Global warming has increased the odds of unprecedented heat extremes across more than 80% of the planet and "has doubled or even, in some areas, tripled the odds of record-setting hot events" in California and the Western U.S., said Stanford University climate scientist Noah Diffenbaugh.

An unprecedented firestorm

When it comes to wildfires, "what we've had in California over the last three to four weeks is unprecedented in our historical experience," Diffenbaugh said.

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"This is more extreme than any other year in living memory," he said, and is consistent with the impact of global warming.

Research by Diffenbaugh and colleagues that was published last month found that the number of days with extreme wildfire weather in California has more than doubled since the early 1980s, primarily due to warming temperatures drying out vegetation.

"It means that even with no change in the frequency of strong wind events, even with no change in the frequency of lightning, the risk of wildfire and risk of large, rapidly growing wildfires goes up as a result of the effect of that warming," he said.

California wildfires map: What's burning now

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And it's that atmospheric warming that has set the stage for the fires raging throughout the western U.S., said Park Williams, a hydroclimatologist at Columbia University's Lamont-Doherty Earth Observatory.

"If we think of the atmosphere as a giant sponge that's always trying to extract water from the landscape, then temperature increases the sponginess," he said.

As soils become drier, heat waves become more intense. That's because the energy in the atmosphere is no longer being used in evaporation but is just building up heat. And as heat increases and soils — and, therefore, fuel for fires — dry out, the risk grows, laying the foundation for the type of wild and destructive fires we are now observing.

"That's why, I think, you keep reading quotes from these firefighters who say they are seeing fire behavior unlike anything they've seen before," he said. "As we go out in the future, in a world with this exponentially growing risk … we're going to see fires far different than we've seen before."

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He noted that fires are not unusual in California — they are an integral part of the state's history and landscape. Bad forest management, combined with human behavior — intentional and unintentional starting of fires — have contributed to the problem. But the effect of climate change is real and growing.

"We have seen the rapid warming of California summers really turbocharge the type of conditions that are suitable for rapid growth of wildfires," Hausfather said. "We see fires growing from essentially nothing to a quarter of a million acres in one day. And that's because the conditions are ripe, and temperature plays a large role."

John Abatzoglou, associate professor in the Department of Management of Complex Systems at UC Merced, agreed.

“What we are seeing play out does indeed have human fingerprints on it, including those from climate change,” he said.

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“We can see how warm and dry years catalyze these fires,” he said, adding, however, that for fires to start, “they need to have ignitions. But the heat and dryness have absolutely set the table for widespread fire activity.”

Dreadful air quality

It was no coincidence that ozone pollution levels in downtown Los Angeles spiked to their highest levels since the mid-1990s on a day in which temperatures reached an all-time high for the county, said Cesunica Ivey, an assistant professor of chemical and environmental engineering at UC Riverside who studies air quality.

The global rise in temperatures observed over decades is also occurring locally, she said, “and these frequently occurring heat waves, this upward trend in basin-wide average temperature, is contributing to ozone exacerbation.”

CALIFORNIA
Rarely have so many Californians been exposed to such gloomy, unhealthy air
Sep. 10, 2020

Southern California regulators have seen decades of progress fighting smog stymied in recent years by hotter weather and stronger, more persistent inversion layers that trap pollution near the ground. Their efforts are being hindered by rising temperatures from climate change, according to air quality experts.

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That's because hotter weather speeds up the photochemical reactions that turn pollutants from vehicle tailpipes and other sources into ozone, the invisible, lung-damaging gas in summer smog. Studies show that ozone levels are about two parts per billion higher than they would be without global warming.

What precisely is driving changes such as elevated smog levels can be hard to tease out in the middle of an extreme event because so much is happening at once, with multiple hazards piling on top of each other in a vicious feedback loop.

The recent heat spells, for instance, both fueled smog formation and led to power outages. Gov. Gavin Newsom suspended air quality rules on power plants and other polluters to ease strain on the grid, allowing more emissions to sully the air. The COVID-19 pandemic has added an additional layer of complexity at a time when Californians are trying to protect their homes, lungs and bodies from threats that seem to be coming from all sides.

"When you add COVID, extreme heat, wildfires and air pollution all together, they're all detrimental to public health, and it just makes things worse," said Yifang Zhu, a professor of environmental health sciences at UCLA Fielding School of Public Health who studies air pollution and its effects. "These stressors are happening at the same time. So the impact is cumulative and maybe even synergistic to each other."

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That cascading effect, in which one extreme compounds another, is a feature of global warming that experts have long warned about.

Ivey, of UC Riverside, said she and other scientists aren't surprised to see so many extremes hitting simultaneously, "but to see it playing out is scary."

"It's one of those moments where ozone converged with record acres burned and a heat wave," she said. "If the writing isn't on the wall, then I don't know what to tell folks."

Attachment A

Global warming is also fueling increases in wildfire pollution, a mix of soot particles and gases that can fuel ozone formation and dramatically worsen smog. Those added emissions are only going to get worse as the severity and frequency of fires increases.

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"People may not directly connect local air pollution to global climate change, but they are intertwined," said Zhu. "They are two sides of the same coin."

What this year's extreme heat, fire and air quality degradation is showing, said Columbia's Williams, is that we are, in a sense, blindly stepping off a cliff from a world in which we could somewhat predict what was going to happen, based on decades and centuries of data.

"We're finding that we've lost complete control," he said. "The baselines we've used for decades no longer apply. There really isn't a normal anymore."

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Susanne Rust

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Attachment A

Susanne Rust is an award-winning investigative reporter specializing in environmental issues. She is based in the Bay Area.

Tony Barboza

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Tony Barboza is a reporter who covers air quality and the environment with a focus on Southern California. He has been on staff at the Los Angeles Times since 2006, is a graduate of Pomona College and completed a Ted Scripps Fellowship in Environmental Journalism at the University of Colorado. News tips? Send messages or documents privately using the Signal smartphone app: (213) 421-1511.

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E&E NEWS

CLIMATE

Fast-Moving California Wildfires Boosted by Climate Change

Nearly two dozen large blazes have burnt more than 1 million acres of the state

By Anne C. Mulkern, E&E News on August 24, 2020

Embers blow off a burned tree after the LNU Lightning Complex Fire burned through the area on August 18, 2020 in Napa, California. Credit: Justin Sullivan *Getty Images*

Firefighters battled nearly two dozen wildfires in California yesterday after a week of raging blazes blackened more than 1 million acres across the state.

The fast-moving fires, which are seen by many scientists as a sign of climate change, have killed five people, destroyed more than 1,000 structures and forced thousands to flee. More than 238,000 people either evacuated or were ready to go as more thunderstorms threatened to light new fires yesterday afternoon, according to officials.

Still-active fires are affecting at least 23 counties in Northern California, stretching from Butte to Fresno. Two of the blazes rank among the largest in state history.

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The LNU Lightning Complex Fire, a group of fires centered in Napa and Sonoma counties, has grown into the second-largest blaze ever seen in California. The SCU Lightning Complex Fire, a cluster of blazes in Santa Clara, Alameda and nearby counties, is the third-largest.

Altogether, the fires have burned an area the size of Rhode Island.

"The scope [of the damage] is absolutely astonishing," said Daniel Swain, a climate scientist at UCLA. It's "hard to impress on people just how vast the acreage burned is, especially considering there were no strong offshore winds" to drive the spread.

President Trump on Saturday issued a major disaster declaration to fulfill a request by Gov. Gavin Newsom (D) to bolster the state's emergency resources. Meanwhile, the National Weather Service issued a red flag warning for more thunderstorms and lightning through today.

The racing flames show how climate change is affecting the nation's most populous state, experts said. Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation. Climate change also affects how much moisture is in the air, Swain said.

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"It's actually drying out the air during these extreme heat events," which zaps plants of additional moisture, Swain said. That left much of the state a tinderbox when hundreds of lightning strikes scorched the countryside last week.

"This is really a testament to how dry the vegetation is, in terms of how quickly these fires spread when they were ignited by lightning," he said.

The amount of land burned last week is more than the total burned in all of 2018, and more than double the amount burned in 2017, according to data released by the California Department of Forestry and Fire Protection (Cal Fire).

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The fires on Saturday burned part of the oldest state park in California, Big Basin Redwoods State Park in Santa Cruz County. Flames damaged historic buildings, the campground and "all of the infrastructure," said Christine McMorrow, a spokeswoman with Cal Fire. It wasn't known whether redwood trees were engulfed.

The blazes threaten to outpace the state's ability to respond. Nearly all of Cal Fire's crews are in the field, with some working 72-hour shifts. Oregon, Washington, Nevada, New Mexico, Texas and other states sent firefighters, equipment or both. Officials said more than 13,000 fire personnel were on the scene.

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"We have more people, but it's not enough," Newsom said at a Friday news conference. "We have more air support, but it's not enough."

REPEAT FIRE TRAUMA

Fires erupted beginning Aug. 15 when more than 1,200 lightning strikes hit the baking landscape within 72 hours.

Those came "the exact week that we were experiencing some of the hottest temperatures ever recorded in human history, 130-degree temperatures in the southern part of the state," Newsom said. It was "maybe the hottest modern recorded temperature in the history of the world," he said.

He was referring to the temperature of 130 degrees Fahrenheit on Aug. 16 in Death Valley, a high not reached on Earth in 89 years. The highest temperature ever recorded on the planet is 134 Fahrenheit. It was reached in 1913 in Death Valley. Its accuracy is

disputed by some observers because there was a lack of modern technology (*Climatewire*, Aug. 18).

Altogether, more than 12,000 lightning strikes hit California last week, igniting over 600 fires. Firefighters knocked down smaller ones, but others merged into major "complex" fires.

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The week was filled with horror stories and heroic efforts. Volunteers helped evacuate senior citizens from a Vacaville retirement home in the middle of the night as a fire raced toward the facility. Others helped rescue "dozens and dozens of individuals with intellectual disabilities" in Santa Clara, Newsom said.

Hundreds saw their homes destroyed.

"Tuesday night when I went to bed, I had a beautiful home on a beautiful ranch," Hank Hanson, 81, of Vacaville, told the Associated Press. "By Wednesday night, I have nothing but a bunch of ashes."

State Assemblywoman Cecilia Aguiar-Curry, who represents the Napa wine region, said at a news conference Friday that she has "half a dozen really good friends who don't have a home right now."

The American Red Cross, wary of the coronavirus pandemic, put some survivors in hotel rooms so they could be separated from other evacuees, said Jim Burns, a Red Cross spokesman. Others went to evacuation shelters where protocols were in place to keep people spaced out. The Red Cross was also talking to colleges to see whether dorm rooms were available.

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The fires swept across heavily populated cities that have endured major fires in recent years. Susan Gorin, a Sonoma County supervisor, lost her home in the 2017 Tubbs Fire, a blaze that killed 22 people. She built a new house in the same location; on Friday, she found ashes on her patio from a nearby firestorm.

"It just seems so terrifyingly familiar," Gorin said as she traveled to Lake Tahoe to escape the smoke and mayhem. "This is now the third major fire in four years. We are battle-weary."

CLIMATE CONNECTION SCRUTINIZED

Swain with UCLA and other scientists earlier this year published a study that said climate change has doubled the number of extreme-risk days for California wildfires.

It said temperatures statewide rose 1.8 degrees Fahrenheit since 1980, while precipitation dropped 30%. That doubled the number of autumn days that offer extreme conditions for the ignition of wildfires (*Climatewire*, April 3).

The heat is expected to get worse with time. Climate models estimate that average state temperatures will climb 3 degrees Fahrenheit by 2050 unless the world makes sharp cuts in greenhouse gas emissions, said Michael Wehner, a senior scientist at Lawrence Berkeley National Laboratory.

Even with emissions cuts, average temperatures would rise 2 degrees by midcentury, he said.

Jon Keeley, a senior scientist at the U.S. Geological Survey Western Ecological Research Center, argued that the study from Swain and others failed to show that hotter temperatures are driving wildfires.

"Show us data that shows that level of temperature increase is actually associated with increased fire activity," Keeley said. "They don't show that."

Keeley added, "We ought to be much more concerned with ignition sources than a 1- to 2-degree change in temperature."

A big contributor to large California fires is that the state has focused on extinguishing blazes for about a century rather than allowing for controlled burns, he said. That has caused dead vegetation to accumulate.

Trump has accused California of failing to "sweep" its forests, which he has linked to fires in the state.

Keeley said that "we don't sweep forests here in the U.S., but what we do is prescription burning. ... It's potentially the same thing. It's modifying the fuels prior to a fire."

Swain, the UCLA climate scientist, said global warming is affecting how big fires get and how fast they move.

"What happens when they start burning, what is the character of those fires, and is it changing?" Swain asked. "The answer is yes."

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EXHIBIT C

Attachment A

2020 Incident Archive

A summary of all 2020 incidents, including those managed by CAL FIRE and other partner agencies.

4,257,863 Acres
Estimated Acres Burned

9,917 Incidents
Number of Incidents

33 Fatalities
Confirmed Loss of Life

10,488 Structures
Structures Damaged or Destroyed

2020 Incidents

Name	Start Date	Counties	Acres	Containment
Sanderson Fire	12/12/2020	Riverside	1,933	100%
Cornell Fire	12/7/2020	Ventura	174	100%
Thomas Fire	12/3/2020	Lassen	24	100%
Cerritos Fire	12/2/2020	Riverside	200	100%
Bond Fire	12/2/2020	Orange	6,686	100%
Willow Fire	12/2/2020	San Diego		
Airport Fire	12/1/2020	Riverside	1,087	100%
257 Fire	11/17/2020		49	100%
San Dimas Fire	11/5/2020	Los Angeles	131	100%
Cypress Fire	11/1/2020	Riverside and San Bernardino	150	100%

Attachment A

2020 Fire Season

The 2020 California wildfire season was characterized by a record-setting year of wildfires that burned across the state of California as measured during the modern era of wildfire management and record keeping. As of the end of the year, nearly 10,000 fires had burned over 4.2 million acres, more than 4% of the state's roughly 100 million acres of land, making 2020 the largest wildfire season recorded in California's modern history. California's August Complex fire has been described as the first "gigafire" as the area burned exceeded 1 million acres. The fire crossed seven counties and has been described as being larger than the state of Rhode Island. On August 19, 2020, California Governor Gavin Newsom reported that the state was battling 367 known fires, many sparked by intense thunderstorms on August 16–17. In early September 2020, a combination of a record-breaking heat wave, and Diablo and Santa Ana winds sparked more fires and explosively grew the active fires, with the August Complex more than doubling the Mendocino Complex's size to become California's largest recorded wildfire.

Search our Incident Database

Search by Incident Name, Year, County or Keyword

Annual Fire Season Pages

ACTIVE | **2021** | **2020** | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **2013**

EXHIBIT D

BUILT TO BURN

California's Wildlands Developments Are Playing With Fire

Center for Biological Diversity • February 2021

Satellite image of the 2018 Camp Fire near Paradise, California / NASA.

BUILT TO BURN:

California's Wildlands Developments Are Playing With Fire

Bold Land-use Reforms Needed Now to Ensure Safer, Sustainable Future

A report by the Center for Biological Diversity:
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Aruna Prabhala, Urban Wildlands Program Director, Senior Attorney

February 2021
Published by the Center for Biological Diversity
BiologicalDiversity.org

Cover photo: A ermath of the 2017 Tubbs Fire in the Co ey Park neighborhood of Santa Rosa, California / Bay Area Media Masters, CC-BY

Guenoc Valley area, where the 2020 LNU Complex Fire burned through / Drew Bird Photography

EXECUTIVE SUMMARY

Wild res have occurred on California's landscapes for millennia. ey're a natural and necessary process for many of California's ecosystems. But some of the recent res have been exceptionally harmful to communities.

Since 2015 almost 200 people in the state have been killed in wild res, more than 50,000 structures have burned down, hundreds of thousands have had to evacuate their homes and endure power outages, and millions have been exposed to unhealthy levels of smoke and air pollution. Meanwhile costs for re suppression and damages have skyrocketed.

Policymakers must reckon with California's wild re history and acknowledge that reckless land-use policies are increasing wild re risk and putting more people in harm's way. Legislation that prioritizes the following proactive measures is needed immediately:

- Stop building new homes in highly re-prone wildlands;
- Retro t existing homes with high re risk.

Where we place homes in uences re risk. Almost all contemporary wild res in California, 95-97%, are caused by human sources such as power lines, car sparks and electrical equipment. Building new developments in highly re-prone wildlands increases unintentional ignitions and places more people in danger.

Hotter, drier and windier conditions due to climate change make the landscape more conducive to wild re ignitions and spread.

Most destruction to human communities from re has been caused by wind-driven, human-ignited res in highly re-prone shrubland habitats. More than 2 million homes have high re risk, and local governments

continue to approve new construction in highly re-prone wildlands. Such reckless sprawl development endangers all Californians.

Elected o cials and planners need to consider the state's complex re history and re ecology to implement smarter land use that protects people and native biodiversity. Many of California's ecosystems have adaptations to survive and thrive with wild res. But long-term re resilience is varied depending on the habitat type and re regime (i.e., the frequency, intensity, severity, spatial complexity and seasonality of re over time). Changes to re regimes threaten human communities as well as native habitats and wildlife.

Increased human ignitions due to sprawl development in highly re-prone native shrublands are harmful to people and biodiversity. Native shrubland habitats, like chaparral and sage scrub, are adapted to high severity wild res at relatively infrequent intervals ranging between 30 to 130 years or more. But increased re frequency in these habitats is causing type conversion to non-native grasses and forbs that burn more easily throughout more of the year. is altered re regime endangers human communities and the unique biodiversity those habitats support.

If California policymakers continue to expand development into highly re-prone wildlands and dismiss the need for home hardening in high re-risk areas, then more destructive res will ignite and more structures will burn. More people will be killed by res and have extended exposure to hazardous smoke. More re ghters and rst responders will be put at risk. Some biodiversity and unique ecosystems will be lost. Fire suppression and recovery costs will continue to rise.

We must change these destructive land-use policies and prepare our communities to safely coexist with wild re.

CALIFORNIANS FACING UNPRECEDENTED WILDFIRE IMPACTS

Wild res have occurred on California's landscapes for millennia. Lightning strikes and indigenous burning drove re regimes that varied by habitat, frequency, size, extent and seasonality (Kimmerer and Lake 2001; Stephens et al. 2007; Anderson 2018).

Approximately 4.4 to 11.9 million acres of land are estimated to have burned in California every year prior to European colonization due to lightning-caused res and cultural burning (Stephens et al. 2007). But in the past 200 years, California's highly diverse habitats and their historical re regimes have been disrupted (Stephens and Sugihara 2018). e impacts on human communities due to these changes have now become clear.

Pyrocumulus cloud from the 2020 Ranch 2 Fire near Azusa, California / Russ Allison Loar, Flickr CC-BY-ND

Recent res have been exceptionally destructive to California communities (Figure 1a). Based on re records from the past 100 years, res have become deadlier and more destructive, and large res are occurring at an increasing rate (Stephens and Sugihara 2018). Seventeen of the 20 largest wild res, 18 of the 20 most destructive wild res, and 11 of the 20 deadliest wild res have occurred a er 2003 (Cal Fire 2020a, 2020b, 2020c).

Meanwhile the cost of re suppression and damages in areas managed by the California Department of Forestry and Fire (Cal Fire) has skyrocketed to more than $23 billion during the 2015-2018 re seasons (Figure 1b). A er adjusting for in ation, this is more than double the wild re cost for the previous 26 years of records combined. ese harmful trends will continue unless policymakers reckon with the reckless land-use policies that put our communities in harm's way.

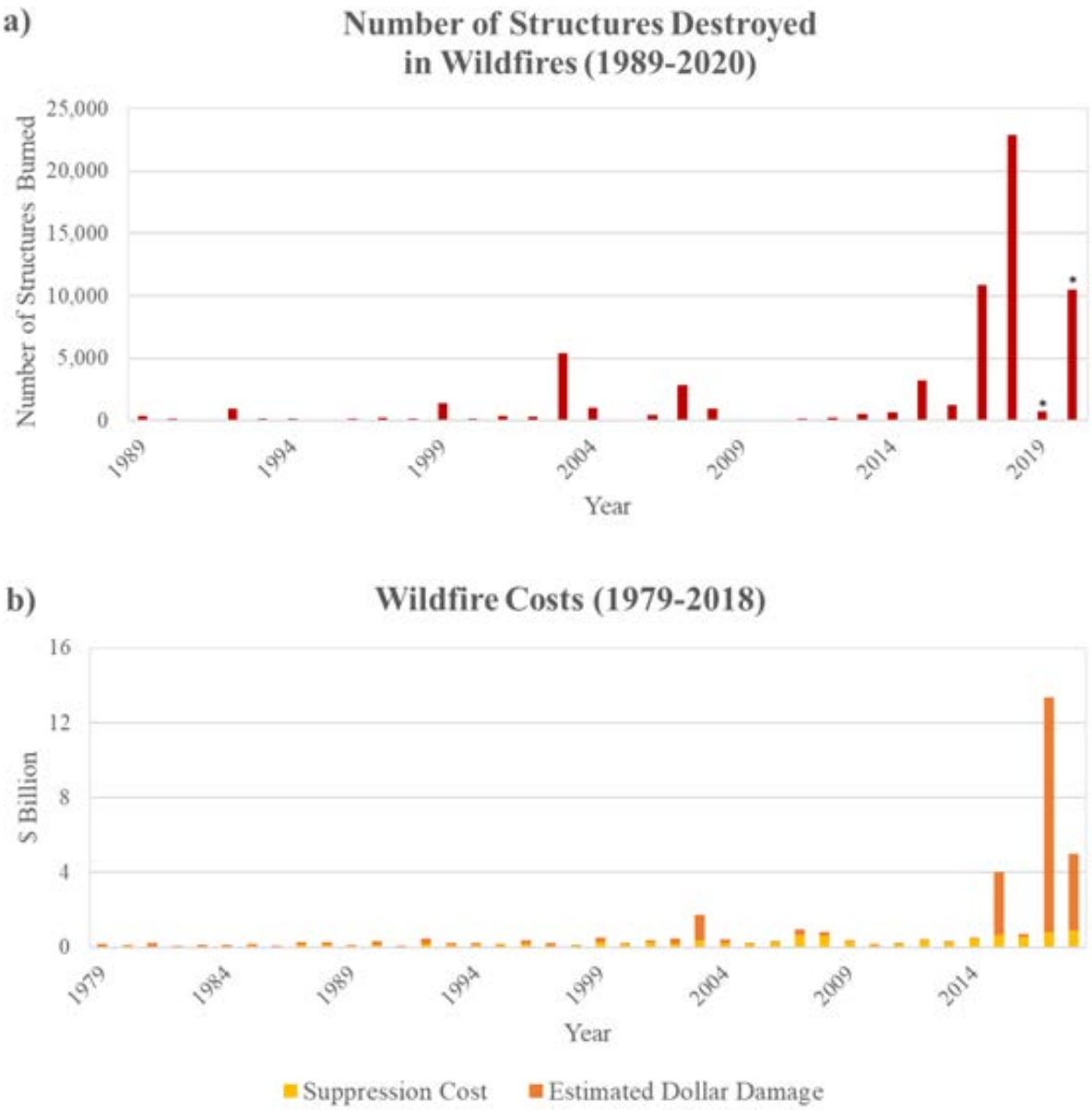


Figure 1. *Wild re destruction and costs over time. (a) Number of structures destroyed from 1989 to 2020 (*2019 and 2020 statistics are not nalized) and (b) Cal Fire wild re-suppression and damage costs from 1979 to 2018, adjusted for in ation. Data source: Cal Fire (https://www. re.ca.gov/stats-events/).*

Owl soars over re / U.S. Fish and Wildlife Service

SPRAWL DISRUPTS FIRE REGIMES AND MAKES WILDLIFE MORE VULNERABLE TO FIRE

Wild res are a natural and necessary process in many of California's ecosystems, providing essential habitat for numerous species. For example, woodpeckers and many other animals of the Sierra Nevada rely on wild re to create the dead trees, shrubs and post- re vegetation within which these animals nd the food they need to survive (e.g., Bond et al. 2009; Campos and Burnett 2015; Taillie et al. 2018; Blakey et al. 2019; Stillman et al. 2019). e critical role of wild re in Sierra Nevada forests has been dramatically disrupted, however, by development, logging and re suppression. As a result, these forests have a de cit of wild re, meaning there's much less re in these forests than there was historically — prior to 1800, an estimated 20 to 53 times more forest area burned each year in California than in recent decades (Stephens et al. 2007).

Researchers therefore recommend that more wild res be allowed to burn each year in the backcountry, instead of being suppressed, in order to allow Sierra Nevada forests to rejuvenate and support the region's exceptional biodiversity. Continued sprawl development in these landscapes is an expanding impediment to e orts to restore natural re regimes at any level.

California's shrubland habitats, on the other hand, such as chaparral and sage scrub, are experiencing a very di erent relationship with re. ese ecosystems are adapted to high-severity wild res at relatively infrequent intervals ranging from 30 to 130 years or more (Keeley and Fotheringham 2001; Stephens et al. 2007; Keeley and Syphard 2018; Baker and Halsey 2020), but increased re frequency from human ignition sources due to sprawl development is now causing these shrubland habitats to receive too much re. is altered re regime is the primary driver of habitat degradation and loss of biodiversity in these ecosystems (Keeley 2005) and leads to conversion of these important habitats to non-native grasses and forbs that burn more easily throughout more of the year, thereby compounding the problem of too much re (Keeley 2005; Syphard et al. 2009; Balch et al. 2013; Sugihara et al. 2018; Syphard et al. 2019). Any additional sprawl development in these highly re-prone habitats further undermines e orts to restore natural re regimes and reduce human ignitions in these areas.

In addition to disrupting re regimes, human activities have also put many of California's wild animals at risk of extinction. As a result, re can sometimes have harmful consequences to endangered species that now only exist in very small, isolated populations due to massive habitat loss and fragmentation from sprawl development combined with other threats.

For example, two mountain lion deaths in the Santa Monica Mountains were attributed in part to the 2018 Woolsey Fire (Figure 2). Although mountain lions are highly mobile and generally able to move away from wild res, these lions were unable to escape to safety because they were boxed in by roads and development. Such deaths can further destabilize the small mountain lion population that's already facing numerous other threats, including low genetic diversity, vehicle strikes and rodenticide poisoning, and make them more vulnerable to local extinction (Benson et al. 2016; Benson et al. 2019).

Similarly, researchers fear, post- re landslides a er the 2020 Bobcat Fire could be the end for remnant populations of sensitive species in the San Gabriel mountains that have been hard hit by sprawl development combined with disease, non-native predators and other threats, including Santa Ana suckers, unarmored threespine stickleback sh, speckled dace, arroyo chub, mountain yellow-legged frogs and western pond turtles (Figure 2) (Sahagun 2020). While historically these species would have been able to recolonize from neighboring populations a er the loss of individuals or populations to re impacts, that ability is now limited by the species' current small and fragmented population structure. Continued alteration of historical re regimes due to sprawl development will further endanger those remnant populations.

Figure 2. * e burned paws of P-64, an adult male mountain lion whose death was attributed to the 2018 Woolsey Fire (le), and a mountain yellow-legged frog, whose remnant populations in the San Gabriel Mountains are threatened by post- re landslides in the wake of the 2020 Bobcat Fire (right). Photo credits: National Park Service and U.S. Geological Survey (Adam Backlin).*

POOR LAND-USE PLANNING FUELS MORE DESTRUCTIVE FIRES

Reckless land-use planning is causing res to be more destructive. Development in highly re-prone areas increases unintentional ignitions, places more people at risk, and destroys native shrubland habitats that support high levels of biodiversity. Almost all contemporary wild res in California (95-97%) are caused by humans in the wildland urban interface (Syphard et al. 2007; Balch et al. 2017; Radelo et al. 2018; Syphard and Keeley 2020).

For example, the 2019 Kincade Fire, 2018 Camp and Woolsey res, and 2017 Tubbs and omas res were sparked by powerlines or electrical equipment. And although many of the 2020 res were sparked by a lightning storm, the Apple Fire was caused by sparks from a vehicle, the El Dorado Fire was caused by pyrotechnics at a gender-reveal celebration, the Blue Ridge Fire was likely caused by a house re, and electrical equipment is suspected to have ignited the Silverado and Zogg res.

More than a million homes were built in the wildland-urban interface between 1990 and 2010 (Radelo et al. 2018), and more than 2 million homes are located in high re-risk areas (Verisk 2020). Such development in California's highly re-prone wildlands is increasing wild re frequency while placing more people in harm's way.

Recent res highlight this issue: 15 of the 20 most destructive California wild res have occurred in the past ve years (Cal Fire 2020b). If current land-use practices continue, scientists estimate, 640,000 to 1.2 million new homes will be built in the state's highest wild re-risk areas by 2050 (Mann et al. 2014), which will only worsen the devastating trend.

e contrast between the 1964 Hanly Fire and 2017 Tubbs Fire o ers a poignant example of how expanding development in highly re-prone areas increases re risk. Both res were caused by people: It's believed that the Hanly Fire was started by a hunter either discarding a cigarette or burning debris, while the Tubbs Fire was caused by faulty electrical equipment on private property.

ese res had similar footprints (Figure 2), yet the Tubbs Fire burned more than 5,500 structures and killed at least 22 people, while the 1964 Hanly Fire only burned about 100 structures and killed no one. From 1964 to 2017 the population of nearby Santa Rosa grew from 30,000 to 170,000 people — sprawl development had extended farther into re-prone wildlands and put more people at re risk (Figure 3) (Keeley and Syphard 2019).

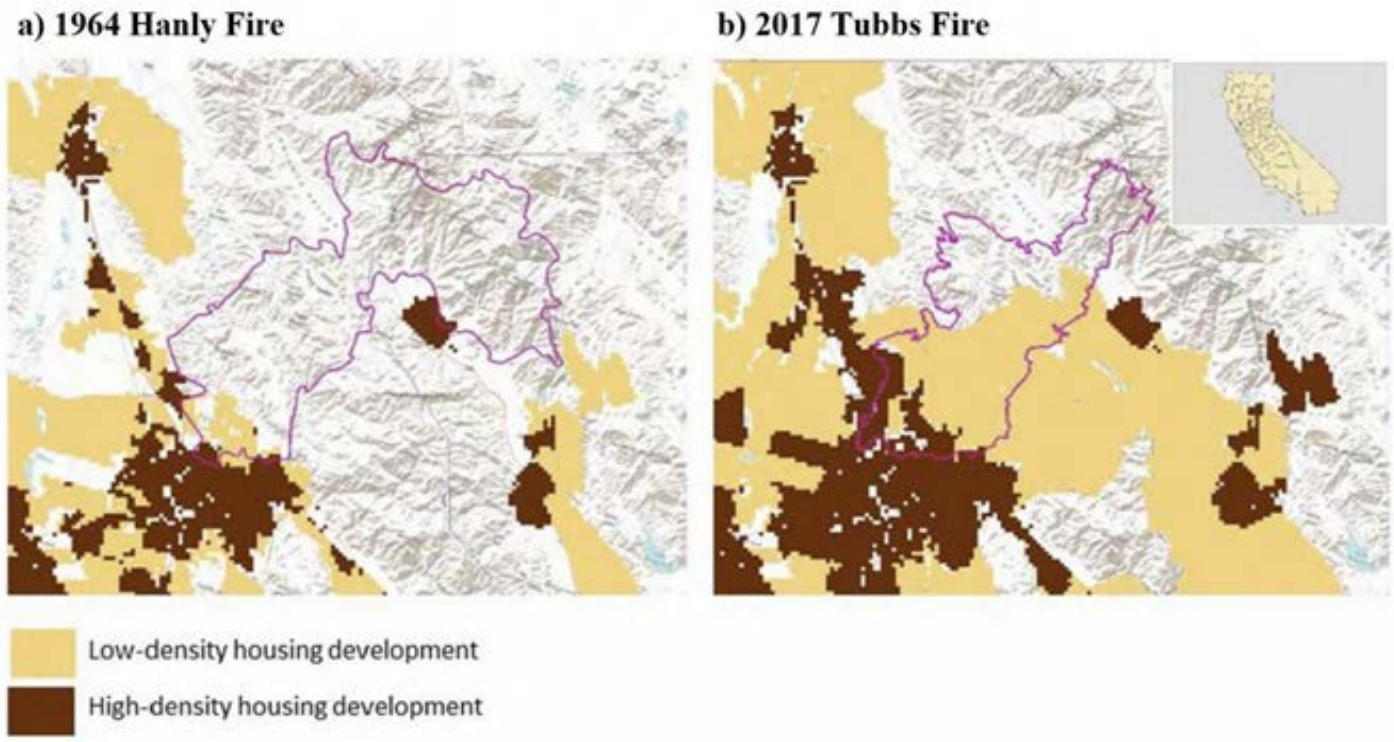


Figure 3. *A tale of two res: the 1964 Hanly Fire (a) and the 2017 Tubbs Fire (b). Despite the simliar re footprints (shown with the purple line), the Hanly Fire caused no deaths, and only about 100 structures were destroyed, while the Tubbs Fire killed 22 people and destroyed more than 5,500 structures. Note the extension of housing development within the re footprint a er the Hanly Fire (Keeley and Syphard 2019).*

Most destruction to human communities from re has been caused by human-ignited res in mixed shrubland habitats (Syphard 2020). Native shrublands like chaparral and sage scrub are highly diverse and adapted to high-intensity, relatively infrequent res.

e 2017 omas Fire near the city of Ventura, California / European Space Agency

Placing developments in these highly re-prone habitats ultimately increases re threat over time. Continued sprawl is causing more frequent res, which convert shrublands to non-native grasses that ignite more easily throughout more of the year. is perpetuates a dangerous cycle that increases wild re ignitions, extends the re season, and eliminates native shrubland habitats and biodiversity.

Wind is another important factor in wild re risk. Foehn winds, referred to as the Santa Ana winds in the south and the Diablo or North winds in the north, commonly occur in the fall. ese are dry, warm, strong winds that can spread res dangerously fast. Winds were clocked at 40 to 95 miles per hour during the 2020 wild re season. Wind-driven res can cover 25,000 acres in one to two days as embers are blown ahead of the res and toward adjacent fuels like ammable vegetation and/or structures (Syphard et al. 2011).

e 2018 Hill Fire in Ventura County spread three miles in 15 minutes (County of Los Angeles 2019). e speed at which these wind-driven res can spread may overwhelm and outpace even the most experienced and capable agencies (County of Los Angeles 2019). And in some cases, high winds in developed areas may play a role in initiating wild res. e 2018 Woolsey Fire, which killed three people and burned more than 1,600 structures, was sparked by powerlines that were knocked down by strong winds.

In addition, progressively hotter, drier and windier conditions due to climate change are making it easier for wild res to ignite and spread. e number of days with extreme re weather conditions in California has doubled since 1980, and further climate change will amplify that trend (Goss et al. 2020).

It's time for California to acknowledge that land use in uences wild re risk. Placing more homes in highly re-prone areas increases the chances of causing larger and more destructive wild res (Keeley and Syphard 2019; Syphard and Keeley 2020).

POLICYMAKERS CONTINUE APPROVING SPRAWL DEVELOPMENT IN HIGHLY FIRE-PRONE AREAS

Local o cials continue to approve sprawl projects in high-wild re zones. For example, in December 2018 the Los Angeles County Board of Supervisors approved the 19,000-home Centennial development in high and very high re-hazard severity zones on the remote northern edge of the county (Agrawal 2018a). Between 1964 and 2015, Cal Fire documented 31 wild res larger than 100 acres within ve miles of the 12,000-acre development site, including four within the project's boundaries (Figure 4a) (Agrawal 2018b).

Similarly, in April 2019 the board approved the 3,150-home Northlake development, which sits in a very high re-hazard severity zone. Multiple res have burned the Northlake project footprint over the last few years (Figure 4b). Both projects were approved by a 4-1 vote, with Supervisor Sheila Kuehl casting the lone opposition vote.

a) Centennial Development **b) Northlake Development**

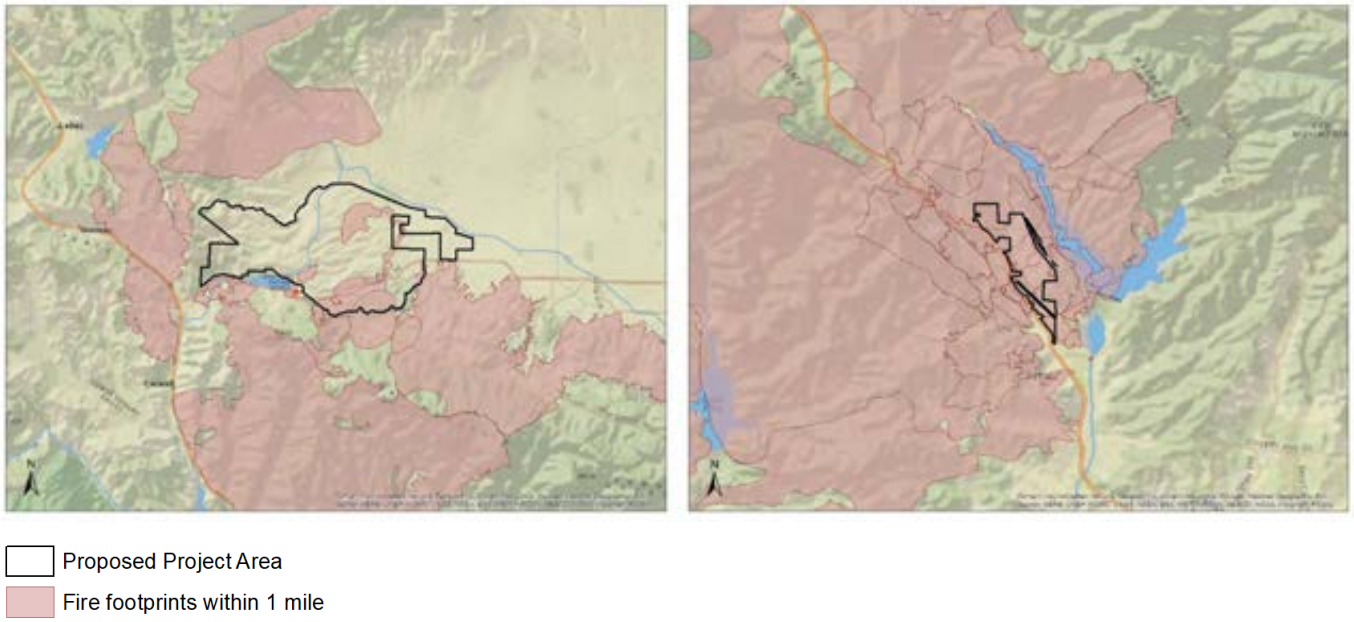


Figure 4: *Wild re burned areas in and near the recently approved development projects of Centennial (a) and Northlake (b). Black outlines indicate development areas, and red indicates previously burned areas.*

is is a trend that's likely to continue throughout the greater Los Angeles region. e Southern California Association of Government's Regional Transportation Plan, which covers Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura counties and was approved in September 2020, estimates that an additional 154,300 housing units will be built in very high re-hazard zones by 2045 (SCAG 2020).

San Diego County has similarly persisted in authorizing new sprawl development in rural, highly re-prone areas of the county. In 2018 the county approved the 2,000-unit Newland Sierra project, which would have been constructed on 2,000 acres in a very high wild re-hazard zone. Voters repealed the county's approval by referendum in March 2020, in part due to re concerns. Also in 2018 the county approved the re-prone Harmony Grove South and Valiano projects, with approximately 800 combined housing units. A judge halted these projects in 2020 a er nding that San Diego county hadn't adequately addressed the safety and evacuation of potential new residents.

In 2019 and 2020, San Diego County approved two more new development projects (Otay Village 14 and Otay Village 13, respectively) with over 3,000 housing units on a combined 3,000 acres in the ecologically sensitive Otay region. e project sites have been burned in several separate res over the past two decades. In a letter to the county urging it not to approve the Otay Village 13 project, the California attorney general cited "the increased risk of wild re that the Project will create."

Los Angeles and San Diego counties were named the top two counties in the state with the highest number of housing units located in high wild re-risk areas (Verisk 2020). Together these counties and their local governments have recently approved the construction of more than 30,000 homes for almost 100,000 people in highly re-prone areas (Table 1).

Table 1. *Approved development projects located in highly re-prone areas in Los Angeles and San Diego counties. Number of people were estimated using 2019 U.S. Census data.*

County/Local Government	Approved Housing Project (Year Approved)	Number of Housing Units	Number of People	Status
Los Angeles	Centennial (2018)	19,333	57,806	Lawsuit is ongoing
Los Angeles	Northlake (2019)	3,150	9,419	Project blocked after successful litigation
San Diego	Newland Sierra (2018)	2,135	6,127	Project blocked after a successful referendum
San Diego	Harmony Grove South (2018)	453	1,300	Project blocked after successful litigation
San Diego	Valiano (2018)	326	936	Project blocked after successful litigation
San Diego	Otay Village 14 (2019)	1,119	3,212	Lawsuit is ongoing
San Diego	Otay Village 13 (2020)	1,938	5,562	Lawsuit is ongoing
City of Santee	Fanita Ranch	2,949	8,464	Lawsuit is ongoing
Total		**31,403**	**92,826**	

e problem of runaway development in risky areas is not con ned to Southern California. For example, in 2020 Lake County approved a massive new luxury residential and resort project on 16,000 acres in the Guenoc Valley, northwest of Sacramento, over the objections of re experts and the attorney general, who cited concerns about the project's risks to public safety. At the time the county was considering the project, the site had experienced at least ve res since 2006. Less than two months a er the county's approval the site burned yet again in the 2020 LNU Complex Fire.

WILDFIRE IMPACTS DISPROPORTIONATELY AFFECT LOW-INCOME, MINORITY COMMUNITIES

Impacts of wild re disproportionately a ect vulnerable communities with less adaptive capacity to respond to and recover from hazards like wild re. Low-income and minority communities, especially Native American, Black, Latinx and Southeast Asian communities, are the most marginalized groups when wild res occur (Davies et al. 2018).

Past environmental hazards have shown that those in at-risk populations (e.g., low-income, elderly, disabled, non-English-speaking, homeless) o en have limited resources for disaster planning and preparedness (Richards 2019). Vulnerable groups also have fewer resources to have cars to evacuate, buy re insurance, implement defensible space around their homes, or rebuild, and they have less access to disaster relief during recovery (Fothergill and Peak 2004; Morris 2018; Harnett 2018; Davis 2018; Richards 2019).

e 2020 Apple Fire north of Beaumont, California / Brody Hessin, CC-BY

In addition, emergency services o en miss at-risk individuals when disasters happen because of limited capacity or language constraints (Richards 2019). For example, evacuation warnings are o en not conveyed to disadvantaged communities (Davies et al. 2018). In the a ermath of wild res and other environmental disasters, news stories have repeatedly documented the lack of multilingual evacuation warnings leaving non-English speakers in danger. (Gerety 2015; Axelrod 2017; Banse 2018; Richards 2019). Survivors are le without resources to cope with the death of loved ones, physical injuries and emotional trauma from the chaos that wild res have in icted on their communities.

Health impacts from wild res, particularly increased air pollution from ne particulates ($PM_{2.5}$) in smoke, also disproportionately a ect vulnerable populations, including low-income communities, people of color, children, the elderly and people with pre-existing medical conditions (Künzli et al. 2006; Del no et al. 2009; Reid et al. 2016; Hutchinson et al. 2018; Jones et al. 2020).

Increased $PM_{2.5}$ levels during wild re events have been associated with increased respiratory and cardiovascular emergency room visits and hospitalizations, which were disproportionately higher for low socioeconomic status communities and people of color (Reid et al. 2016; Liu et al. 2017; Hutchinson et al. 2018; Jones et al. 2020). Similarly, asthma admissions were found to have increased by 34% due to smoke exposure from the 2003 wild res in Southern California, with elderly and child age groups being the most a ected (Künzli et al. 2006).

Farmworkers, who are majority people of color, o en have less access to healthcare due to immigration or economic status. ey are more vulnerable to the health impacts of poor air quality due to increased exposure to air pollution as they work. Yet farmworkers o en have to continue working while res burn, and smoke lls the air, or risk not getting paid (Herrera 2018; Parshley 2018; Kardas-Nelson et al. 2020).

Unprecedented California wild res are increasing negative health impacts within and beyond its borders. A recent study found that wild re smoke now accounts for up to 50% of ambient ne particle pollution in the western United States (Burke et al. 2021). Land-use planning must improve now.

e 2018 Camp Fire near Paradise, California / U.S. Department of Agriculture

CALIFORNIA CAN FORGE A SAFER FUTURE

Policymakers must reckon with California's wild re history and acknowledge that reckless land-use policies are increasing wild re risk and putting more people in harm's way. e combination of sprawl development in highly re-prone wildlands and altered re regimes endangers communities.

Legislation that prioritizes the following proactive measures is needed immediately:

- Stop building new homes in highly re-prone areas;
- Retro t existing homes with high re risk.

Stop Building New Homes in Highly Fire-prone Wildlands

e science is clear. Placing more homes and people in highly re-prone areas leads to more human-caused ignitions and puts more people in danger. California should prohibit new development in high re-risk areas to keep people safe and protect its rich biodiversity.

Californians broadly support this approach — 3 out of 4 want to restrict housing developments in wild re-prone areas, according to a 2019 poll (Dillon 2019). Yet local governments like Los Angeles and San Diego counties continue to push for sprawl development in such areas.

Developers claim that compliance with building codes written in 2008 will make their developments re safe. is is misleading and produces a false sense of security.

While some measures can reduce re risk, they do not make structures or communities reproof. In an analysis that included more than 40,000 structures exposed to wild re between 2013 and 2018 in California, many " re-safe" structures were destroyed (Syphard and Keeley 2019). And although an analysis conducted in the a ermath of the 2017 Camp Fire showed that new building codes improved home survival, with 51% of homes built to code undamaged compared to 18% of homes built prior to 2008, about half of the homes built to re-safety codes were still destroyed in the blaze (Kasler and Reese 2019).

e best way to limit re risk is to avoid building homes in highly re-prone wildlands.

e 2009 Station Fire in La Crescenta, California / Anthony Citrano, CC-BY-NC-ND

Retro t Existing Homes With High Fire Risk

Although there are steps that can be taken to reduce risk, they do not guarantee safety from re. Limiting new development in highly re-prone areas is critical to reducing risk. But for homes already in high re-risk areas, home-hardening is important to minimize the chances of human ignitions and re spread.

It is estimated that more than 2 million homes are located in high re-risk areas (Verisk 2020). Investing resources primarily in re suppression without adequately addressing the human-related cause of the res will not reduce wild re losses (Stephens et al. 2009). State funds must be equitably distributed to retro t existing communities in re-prone areas to reduce the chances of unintentional ignitions and minimize spread should a re ignite.

Retro ts should include ember-resistant vents, re-resistant roofs and irrigated defensible space immediately adjacent to (i.e., within 100 feet of) structures. Although such features do not make homes reproof, they have been shown to improve the chances of structure survival in res (Syphard et al. 2014; Syphard et al. 2017). External sprinklers with an independent water source could reduce structures' ammability when res occur (California Chaparral Institute 2018). Roo op solar and clean energy microgrids could reduce re risk from utilities' infrastructure during extreme weather (Roth 2019).

e state must also engage, prepare and train homeowners to harden their homes, reduce the risk of re ignitions and spread, and be ready to safely defend their homes or evacuate early when needed (Stephens et al. 2009). As communities rebuild from recent wild re destruction, now is the time to instill a culture of coexistence with wild re.

California policymakers can help our state meet this crucial challenge. Strong land use policies that consider the state's diverse re history and ecology will help improve our relationship with wild re and ensure a safer and healthier future for both humans and wildlife.

REFERENCES CITED

Agrawal, N. (2018a, December 4). LA County considers building a new city where re hazard is high. Is Tejon Ranch worht the risk? Los Angeles Times.

Agrawal, N. (2018b, December 11). Supervisors OK 19,000-home development at Tejon Ranch. Los Angeles Times.

Anderson, K. (2018). e Use of Fire by Native Americans in California. In J. W. Van Wagtendonk, N. G. Sugihara, S. L. Stephens, A. E. ode, K. E. Sha er, & J. A. Fites-Kaufman (Eds.), Fire in California's Ecosystems.

Axelrod, J. (2017, December 13). California Wild res Spark Issues of Bilingual Emergency Communications. American City and County.

Baker, B., & Halsey, R. W. (2020). California Chaparral and Woodlands. Reference Module in Earth Systems and Environmental Sciences, 1–12.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Nagy, R. C., Fusco, E. J., & Mahood, A. L. (2017). Human-started wild res expand the re niche across the United States. Proceedings of the National Academy of Sciences, 114(11), 2946–2951.

Balch, J. K., Bradley, B. A., D'Antonio, C. M., & Gómez-Dans, J. (2013). Introduced annual grass increases regional re activity across the arid western USA (1980-2009). Global Change Biology, 19, 173–183.

Banse, T. (2018, April 20). How Do You Say 'Evacuate' in Tagalog? In a Disaster, English Isn't Always Enough. Northwest Public Broadcasting.

Benson, J. F., Mahoney, P. J., Sikich, J. A., Serieys, L. E. K., Pollinger, J. P., Ernest, H. B., & Riley, S. P. D. (2016). Interactions between demography, genetics, and landscape connectivity increase extinction probability for a small population of large carnivores in a major metropolitan area. Proceedings of the Royal Society B: Biological Sciences, 283(1837), 20160957.

Benson, J. F., Mahoney, P. J., Vickers, T. W., Sikich, J. A., Beier, P., Riley, S. P. D., … Boyce, W. M. (2019). Extinction vortex dynamics of top predators isolated by urbanization. Ecological Applications, 29(3), e01868.

Blakey, R. V., Webb, E. B., Kesler, D. C., Siegel, R. B., Corcoran, D., & Johnson, M. (2019). Bats in a changing landscape: Linking occupancy and traits of a diverse montane bat community to re regime. Ecology and Evolution, 9, 5324–5337.

Bond, M. L., Lee, D. E., Siegel, R. B., & Ward, J. P. (2009). Habitat use and selection by California spotted owls in a post re landscape. Journal of Wildlife Management, 73(7), 1116–1124.

Burke, M., Driscoll, A., Xue, J., He -Neal, S., Burney, J., & Wara, M. (2021). e changing risk and burden of wild re in the United States. Proceedings of the National Academy of Sciences, 118(2), e2011048118.

California Department of Forestry and Fire Protection (Cal Fire). (2020a). Top 20 Deadliest California Wild res.

California Department of Forestry and Fire Protection (Cal Fire). (2020b). Top 20 Largest California Wild res.

California Department of Forestry and Fire Protection (Cal Fire). (2020c). Top 20 Most Destructive California Wild res.

California Chaparral Institute. (2018). Independent external sprinklers to protect your home during a wild re.

Campos, B. R., & Burnett, R. D. (2015). Avian Monitoring of the Storrie and Chips Fire Areas 2014 Report.

County of Los Angeles. (2019). A er Action Review of the Woolsey Fire. A er Action Review of the Woolsey Fire.

Davies, I. P., Haugo, R. D., Robertson, J. C., & Levin, P. S. (2018). e unequal vulnerability of communities of color to wild re. PLoS ONE, 13(11), 1–15.

Davis, M. (2018, December 5). A tale of two wild res: devastation highlights California's stark divide. e Guardian.

Del no, R. J., Brummel, S., Wu, J., Stern, H., Ostro, B., Lipsett, M., … Gillen, D. L. (2009). e relationship of respiratory and cardiovascular hospital admissions to the southern California wild res of 2003. Occupational and Environmental Medicine, 66(3), 189–197.

Dillon, L. (2019, June 18). More homes in wild re zones? High number of Californians say no , poll says. LA

Times.

Fothergill, A., & Peak, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological ndings. Natural Hazards, 34, 89–110.

Gerety, R. M. (2015, September 1). Farm Workers in Wild re Areas Aren't Always Aware of Evacuation Plans. National Public Radio Morning Edition.

Goss, M., Swain, D. L., Abatzoglou, J. T., Sarhadi, A., Kolden, C. A., Williams, A. P., & Di enbaugh, N. S. (2020). Climate change is increasing the likelihood of extreme autumn wild re conditions across California. Environmental Research Letters, 15.

Harnett, S. (2018, September 19). Low-Income Communities Struggle to Recover A er a Wild re. KQED.

Herrera, J. (2018, November 14). As Wildire Smoke Fills the Air, Farmworkers Continue to Labor in the Fields. Paci c Standard.

Hutchinson, J. A., Vargo, J., Milet, M., French, N. H. F., Billmire, M., Johnson, J., & Hoshiko, S. (2018). e San Diego 2007 wild res and Medi-Cal emergency department presentations, inpatient hospitalizations, and outpatient visits: An observational study of smoke exposure periods and a bidirectional case-crossover analysis. PLoS Medicine, 15(7), e1002601.

Jones, C. G., Rappold, A. G., Vargo, J., Cascio, W. E., Kharrazi, M., McNally, B., & Hoshiko, S. (2020). Out-of-Hospital Cardiac Arrests and Wild re-Related Particulate Matter During 2015-2017 California Wild res. Journal of the American Heart Association, 9(8), e014125.

Kardas-Nelson, M., Alvarenga, J., & Tuirán, R. A. (2020, October 6). Farmworkers forced to put harvest over health during wild res. Investigate West.

Kasler, D., & Reese, P. (2019, April 11). e weakest link: Why your house may burn while your neighbor's survives the next wild re. Sacramento Bee.

Keeley, J. E. (2005). Fire as a threat to biodiversity in re-type shrublands. Planning for biodiversity: bringing research and management together. USDA Forest Service General Technical Report PSW-GTR-195.

Keeley, J. E., & Fotheringham, C. J. (2001). Historic re regime in southern California shrublands. Conservation Biology, 15(6), 1536–1548.

Keeley, J. E., & Syphard, A. D. (2018). South Coast Bioregion. In Fire in California's Ecosystems (pp. 319–351). Berkeley, CA: University of California Press.

Keeley, J. E., & Syphard, A. D. (2019). Twenty- rst century California, USA, wild res: fuel-dominated vs. wind-dominated res. Fire Ecology, 15(24).

Kimmerer, R. W., & Lake, F. K. (2001). e role of indigenous burning in land management. Journal of Forestry, 99(11), 36–41.

Künzli, N., Avol, E., Wu, J., Gauderman, W. J., Rappaport, E., Millstein, J., … Peters, J. M. (2006). Health e ects of the 2003 Southern California wild res on children. American Journal of Respiratory and Critical Care Medicine, 174, 1221–1228.

Liu, J. C., Wilson, A., Mickley, L. J., Ebisu, K., Sulprizio, M. P., Wang, Y., … Bell, M. L. (2017). Who among the elderly is most vulnerable to exposure to and health risks of ne particulate matter from wild re smoke? American Journal of Epidemiology, 186(6), 730–735.

Mann, M. L., Berck, P., Moritz, M. A., Batllori, E., Baldwin, J. G., Gately, C. K., & Cameron, D. R. (2014). Modeling residential development in California from 2000 to 2050: Integrating wild re risk, wildland and agricultural encroachment. Land Use Policy, 41, 438–452.

Morris, B. (2018, April 23). How the Ultra-Wealthy are Making emselves Immune to Natural Disasters.

Parshley, L. (2018, December 7). e Lingering E ects of Wild res Will Disproportionately Hurt People of Color. Vice, pp. 1–11.

Radelo , V. C., Helmers, D. P., Kramer, H. A., Mockrin, M. H., Alexandre, P. M., Bar-Massada, A., … Stewart, S. I. (2018). Rapid growth of the US wildland-urban interface raises wild re risk. Proceedings of the National Academy of Sciences, 115(13), 3314–3319.

Reid, C. E., Jerrett, M., Tager, I. B., Petersen, M. L., Mann, J. K., & Balmes, J. R. (2016). Di erential respiratory health e ects from the 2008 northern California wild res: A spatiotemporal approach. Environmental Research, 150, 227–235.

Richards, R. (2019, July 25). A er the Fire: Vulnerable Communities Respond and Rebuild. Center for American Progress.

Roth, S. (2019, March 14). California's wild re threat could be an opportunity for clean- energy microgrids - Los Angeles Times. Los Angeles Times.

Sahagun, L. (2020, November 1). Rescue operations underway in the San Gabriel Mountains for rare species marooned by wild re. Los Angeles Times.

Southern California Association of Governments (SCAG). (2020). Certi ed Final Connect SoCal Program Environmental Impact Report.

Stephens, S. L., Adams, M. A., Handmer, J., Kearns, F. R., Leicester, B., Leonard, J., & Moritz, M. A. (2009). Urban-wildland res: How California and other regions of the US can learn from Australia. Environmental Research Letters, 4, 014010.

Stephens, S. L., Martin, R. E., & Clinton, N. E. (2007). Prehistoric re area and emissions from California's forests, woodlands, shrublands, and grasslands. Forest Ecology and Management, 251(3), 205–216.

Stephens, S. L., & Sugihara, N. G. (2018). Fire Management and Policy since European Settlement. In J. W. Van Wagtendonk, N. G. Sugihara, S. L. Stephens, A. E. ode, K. E. Sha er, & J. A. Fites-Kaufman (Eds.), Fire in California's Ecosystems. UC Berkeley.

Stillman, A. N., Siegel, R. B., Wilkerson, R. L., Johnson, M., & Tingley, M. W. (2019). Age-dependent habitat relationships of a burned forest specialist emphasise the role of pyrodiversity in re management. Journal of Applied Ecology, 56(4), 880–890.

Sugihara, N. G., Van Wagtendonk, J. W., Fites-Kaufman, J., Sha er, K., & ode, A. E. (2018). e Future of Fire in California's Ecosystems. In Fire in California's Ecosystems (pp. 538–544).

Syphard, A. D. (2020). A Conversation About Fire Resliency. Sierra Club Redwood Chapter Presentation.

Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2014). e role of defensible space for residential structure protection during wild res. International Journal of Wildland Fire, 23(8), 1165–1175.

Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2017). e importance of building construction materials relative to other factors a ecting structure survival during wild re. International Journal of Disaster Risk Reduction, 21, 140–147.

Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2019). Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. Diversity and Distributions, 25, 90–101.

Syphard, A. D., & Keeley, J. E. (2019). Factors associated with structure loss in the 2013–2018 California wild res. Fire, 2(3), 49.

Syphard, A. D., & Keeley, J. E. (2020). Why are so many structures burning in California. Fremontia, 47(2), 28–35.

Syphard, A. D., Keeley, J. E., & Brennan, T. J. (2011). Comparing the role of fuel breaks across southern California national forests. Forest Ecology and Management, 261(11), 2038–2048.

Syphard, A. D., Radelo , V. C., Hawbaker, T. J., & Stewart, S. I. (2009). Conservation threats due to human-caused increases in re frequency in mediterranean-climate ecosystems. Conservation Biology, 23(3), 758–769.

Syphard, A. D., Radelo , V. C., Keeley, J. E., Hawbaker, T. J., Clayton, M. K., Stewart, S. I., … Hammer, R. B. (2007). Human in uence on California re regimes. Ecological Society of America, 17(5), 1388–1402.

Taillie, P. J., Burnett, R. D., Roberts, L. J., Campos, B. R., Peterson, M. N., & Moorman, C. E. (2018). Interacting and non-linear avian responses to mixed-severity wild re and time since re. Ecosphere, 9(6).

Verisk. (2020). FireLine State Risk Report – California.

EXHIBIT E

TRABUCO CANYON WATER DISTRICT
REGULAR BOARD MEETING | MARCH 19, 2025

ACTION CALENDAR
ENGINEERING MATTERS
ITEM 12: CONSIDERATION OF AMENDMENT NO. 1 TO PROCESSING AGREEMENT IN CONNECTION WITH REQUEST FOR CONDITIONAL WILL-SERVE LETTER FOR SADDLEBACK MEADOWS DEVELOPMENT

California Quartet (Developer) is a California limited partnership that owns approximately 222 acres of land on the east side of El Toro Road between Valley Vista Way and Ridgeline Road within Trabuco Canyon Water District's (District) jurisdiction. Developer is proposing to develop 181 residential units on its property (the Project) and has obtained approval from the County of Orange of Vesting Tentative Tract Map No. 15230. Proposed Final Map No. 15230 (Final Map) is being currently reviewed and processed by the County of Orange and the County is prepared to present the Final Map to the Board of Supervisors for approval pursuant to the Subdivision Map Act, pending District's signature on the Final Map solely for the purpose of accepting and abandoning easements and for no other purposes.

Because development of the Project will require water and sewer services from the District, Developer has requested a Will-Serve Letter from the District. The District has reviewed the Project and determined that a Conditional Will-Serve Letter is required because of limitations in water storage capacity available to serve the Project based upon the Sub Area Master Plan (SAMP) approved for the Project by the District in January 2022. Per the SAMP, the Developer and District agreed to pursue an off-site storage option at the District's Harris Grade reservoir site through a joint participation agreement, based upon Developer's assessment that on-site storage was infeasible. Developer and District entered into a Processing Agreement in October 2023 to address, among other things, the Developer's responsibility to pay for District costs in connection with the Conditional Will-Serve Letter and the negotiation and preparation of the joint participation agreement.

In April 2024, the District removed the storage reservoir project at Harris Grade from its Capital Improvement Program based on the projected costs of its share of a joint storage project. In December 2024, Developer and District discussed alternative resolutions to the Developer's storage requirement, resulting in a proposal in which the Developer will: i) identify and acquire an off-site property to site a 1 million gallon (MG) reservoir; ii) pay the District to prepare a revised SAMP that includes the proposed new reservoir using the District's 2022 Master Plan update water supply assumptions; and, iii) design and construct the new reservoir and appurtenant connections to the District's system, solely at the Developer's expense and all as approved by the District.

The proposed *Amendment No. 1 to Processing Agreement in Connection with Request for Conditional Will-Serve Letter* (Amendment No. 1) amends the October 2023 Processing Agreement to reflect both parties' intent to negotiate an agreement for the proposed new Developer-funded reservoir rather than the joint project at Harris Grade. All other terms and conditions of the Processing Agreement will remain in full force and effect. Upon execution of Amendment No. 1, the District agrees to sign the Final Map, which will include as part of the Trabuco Canyon Water District Acceptance Certificate that the tract map is subject to the terms and conditions of Amendment No. 1.

FUNDING SOURCE:
Not applicable.

FISCAL IMPACT:
The Processing Agreement will ensure that the Developer will pay for eligible District costs and services related to the advancement of the Saddleback Meadows development.

ENVIRONMENTAL COMPLIANCE:
Not applicable.

TRABUCO CANYON WATER DISTRICT
REGULAR BOARD MEETING | MARCH 19, 2025

COMMITTEE STATUS:
This item was previously discussed by the Board of Directors at the January 13, 2025 Regular Board Meeting.

RECOMMENDED ACTION:
That the Board of Directors authorizes the General Manager to execute Amendment No. 1 to the Processing Agreement in Connection with Request for Conditional Will-Serve Letter, which includes approval to sign Final Map No. 15230.

EXHIBIT(S):
1. Final Draft Amendment No. 1 to Processing Agreement in Connection with Request for Conditional Will-Serve Letter
2. Processing Agreement in Connection with Request for Conditional Will-Serve Letter (October 2023)

CONTACTS (staff responsible): PALUDI/LAUSTEN

Revised: 3/11/2025

AMENDMENT NO. 1

PROCESSING AGREEMENT IN CONNECTION WITH REQUEST FOR CONDITIONAL WILL-SERVE LETTER

VESTING TENTATIVE TRACT NO. 15230 SADDLEBACK MEADOWS

COUNTY OF ORANGE

This Amendment No. 1 to the Processing Agreement In Connection With Request For Conditional Will-Serve Letter ("Amendment No. 1") shall be deemed effective as of the date of the last Party to sign (the "Effective Date") and is entered into by and between the TRABUCO CANYON WATER DISTRICT (the "District" or "TCWD"), a County water district organized and operating pursuant to Water Code sections 30000 *et seq*., and CALIFORNIA QUARTET, a California limited partnership ("Developer"). The District and Developer may each be referred to herein individually as a "Party" and collectively as the "Parties". There are no other Parties to this Amendment No. 1.

This Amendment No. 1 is made with reference to the following facts.

RECITALS

A. Developer owns approximately 222 acres in the County of Orange within the service area of District. Developer is proposing to develop 181 residential units on its property and has obtained approval, among other land use entitlements, from the County of Orange of Vesting Tentative Tract Map No. 15230 (the "Project"). Proposed Final Map No. 15230 ("Final Map") is being currently reviewed and processed by the County of Orange and the County is prepared to present the Final Map to the Board of Supervisors for approval pursuant to the Subdivision Map Act, pending District's signature on the Final Map solely for the purpose of accepting and abandoning easements and for no other purposes.

B. Effective October 16, 2023, the Parties entered into the Processing Agreement In Connection with Request For Conditional Will-Serve Letter (the "Processing Agreement").

C. The Processing Agreement described the process by which the Parties could enter into a Cost Sharing Agreement pursuant to which the Parties would jointly fund costs related to an offsite storage site, to be constructed by the District, and which would, in part, reserve the necessary storage capacity to serve the Project, as detailed further in the Sub Area Master Plan ("SAMP") approved for the Project by the District in January 2022.

D. The SAMP approved for the Project by the District in January 2022 discussed storage options for the Project on either on-site or off-site locations, and stated that the most feasible alternative available to the District for providing off-site storage, which the

developer could contribute to, was a project at the District's existing Harris Grade Reservoir site.

E. In April 2024, upon further review, the District removed a new water tank at the Harris Grade Reservoir site from its 2024-25 Capital Improvement Project budget.

F. In December, 2024, the Parties discussed alternative resolutions to the Developer's storage requirement. The District proposed that Developer: i) identify and acquire an off-site property ("Off-Site Property") to site a 1 MG reservoir ("New Reservoir"); ii) pay the District to prepare a revised SAMP that includes the New Reservoir using the District's 2022 Master Plan update water supply assumptions; and, iii) design and construct a New Reservoir and appurtenant connections to the District's system on the Off-Site Property, all as approved by the District.

G. District also proposed that upon acceptance of fee title to the Off-Site Property, the District will convey fee title to the District's 3.78 acre parcel (APN 856-091-01) to Developer.

H. Since execution of the Processing Agreement, the District's plan review of Developer's plans has sufficiently progressed to enable the District to determine, confirm, and accept the location of required easements, and quitclaim existing easements no longer required by District for purposes of signing the Final Map.

I. As stated in Section 4 of the SAMP, water capital improvement charges for up to 705 equivalent dwelling units ("EDUs") were previously purchased in connection with Tract No. 10692 which encompasses the land area now within Vesting Tentative Tract No. 15230 by Developer's predecessor in interest through an agreement with the District dated September 21, 1988, and have been reserved by the District for this development. Therefore, no water capital improvement charges or supplemental water capacity fees are due for the Project.

J. As stated in Section 4 of the SAMP, Developer's predecessor in interest purchased wastewater collection and treatment capacity rights over thirty years ago in connection with Tract No. 10692 that created residential lots for 705 EDUs which is substantially more dwelling units than the 181 EDUs now proposed by the Project, therefore, no sewer capacity charges are due for the Project.

NOW, THEREFORE, in consideration of the mutual agreements, covenants and conditions set forth herein and Developer's commitment to proceed with Developer's obligations as provided herein, the Parties agree as follows:

Revised: 3/11/2025

Section 1. Processing Agreement Amendment. In consideration of the County's desire to agendize Final Map No. 15230 for approval, and in recognition of the Project's substantial investment in water and wastewater facilities as set forth in Recitals I., J., above, the Parties agree to amend the Processing Agreement as follows:

A. The District agrees to sign the Final Map concurrent with the Effective Date of this Amendment No. 1 that includes the following language:

TRABUCO CANYON WATER DISTRICT ACCEPTANCE CERTIFICATE:

I, _____, _____ OF THE BOARD OF DIRECTORS OF TRABUCO CANYON WATER DISTRICT DO HEREBY CERTIFY THAT THIS MAP WAS PRESENTED FOR ACCEPTANCE AND DEDICATION TO THE BOARD OF DIRECTORS OF THE TRABUCO CANYON WATER DISTRICT AT A REGULAR MEETING OF THE BOARD OF DIRECTORS HELD ON THE 19th DAY OF MARCH, 2025, AND THAT THEREUPON SAID BOARD DID, BY AN ORDER DULY PASSED AND ENTERED, ACCEPT THE WATER RIGHTS AND EASEMENTS FOR WATER, SEWER PIPELINES, APPURTENANCES, ACCESS, ROADWAY, MAINTENANCE AND DRAINAGE PURPOSES DEDICATED HEREON.

THIS TRACT MAP IS SUBJECT TO THE TERMS AND CONDITIONS OF AMENDMENT NO. 1 TO THE PROCESSING AGREEMENT IN CONNECTION WITH REQUEST FOR CONDITIONAL WILL-SERVE LETTER, DATED _____.

WE ALSO HEREBY ABANDON, PURSUANT TO GOVERNMENT CODE SECTION 66434 (g) OF THE SUBDIVISION MAP ACT, THE WATER RIGHTS, THE EASEMENTS FOR INGRESS AND EGRESS, DOMESTIC WATER SYSTEM AND SEWER SYSTEM PURPOSES AS DEDICATED TO THE TRABUCO CANYON WATER DISTRICT, SUCCESSOR IN INTEREST TO SANTA ANA MOUNTAINS COUNTY WATER DISTRICT PER TRACT NO. 10692, M.M. 621/9-26, NOT SHOWN ON THIS MAP.

B. Developer shall identify and acquire an Off-Site Property for the New Reservoir that is suitable for the construction of the New Reservoir, as approved by the District in its reasonable discretion. Developer shall obtain a Phase I Environmental Site Assessment, preliminary title report, ALTA survey, and other documents relating to the proposed site as requested by the District prior to acquisition of the Off-Site Property.

C. The District and Developer will enter into an agreement providing the terms and conditions under which the Developer will construct and dedicate to the District the New Reservoir on the Off-Site Property. The District reserves complete discretion and authority regarding the contents, scope, and analysis of the agreement and District determinations and decisions on the Project and future development of the Property. Nothing in this Amendment No. 1 shall in any way commit or obligate the District to provide water or sewer services to any portion of the Property, or to enter into the agreement.

D. Upon acceptance of fee title to the Off-Site Property, District will convey fee title to the District's 3.78 acre parcel (APN 856-091-01) to Developer.

E. Developer shall pay the District's reasonable costs to prepare a revised SAMP that includes the New Reservoir using the District's 2022 Water Master Plan update water supply assumptions.

F. Developer shall pay all costs associated with the design and construct the New Reservoir and appurtenant connections to the District's system, in accordance with the agreement and in accordance with District's design specifications, as approved by the District on the Off-Site Property which approval shall not be unreasonably withheld. District will cooperate with Developer and the Developer shall pay all costs associated with preparing and certifying all California Environmental Quality Act (CEQA) requirements, including District acting as CEQA lead agency for the New Reservoir, and certifying the requisite CEQA document(s).

G. Upon request by Developer and/or as required by the County of Orange, District shall issue a Will-Serve Letter to include the provisions of the attached Conditional Will-Serve Letter as updated for: i) the revised SAMP provided for in Section 1.E. hereinabove, ii) description of fees and charges, and costs, and iii) provisions addressing storage as set forth in this Agreement. Other than as provided in this Agreement or the agreement, Developer shall not be responsible for the construction of or payment for any other capital facilities.

H. The Parties acknowledge and agree that the Developer shall construct the New Reservoir and may concurrently begin grading and constructing the 181 residential units on its property consistent with the Final Map and Area Plan 98-2 approved by the County of Orange. The Parties agree that no later than the completion of rough grading of the Project area, Developer shall have executed a construction contract for the New Reservoir, and prior to the completion of finish grading of the Project area, Developer shall have commenced construction of the New Reservoir. Upon commencement of construction of the New Reservoir, District agrees to provide water and sewer service to the Project, and shall provide or authorize setting meters to the first ninety (90) houses constructed on the Project area. The Parties agree that prior to the setting of the 91st water meter, Developer and District shall meet and confer to review the status of the New Reservoir construction and evaluate whether service beyond the first 90 houses can be provided based upon the District's determination of its water supply, storage, and those rules and regulations in effect at the time.

I. For clarification, the Parties no longer intend to pursue the Cost Sharing Agreement relating to Harris Grade, and instead intend to negotiate an agreement for the New Reservoir as described in Section 1.C., above. All other terms and conditions of the Processing Agreement will remain in full force and effect. References to the "Cost Sharing Agreement" will mean the Section 1.C. agreement and "Project Related Tasks" shall mean District-related tasks associated with the New Reservoir. To the extent a conflict arises between the Processing Agreement and this Amendment No. 1, the terms and conditions of Amendment No. 1 will control.

J. With regard to the obligations set forth in this Amendment No. 1 time is of the essence.

K. Successors and Assigns. The Parties may assign any or all of their respective rights, interests and obligations subject to the written consent of the other Party. The terms, covenants and conditions of this Amendment No. 1 shall be binding upon and shall inure to the benefit of the heirs, executors, administrators and assignees of the respective Parties. If any Party assigns its interest in this Amendment No. 1, the assignee shall expressly assume any and all obligations of the assignor as set forth in this Amendment No. 1.

SIGNATURES ON THE FOLLOWING PAGE

Revised: 3/11/2025

IN WITNESS WHEREOF, District and Developer have executed this Amendment, effective as of the last date set forth below.

Date: _____

"DISTRICT"

TRABUCO CANYON WATER DISTRICT

By: _____

Edward Mandich, President

Board of Directors

Date: _____

"DEVELOPER"

CALIFORNIA QUARTET, a California Limited Partnership

By: ARADI LTD., its General Partner

By: ARADI INC., its General Partner

Name: _____

Title: _____

RECORDING REQUESTED BY
AND WHEN RECORDED MAIL TO:

Trabuco Canyon Water District
32003 Dove Canyon Drive
Trabuco Canyon, CA 92679

Exempt from recording fees – request by public agency
(Cal. Gov. Code §§ 6103, 27383)

(Space above this line for recorder's use)

PROCESSING AGREEMENT IN CONNECTION WITH
REQUEST FOR CONDITIONAL WILL-SERVE LETTER

SADDLEBACK MEADOWS

ORANGE COUNTY TRACT NO. 15230

This PROCESSING AGREEMENT IN CONNECTION WITH REQUEST FOR CONDITIONAL WILL-SERVE LETTER ("**Agreement**") shall be deemed effective as of the date of the last Party to sign, (the "**Effective Date**") by and between the TRABUCO CANYON WATER DISTRICT (the "**District**" or "**TCWD**"), a county water district organized and operating pursuant to Water Code sections 30000 et seq., and CALIFORNIA QUARTET, a California limited partnership, ("**Developer**"). The District and the Developer may each be referred to herein individually as a "Party" and collectively as the "**Parties**." There are no other parties to this Agreement.

This Agreement is made with reference to the following facts:

RECITALS

A. Developer owns, controls, or has an interest in 222.222 acres of land on the east side of El Toro Road between Valley Vista Way and Ridgeline Road (the "**Property**"), which is subject to development rights under the subdivision map for Orange County Tract No. 15230, consisting of the development of 181 single-family residences and related public utilities as depicted therein (the "**Project**"). Because development of the Project on the Property will require water and sewer services from the District, the Developer has requested a Will-Serve Letter from the District.

B. The District has reviewed the Project and determined that a Conditional Will-Serve Letter is required because of limitations in water storage capacity available to serve the Project per the Sub Area Master Plan ("**SAMP**") approved for the Project by the District in January 2022. Section 2.3 of the SAMP noted the Developer and District have agreed to pursue the off-site storage option at the Harris Grade site through a joint participation agreement.

C. This Agreement is for the purpose of addressing the Conditional Will-Serve Letter costs and indemnification of the District in connection with the District's issuance of the Conditional Will-Serve Letter, and the negotiation and preparation of a joint participation agreement for the Developer to fund the Developer's share of the cost of constructing water storage capacity at the Harris Grade site ("**Cost Sharing Agreement**"). Services provided by

the District may include the following: costs to review and analyze the Project and related plans; consult with Developer and its representatives; research and visit Project site; prepare staff reports, recommendations, conditions, resolutions, exhibits and other Project-related documents; attend Project-related meetings, phone calls, emails, and other work involving the Developer, District, and potentially outside agencies (collectively, the "**Project-Related Tasks**"). The Project-Related Task shall culminate with the Conditional Will-Serve Letter and Cost Sharing Agreement being concurrently presented to the District Board for approval, pursuant to District Rules and Regulations and the terms of this Agreement.

D. Pursuant to Section 5.4.4.1 of the District's Rules and Regulations, prior to the District approving a Conditional Will-Serve Letter, the Developer shall enter into an agreement to pay for the District's reasonable attorneys' fees, engineering fees, and costs, related to the negotiation of the agreement (the Cost Sharing Agreement) and the Conditional Will-Serve Letter; and, Developer shall indemnify the District for any and all damages, costs and liability accruing from the District's requirements for issuing a Conditional Will-Serve Letter.

E. Developer has requested that the District proceed with plan review in conjunction with District processing of the Conditional Will-Serve Letter. This Agreement therefore includes provisions for the District to process plan review concurrently with the District's preparation of the Conditional Will-Serve Letter and the parties' negotiation of the Cost Sharing Agreement, provided that Developer acknowledges it is proceeding at its own risk given that the Conditional Will-Serve Letter and Cost Sharing Agreement have not yet been presented to the Board for approval.

NOW, THEREFORE, in consideration of the mutual agreements, covenants and conditions set forth herein, the Parties agree as follows:

Section 1. Funding for Conditional Will-Serve Letter and Cost Sharing Agreement.

(a) The Developer agrees to provide funding to District to cover the reasonable cost of negotiating this Agreement and the Project-Related Tasks, subject to the terms of this Agreement. The District may utilize staff and contract services for the work and services to be performed for the Project-Related Tasks; (2) billing under this Agreement will include the fully burdened labor costs of District employees (as set forth in **Exhibit A**) and the actual contract fees and costs for District contract service providers. The Developer's initial payment constitutes a deposit toward such costs. The District will prepare and provide to Developer an estimate of costs of the Project-Related Tasks for the purpose of enabling Developer to budget and expeditiously provide funding for the Project-Related Tasks.

(b) Developer will initially deposit $25,000 with the District as funding toward the cost of negotiating this Agreement and the Project-Related Tasks. District will draw on this deposit to reimburse District for the cost of District employee time and materials and to pay or reimburse periodic invoices from District contract service providers. If, prior to the completion of the Project-Related Tasks, 20% or less of the deposit remains or the deposit otherwise becomes depleted below $5,000, the District reserves the right to require additional deposits to cover additional anticipated District costs. Developer shall pay additional deposits within 30 calendar days of each request from the District. The District will maintain a record of costs related to Project-Related Tasks, which shall include the amount of time and expenses charged against Developer's deposit. Such records shall be provided or made available to Developer upon request.

(c) If any requested deposit is not timely made, the District will notify the Developer and the Developer will have ten (10) days to restore the deposit. If deposit or payment has not been made within the ten-day period or if the funds become depleted, then the District will suspend all work on the Project-Related Tasks pending receipt of the deposit or payment. If the deposit or payment remains unpaid for a period of thirty (30) days, District may terminate this Agreement by giving written notice of termination to Developer and District may cease work on the Project- Related Tasks if Developer does not restore the deposit within ten (10) days from the date of the written notice to terminate this Agreement.

(d) The District shall deposit the Developer's deposits into a special general ledger account (the **"Special Fund"**) for the purpose of paying and reimbursing the District costs on the Project-Related Tasks. Any Developer deposit remaining upon completion of the Project- Related Tasks shall be refunded without interest to Developer. If the total cost of the Project- Related Tasks exceeds the amount of the deposit(s), Developer shall promptly pay any such difference to the District within 30 calendar days of such request by the District.

Section 2. Funding for Concurrent Plan Check and Inspection Costs. The District shall require a separate deposit in the initial amount of $25,000 for review and processing the plans for the proposed improvements as provided in Section 5.6 of the District's Rules and Regulations (**"Plan Check Costs"**). The initial deposit shall be replenished to $25,000 whenever the initial balance maintained by the District falls below $5,000. District agrees to conduct plan check concurrently with processing the Project-Related Tasks, however, the District's plan check review shall in no way effect the District Board's discretion to approve or deny the Conditional Will-Serve Letter and Cost Sharing Agreement.

Section 3. Term. This Agreement shall take effect upon the Effective Date and shall commence through the date that the Conditional Will-Serve Letter and Cost Sharing Agreement are concurrently presented for approval by the District Board at a public hearing. District reserves the right to continue the hearing on the Conditional Will-Serve Letter until such time that both agreements may be concurrently presented to the District Board.

Section 4. Termination. This Agreement may be terminated in one of the following manners: (a) by completion of the Project-Related Tasks as provided in Section 3 above, and Developer's payment in full of all costs related to the Project-Related Tasks and Plan Check Costs; (b) by mutual written consent of the Parties; (c) by District pursuant to section 1(c); or, (d) by the Developer giving written notice of termination to the District, provided that all costs for the Project-Related Tasks and Plan Check Costs must be satisfied up to the date of Developer's termination. If Developer provides a written notice of termination, the District will cease work on the Project-Related Tasks. Any Developer deposit remaining upon termination of the Agreement will be refunded without interest to Developer after District has paid all Project-Related Tasks costs incurred up to termination.

Section 4. Record Keeping. The District shall keep and maintain accurate records relating to the District's performance of the Project-Related Tasks costs and Special Fund, including all deposits into the Special Fund and all District costs paid or reimbursed from the Special Fund. District will also keep and maintain accurate records for Plan Check Costs, including all deposits and District costs paid or reimbursed. Developer and its employees, accountants, attorneys and agents may review, inspect, copy and audit these records, including all non-privileged source documents.

Section 5. Reservation of District Authority. The District reserves complete discretion and authority regarding the (a) outcome of its work funded by the Project-Related Tasks, (b) contents, scope, analysis and conclusions of any Project-Related Tasks documents,

and (c) District determinations and decisions on the Project and future development of the Property. Nothing in this Agreement shall in any way commit or obligate District to provide water or sewer services to any portion of the Property, or to enter into the Cost Sharing Agreement. District staff and contract service providers work directly for the District and will be responsible only to the District.

Section 6. Indemnity. Developer agrees to indemnify, defend, protect and hold harmless the District, and its officers, employees, and agents, from and against any and all liability, losses, claims, damages, expenses, and costs (including attorney, expert witness and consultant fees, and litigation costs) arising out of or in connection with (a) the performance and actions under this Agreement by the Developer or its employees, contractors or agents, or failure to perform or act under this Agreement, except such loss or damage that was caused by the sole negligence or willful misconduct of District or except as otherwise limited by law. The Parties acknowledge that additional indemnities or waivers may be required of Developer for the benefit of the District in connection with the Cost Sharing Agreement. Developer further agrees to waive any claims against the District and hold harmless the District, and its officers, employees, and agents, from and against any and all liability, losses, claims, damages, expenses, and costs (including attorney, expert witness and consultant fees, and litigation costs) arising out of or in connection with District review and approval of the Conditional Will-Serve Letter and Cost Sharing Agreement. Developer expressly acknowledges that it is proceeding with concurrent plan review at its own risk prior to the District's consideration and approval of the Conditional Will-Serve Letter and Cost Sharing Agreement.

Section 7. General Provisions.

(a) Entire Agreement. The Parties intend this writing to be the sole, final, complete, exclusive and integrated expression and statement concerning the subject matter of this Agreement, namely funding for Project-Related Tasks and plan review and inspection costs.

(b) Waiver. Either Party may specifically and expressly waive, in writing, the requirements of any portion of this Agreement, or any breach thereat but no such waiver shall constitute a further or continuing waiver of the obligation of any preceding or succeeding breach of the same or any other provision. A waiving Party may, at any time thereafter, require future compliance by the other Party hereto with the provisions that are so waived. The consent of one Party to any acts by the other party for which such written consent was required shall not be deemed to imply consent or waiver of the necessity of obtaining such consent for the same or any similar acts in the future. No waiver or consent shall be implied from silence or any failure of any Party to act, except as otherwise specified in this Agreement. All rights, remedies, undertakings, obligations, covenants, conditions and agreements contained in this Agreement shall be cumulative and no one of them shall be exclusive of any other.

(c) Remedies Not Exclusive. The remedies provided in this Agreement are cumulative and not exclusive, and are in addition to any other remedies that may be provided by law or equity. The exercise by either Party of any remedy under this Agreement will be without prejudice to the enforcement of any other remedy.

(d) Assignment. The Developer shall not assign its obligations under this Agreement to any transferee of all or any part of the Property or any other third party without the express written consent of District, which consent will not be withheld unreasonably. Prior to any assignment of this Agreement by the Developer, there shall be a complete substitution of all securities, required by this Agreement, with the District. Developer shall also inform all future assignees, if any, of the terms and conditions of this Agreement.

(e) **Amendment**. No addition to, or modification of, any provision contained in this Agreement shall be effective unless fully set forth in writing signed by the authorized representatives of both Parties.

(f) **Governing Law and Venue**. Except as otherwise required by law, (a) this Agreement will be interpreted, governed by, and construed under the laws of the State of California; (b) the County of Orange will be venue for any state court litigation and (c) the Central District of California will be the venue for any federal court litigation seeking to enforce or construe this Agreement.

(g) **Enforcement**. If either Party brings an action or a proceeding against the other by reason of default of any term or condition of this Agreement, or otherwise arising out of this Agreement, the prevailing Party in such action or proceeding shall be entitled to recover reasonable attorney's fees, as an element of its costs of suit and not as damages, which shall be payable whether or not such action is prosecuted to judgment. The "prevailing Party" as the term is used herein, shall be the Party who is entitled to recover costs of suit, whether or not suit proceeds to final judgment, and shall include, without limitation, a party who dismisses an action for recovery hereunder in exchange for payment of the sums allegedly due, performance of covenants allegedly breached, or considerations substantially equal to the relief sought in such action.

(h) **Notices**. Any notice, request, demand. consent, approval, or other communication required or permitted hereunder by law, shall be validly given and made only if in writing and delivered in person to an officer or duly authorized representative of the Party or deposited in the United States mail, first class postage prepaid and addressed to the Party for whom it is intended, as follows:

If to the District: Trabuco Canyon Water District
32003 Dove Canyon Drive
Trabuco Canyon, CA 92679

If to the Developer: California Quartet, LP
C/O
Capital Guidance Corp.
1000 Maine Avenue SW,
Suite 301
Washington, DC 20024

Any Party may, from time to time, by written notice to the other Party hereto, designate a different address which shall be substituted for that above. If any notice or other documents is sent by mail as aforesaid, the same shall be deemed fully delivered and received 48 hours after mailing as provided above.

(i) **Interpretation**. The Parties acknowledge and agree that each has been given the opportunity to independently review this Agreement with legal counsel, and has the requisite experience and sophistication to understand, interpret and agree to the particular provisions of this Agreement. In the event of a controversy or dispute between the Parties concerning the provisions herein, this document shall be interpreted according to the provisions herein and no presumption shall arise concerning the draftsman of such provision.

(j) **Authority of Signatories**. The signatories hereto represent that they have been appropriately authorized to enter into this Agreement on behalf of the Party forwhom they signed.

IN WITNESS WHEREOF, the Parties have executed this Agreement as of the above-referenced Effective Date.

TRABUCO CANYON WATER DISTRICT

By: 10/13/23
Stephen Dopudja, District President

By: 10/16/2023
Michal Perea, District Secretary
Michael

DEVELOPER

CALIFORNIA QUARTET, a California limited partnership

By: ARIDI LTD., its General Partner

By: ARIDI INC., its General Partner

Name: _____

Title: Vice President

Exhibit A

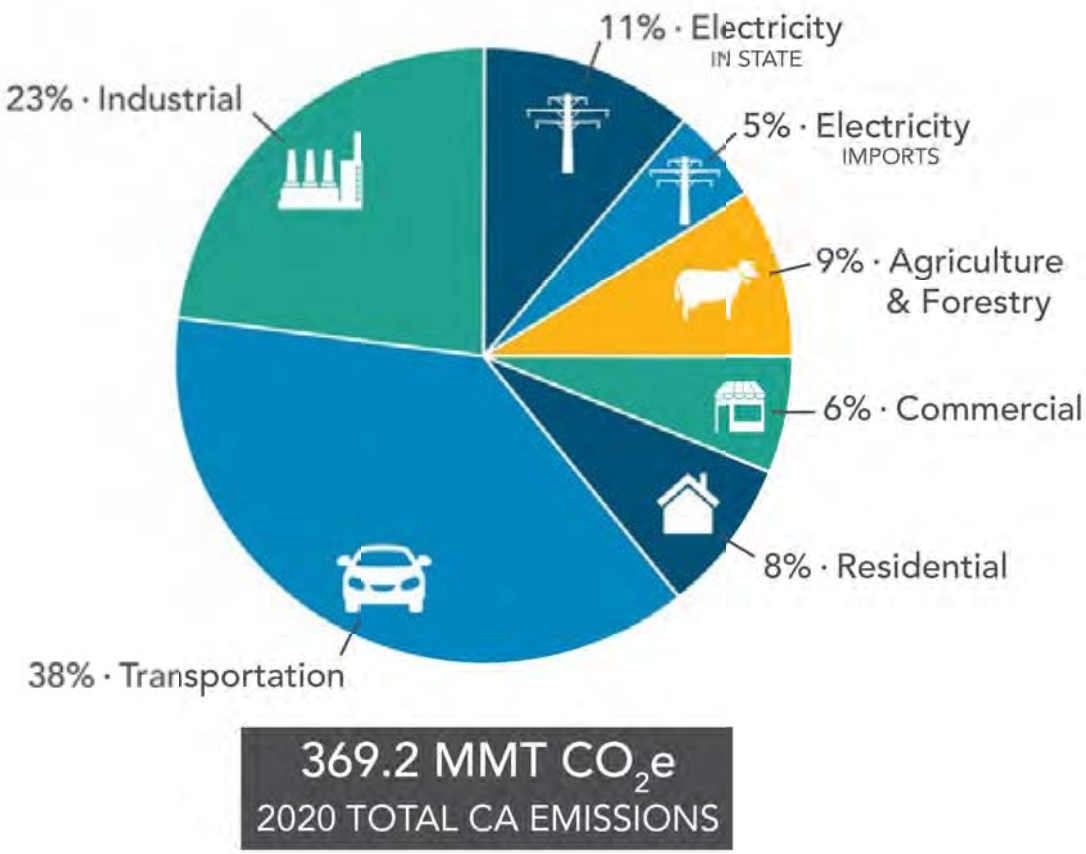
Trabuco Canyon Water District

Staff Hourly Labor Rates (fully burdened)

Labor Rates	$/Hr
General Manager (GM)/Asst. GM	$165.00
District Engineer	$129.00
Finance	$99.00
Administration	$79.00
Operations	$81.00

EXHIBIT F

2000-2020 GHG Inventory (2022 Edition)



Graphic: California's greenhouse gas emissions in 2020 broken out by economic sector

ORDINANCE NO. 02-008

AN ORDINANCE OF THE COUNTY OF ORANGE, CALIFORNIA, AMENDING THE BWR DISTRICT OF THE FOOTHILL/TRABUCO SPECIFIC PLAN (ZC98-3)

The Board of Supervisors of the County of Orange, California, does ordain as follows:

SECTION 1. Ordinance No. 3177, 3398, and 3468, which established regulations for the Saddleback Meadows (a.k.a. Bridlewood) Planned Community, are hereby repealed.

SECTION 2. The Foothill/Trabuco Specific Plan Section III.D.3, "Bridlewood Residential District," is hereby amended per Zone Change 98-3 as shown in Exhibit 1.

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This ordinance shall take effect and be in full force thirty (30) days from and after its passage and before the expiration of fifteen (15) days after the passage thereof, shall be published once in an adjudicated newspaper in the County of Orange.

THE FOREGOING was **PASSED** and **ADOPTED** by the following vote of the Orange County Board of Supervisors on November 05, 2002 , to wit:

AYES: Supervisors: TODD SPITZER, CHARLES V. SMITH, CYNTHIA P. COAD
NOES: THOMAS W. WILSON
EXCUSED: JAMES W. SILVA
ABSTAINED:

Cynthia P. Coad
CHAIR

STATE OF CALIFORNIA)
) ss:
COUNTY OF ORANGE)

I, DARLENE J. BLOOM, Clerk of the Board of Orange County, California, hereby certify that a copy of this document has been delivered to the Chair of the Board and that the above and foregoing Ordinance was duly and regularly adopted by the Orange County Board of Supervisors.

IN WITNESS WHEREOF, I have hereto set my hand and seal.

DARLENE J. BLOOM
Clerk of the Board.
County of Orange, State of California

Ordinance No.: 02-008
Agenda Date: 11/05/2002
Item No.: 101

I certify that the foregoing is a true and correct copy of the Ordinance adopted by the Board of Supervisors , Orange County, State of California

DARLENE J. BLOOM, Clerk of the Board of Supervisors

By:_____
Deputy

Exhibit 1

3.0 Bridlewood Residential (BWR) District

3.1 Purpose and Intent

The Bridlewood Residential District is established to provide for the development and maintenance of low density detached single-family residential neighborhoods in steep hillside areas in such a manner that generous open space areas are featured.

3.2 Uses Permitted

Per the Residential Estates (Planned Development) District regulations: Zoning Code sections 7-9-68 and 7-9-110.

3.3 Site Development Standards

Per the Residential Estates (Planned Development) District regulations: Zoning Code sections 7-9-68 and 7-9-110.

3.4 Special Provisions

a. The maximum number of dwelling units for this District shall be 283.

b. The minimum amount of open space dedicated to the County in fee and/or easement shall be 71%.

c. Prior to the approval of a tentative subdivision map that creates residential building sites, an area plan addressing the entire district shall be approved.

d. A preliminary grading permit may be issued in compliance with the Grading and Excavation Code subsequent to the approval of an area plan and tentative tract map that creates residential building sites. The Grading Official shall require a performance bond prior to the issuance of the grading permit.

e. Prior to the issuance of any building permits for residential structures, a use permit shall be approved by the Planning Commission per Zoning Code section 7-9-150.

WESTERN FIRE CHIEFS ASSOCIATION

History of California Wildfires

Explore the history of California wildfires with details on the top 20 largest, most deadly, and most destructive fires as well as interesting stats and figures.

Published:November 17, 2022
Edited:January 22, 2025

Explore the history of California wildfires with details on the top 20 largest, most deadly, and most destructive fires, as well as interesting stats and figures.

California has a long and intense history with wildfire, with several in the past decade setting records for the largest, most deadly, and most destructive fires in the history of the United States as a whole. They have destroyed millions of acres of land, burned down hundreds of thousands of structures, and caused the deaths of humans, animals, and plants.

Perhaps worst of all, most of these wildfires were caused by human activity, which means they could have been prevented.

Knowing the history of wildfires in California is important because it helps us to prepare for what may be next. In this article, we will take you through the earliest records of fire in the state all the way up to the present day, where we take a peek into California's possible future.

Many of the most dangerous and destructive fires in California have happened within the last several years due to climate change.

The Earliest Records of Fire in California

The earliest known wildfire in California history was the Santiago Canyon Fire of 1889. It burned around 300,000 acres in parts of Orange County, San Diego County, and Riverside County.[1] Before 2018, this was the largest wildfire in the state's history in terms of acreage burned.

There were no records of any human lives lost during the Santiago Canyon Fire of 1889. However, farmers' crops and thousands of sheep were reportedly destroyed.[2]

The wildfire, which was human-made, was preceded by a severe drought coupled with high-speed winds that further dried out the land. The conditions were just right for an intense and destructive fire.

California's official fire records, however, do not start until 1932. The most notable fire that took place during this early part of the 20th century was the Matilija Fire, which burned approximately 220,000 acres in Ventura County.[3]

Top 20 Largest California Wildfires

Below are the top 20 largest California wildfires so far.[4]

1. **August Complex** in Mendocino, Humboldt, Trinity, Tehama, Glenn, Lake, and Colusa counties, August 2020: 1,032,648 acres burned, 935 structures destroyed, 1 death
2. **Dixie** in Butte, Plumas, Lassen, Shasta, and Tehama counties, July 2021: 963,309 acres burned, 1,311 structures destroyed, 1 death
3. **Mendocino Complex** in Colusa, Lake, Mendocino, and Glenn counties, July 2018: 459,123 acres burned, 280 structures destroyed, 1 death
4. **SCU Lightning Complex** in Stanislaus, Santa Clara, Alameda, Contra Costa, and San Joaquin counties, August 2020: 396,625 acres burned, 225 structures destroyed, 0 deaths
5. **Creek** in Fresno and Madera counties, September 2020: 379,895 acres burned, 858 structures destroyed, 0 deaths
6. **LNU Lightning Complex** in Napa, Solano, Sonoma, Yolo, Lake, and Colusa counties, August 2020: 363,220 acres burned, 1,491 structures destroyed, 6 deaths
7. **North Complex** in Butte, Plumas, and Yuba counties, August 2020: 318,935 acres burned, 2,352 structures destroyed, 15 deaths
8. **Thomas** in Ventura and Santa Barbara counties, December 2017: 281,893 acres burned, 1,060 structures destroyed, 2 deaths
9. **Cedar** in San Diego county, October 2003: 273,246 acres burned, 2,820 structures destroyed, 15 deaths
10. **Rush** in Lassen county, August 2012: 271,911 acres burned (in CA), 0 structures destroyed, 0 deaths
11. **Rim** in Tuolumne county, August 2013: 257,314 acres burned, 112 structures destroyed, 0 deaths
12. **Zaca** in Santa Barbara county, July 2007: 240,207 acres burned, 1 structure destroyed, 0 deaths
13. **Carr** in Shasta and Trinity counties, July 2018: 229,651 acres burned, 1,614 structures destroyed, 8 deaths
14. **Monument** in Trinity county, July 2021: 223,124 acres burned, 28 structures destroyed, 0 deaths
15. **Caldor** in Alpine, Amador, and El Dorado counties, August 2021: 221,835 acres burned, 1,005 structures destroyed, 1 death

16. **Matilija** in Ventura county, September 1932: 220,000 acres burned, 0 structures destroyed, 0 deaths
17. **River Complex** in Siskiyou and Trinity counties, July 2021: 199,359 acres burned, 122 structures destroyed, 0 deaths
18. **Witch** in San Diego county, October 2007: 197,990 acres burned, 1,650 structures destroyed, 2 deaths
19. **Klamath Theater Complex** in Siskiyou county, June 2008: 192,038 acres burned, 0 structures destroyed, 2 deaths
20. **Marble Cone** in Monterey county, July 1977: 177,866 acres burned, 0 structures destroyed, 0 deaths

Top 20 Deadliest California Wildfires

In this section, we list the top 20 deadliest wildfires in California history (as of today) reported by the California Department of Forestry and Fire Protection (CAL FIRE).[5]

1. **Camp Fire** in Butte county, November 2018: 85 deaths
2. **Griffith Park** in Los Angeles county, October 1933: 29 deaths
3. **Tunnel-Oakland Hills** in Alameda county, October 1991: 25 deaths
4. **Tubbs** in Napa and Sonoma counties, October 2017: 22 deaths
5. **North Complex** in Butte, Plumas, and Yuba counties, August 2020: 15 deaths
6. **Cedar** in San Diego county, October 2003: 15 deaths
7. **Rattlesnake** in Glenn county, July 1953: 15 deaths
8. **Loop** in Los Angeles county, November 1966: 12 deaths
9. **Palisades Fire** in Los Angeles County, January 2025: 11 deaths[11] – *Updated January 2025*
10. **Hauser Creek** in San Diego county, October 1943: 11 deaths
11. **Inaja** in San Diego county, November 1956: 11 deaths
12. **Iron Alps Complex** in Trinity county, August 2008: 10 deaths
13. **Redwood Valley** in Mendocino county, October 2017: 9 deaths
14. **Harris** in San Diego county, October 2007: 8 deaths
15. **Canyon** in Los Angeles county, August 1968: 8 deaths
16. **Carr** in Shasta and Trinity counties, July 2018: 7 deaths
17. **LNU Lightning Complex** in Napa, Sonoma, Yolo, Stanislaus, and Lake counties, August 2020: 6 deaths
18. **Atlas** in Napa and Solano counties, October 2017: 6 deaths
19. **Old** in San Bernardino county, October 2003: 6 deaths
20. **Decker** in Riverside county, August 1959: 6 deaths

Hacienda ~~in Los Angeles county, September 1955: 6 deaths~~ – Removed January 22, 2025

Top 20 Most Destructive California Wildfires

Below you will find the top 20 most destructive California wildfires in terms of structures destroyed, as reported by CAL FIRE.[6]

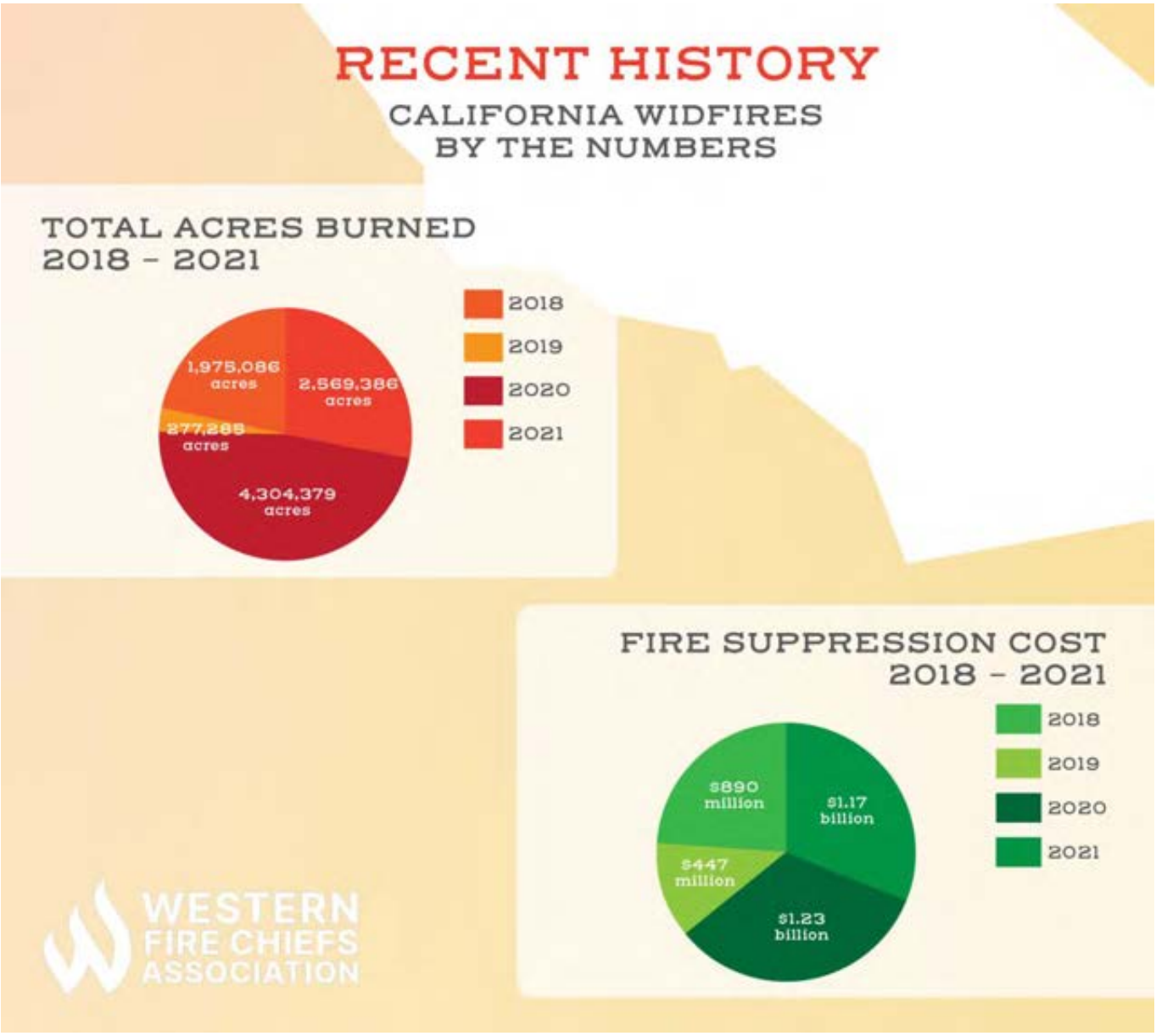
1. **Camp Fire** in Butte county, November 2018: 18,804 structures destroyed

2. **Palisades Fire** in Los Angeles County, January 2025: 6,662 structures destroyed[11] – *Updated January 2025*
3. **Tubbs** in Napa and Sonoma counties, October 2017: 5,636 structures destroyed
4. **Tunnel-Oakland Hills** in Alameda county, October 1991: 2,900 structures destroyed
5. **Cedar** in San Diego county, October 2003: 2,820 structures destroyed
6. **North Complex** in Butte, Plumas, and Yuba counties, August 2020: 2,352 structures destroyed
7. **Valley** in Lake, Napa, and Sonoma counties, September 2015: 1,958 structures destroyed
8. **Witch** in San Diego county, October 2007: 1,650 structures destroyed
9. **Woolsey** in Ventura county, November 2018: 1,643 structures destroyed
10. **Carr** in Shasta and Trinity counties, July 2018: 1,614 structures destroyed
11. **Glass** in Napa and Sonoma counties, September 2020: 1,520 structures destroyed
12. **LNU Lightning Complex** in Napa, Sonoma, Yolo, Stanislaus, and Lake counties, August 2020: 1,491 structures destroyed
13. **CZU Lightning Complex** in Santa Cruz and San Mateo counties, August 2020: 1,490 structures destroyed
14. **Nuns** in Sonoma county, October 2017: 1,355 structures destroyed
15. **Dixie** in Butte, Plumas, Lassen, and Tehama counties, July 2021: 1,311 structures destroyed
16. **Thomas** in Ventura and Santa Barbara counties, December 2017: 1,063 structures destroyed
17. **Caldor** in Alpine, Amador, and El Dorado counties, August 2021: 1,005 structures destroyed
18. **Old** in San Bernardino county, October 2003: 1,003 structures destroyed
19. **Butte** in Amador and Calaveras counties, September 2015: 965 structures destroyed
20. **Jones** in Shasta county, October 1999: 954 structures destroyed

~~**August Complex** in Mendocino, Humboldt, Trinity, Tehama, Glenn, Lake, and Colusa counties, August 2020: 935 structures destroyed~~ – Removed January 22, 2025

California Fire History: By the Numbers

In this section, we highlight California's fire history over the last five years by summing up the state's total number of fires and acres burned per year (with CAL FIRE and the US Forest Service's recorded incidents combined), and other interesting facts.[7]



The price of large fires, in dollars and damage, is extremely high.

Number of Recorded Fires Per Year

2017: 9,280

2018: 7,948

2019: 7,148

2020: 8,648

2021: 7,396

5-Yr Average: 8,607

Number of Acres Burned Per Year

2017: 1,548,429 acres

2018: 1,975,086 acres

2019: 277,285 acres

2020: 4,304,379 acres

2021: 2,569,386 acres

5-Yr Average: 1,618,833 acres

Fire Suppression Costs[8]

2017: $773 million

2018: $890 million

2019: $447 million

2020: $1.23 billion

2021: $1.17 billion

California Fire History: A Visual

For visual reference, an interactive map of California's wildfire history is available here.

Where We Are Now: The Future of Fires in California

As you can see, some of California's largest, deadliest, and most destructive wildfires have occurred within the last five years. This is due to climate change, which is a result of humans burning fossil fuels which create greenhouse gases that warm up our planet. Global warming causes both land and air to become drier than normal, thus making the perfect conditions for wildfires to ignite.[9]

Experts predict that, as climate change continues unabated, and global temperatures continue to rise, wildfire season in California will continue to burn longer and more intensely year by year.[10]

That is why it is more important than ever for California residents, and United States citizens in general, to stay informed about the history and nature of wildfires, and to take swift action to mitigate climate change.

Sources

1. Los Angeles Times, "Thomas fire could become largest on record in California." Accessed October 24, 2022.
2. OC Historyland, "The Biggest Fire You've (N)ever Heard Of." Accessed October 24, 2022.
3. KQED, "California's Largest, Deadliest and Most Destructive Wildfires." Accessed October 24, 2022.
4. CAL FIRE, "Top 20 Largest California Wildfires." Accessed October 24, 2022.
5. CAL FIRE, "Top 20 Deadliest California Wildfires." Accessed October 24, 2022.
6. CAL FIRE, "Top 20 Most Destructive California Wildfires." Accessed October 24, 2022.
7. CAL FIRE, "Stats and Events." Accessed October 24, 2022.
8. CAL FIRE, "Emergency Fund: Fire Suppression Expenditures." Accessed October 24, 2022.
9. WFCA, "Wildfires and Climate Change." Accessed October 24, 2022.

10. C2ES, "Wildfires and Climate Change." Accessed October 24, 2022.
11. CAL FIRE, "Incident Update Palisades Fire 1/22/2025." Accessed January 22, 2025.

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(800)785-3473

wfca@wfca.com

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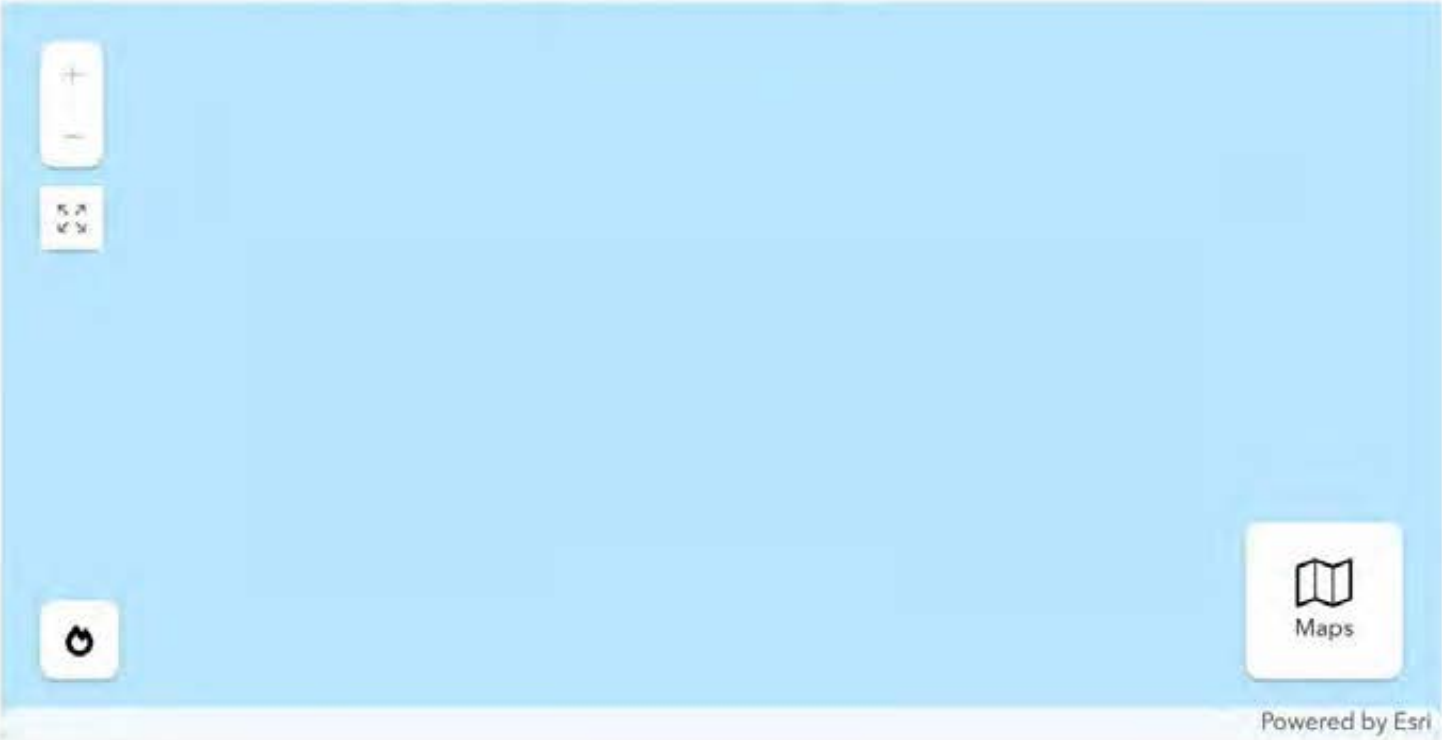
SEARCH

Silverado Fire

100% Contained 12,466 Acres 1 County: Orange



LAYERS

- [x] Air Assets
- [x] Evacuation Orders and Warnings
- [x] Recent Perimeters
- [ ] Wind
- [ ] 5-Year Fire History

Date Started
10/26/2020 7:54 AM

Last Updated
10/21/2022 1:16 PM

ASK CAL FIRE
Let's Chat

Date Contained

Incident Maps and Reports

11/07/2020 7:07 AM **(Active for 12 days)**

- 3D Map

Admin Unit

CAL FIRE & Orange County Fire Authority and Orange County Sheriff

Location

Off the 241 in the Irvine area
[33.73614,-117.65719]

Reports

Status reports

Resources Assigned

784	1	85	5	3	10
Personnel	Helicopters	Engines	Dozers	Water Tenders	Crews

Numerous firefighting air tankers from throughout the State are flying fire suppression missions as conditions allow.

Damage Assessment

Confirmed Damage to Property, Injuries, and Fatalities.

11	5	2
Structures Damaged Residential, Commercial and Other	Structures Destroyed Residential, Commercial and Other	Confirmed Civilian Injuries

Contact Information

Information Line
714-628-7085

Media Line
949-396-3998 & 949-573-5703

Email Updates (Sign up)
http://www.tinyurl.com/CALFIREMEDIA

Online Evacuation Map
http://www.tinyurl.com/OCevac

Agency Information

Orange County Fire Authority
https://twitter.com/OCFA_PIO

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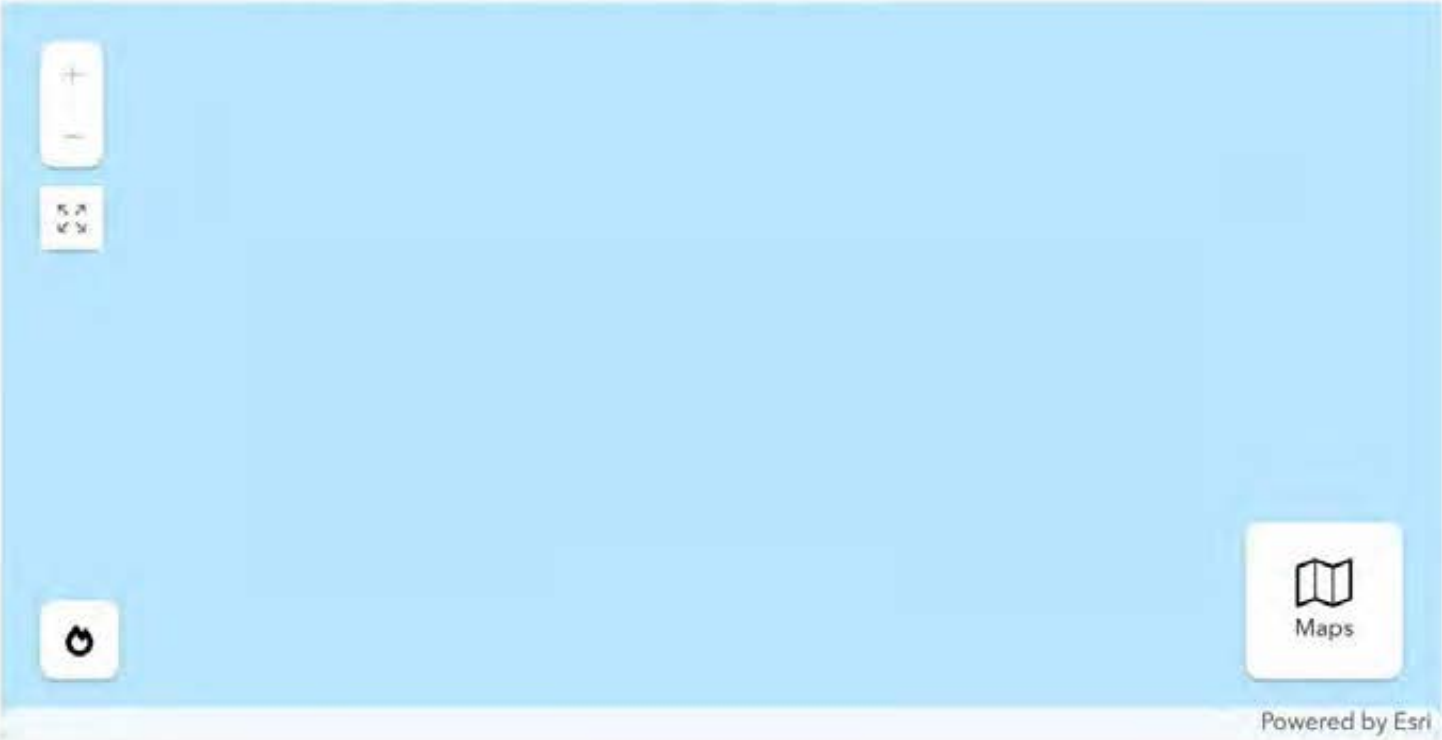
SEARCH

Bond Fire

100% Contained 6,686 Acres 1 County: Orange



LAYERS

- [x] Air Assets
- [x] Evacuation Orders and Warnings
- [x] Recent Perimeters
- [ ] Wind
- [ ] 5-Year Fire History

ASK CAL FIRE

Let's Chat

Date Started
12/02/2020 10:14 PM

Last Updated
12/17/2020 1:15 PM

Date Contained

Incident Maps and Reports

12/10/2020 6:59 PM **(Active for 8 days)**

- 3D Map

Admin Unit

Unified Command: CAL FIRE, Orange County Fire Authority, and USFS

Location

Silverado Canyon
[33.743842,-117.674967]

Reports

Status reports

Status Update

Situation Summary

Bond Fire Evacuation Warnings - Effective Immediately

All Remaining Evacuation Warnings Have Been Lifted

- **ZONE BLK01:** Blackstar Canyon and Baker Canyon areas
- **ZONE SLU01/SIL01:** Silverado Canyon area
- **ZONE SCU01/WIL01:** Williams Canyon area
- **ZONE MJU01/MOD01:** Modjeska Canyon area
- **ZONE LKF04:** Portola Hills area of the City of Lake Forest
- **ZONE LKF05:** Portola Hills area of the City of Lake Forest
- **ZONE TBU02:** The northern Trabuco Canyon Area
- **ZONE TBU03:** Valley Vista and Meadow Ridge

Road closures have also been lifted. Vehicular traffic may access the area.

In the coming days, be prepared for intermittent and/or extended road closures to allow crews to perform infrastructure repair.

SAFETY MESSAGE: The public is reminded to stay vigilant. Fire personnel, crews working on

infrastructure, and unseen dangers may be present in and around the fire area. Drive slowly, yield to emergency personnel and stay off the roadways unless necessary. If at any time you feel unsafe, please call 9-1-1.

Interactive evacuation map available here

Decrease in acreage reflected in today's update is due to more accurate mapping. Overnight, strong, gusty winds developed over the fire area. Firefighters worked to construct and improve fireline, and patrol the fire area. Firelines continue to hold and today crews will continue to patrol diligently in areas where strong winds could have the potential to spread the fire and threaten adjacent communities.

Santa Ana winds are expected to peak this morning; dry conditions will continue and humidities will be low. A Red Flag Warning remains in effect for the area through the evening.

Damage assessment teams have completed a systematic survey of the fire area

Evacuations/Road Closures

All Evacuation Orders have been lifted

- Hard Road Closures:

All road closures have been lifted.

Resident Traffic Only:

Santiago Canyon Road at Ridgeline Road

Evacuation Centers:

El Modena High School – 3920 E Spring Street, Orange, CA 92869

Animal Evac. Center(s):

Anaheim Equestrian Center – 1370 S Sanderson Avenue, Anaheim, CA 92806

Orange County Fair & Event Center – 88 Fair Drive, Costa Mesa, CA 92626

Damage Assessment

Confirmed Damage to Property, Injuries, and Fatalities.

21	31
Structures Damaged Residential, Commercial and Other	Structures Destroyed Residential, Commercial and Other

Contact Information

Public Information Hotline
(714) 628-7085

Agency Information

Orange County Fire Authority
https://twitter.com/OCFA_PIO

Orange County Sheriff's Office
https://ocsheriff.gov/commands-divisions/field-operations-investigations-command/emergency-management/resources-during

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SEARCH

Airport Fire

100% Contained 23,526 Acres 2 Counties: Orange, Riverside

Not a CAL FIRE Incident. Updates will be made as they become available.

Maps

Powered by Esri

LAYERS

Air Assets Evacuation Orders and Warnings Recent Perimeters Wind ory

ASK CAL FIRE

Let's Chat

Date Started **Last Updated**

09/09/2024 1:21 PM

10/06/2024 8:05 AM

Date Contained

10/05/2024 10:00 PM **(Active for 26 days)**

Cause

Equipment

Incident Maps and Reports

- 3D Map

Admin Unit

Cleveland National Forest

Incident Management Team

No team assigned

Location

Trabuco Canyon and Rose Canyon, Trabuco Canyon
[33.6676762,-117.566221]

Reports

Status reports

Status Update

Situation Summary

Crews remain on the fireline today, conducting patrol, monitoring, fire suppression repair and infrastructure repair. The Burned Area Emergency Response (BAER) team also remains on site, working in conjunction with these resources.

A drone outfitted with infrared sensors flew the fire yesterday. It reported no additional heat signatures near any of the containment lines. The fire has been static for a week, meaning it has not expanded or consumed any more acreage. Fire engines and crews continue to be posted in strategic areas around the fire, watching out for any changes. There was some smoke reported to the east of the Airport fire. This is from the Line fire on the San Bernardino National Forest and does not affect any operations here.

Fire suppression repair efforts are ongoing in all areas of the incident, with focus for the next few days centering on the Bedford Road and Santiago Ridge trails. Work continues on several sections in the south. Hazardous tree mitigation is also nearly complete in the Trabuco Canyon areas, with completion

expected in the next day or two.

The temporary flight restriction (TFR) that was initiated at the beginning of the Airport Fire has been removed. However, the Forest Closure Order is still in effect for the Trabuco Ranger District of the Cleveland National Forest. Please do not enter the closure area or recreate on any of the fire lines constructed for the incident. The scope of the closure may be reduced in the near future if deemed prudent and safe. For now, the full closure remains.

To view the Forest Orders and Maps, visit our website. For additional information and possible changes. Southern California Edison has restored power to the El Cariso and Decker Canyon communities. They are continuing to replace damaged power poles, lines and equipment in the Lake Elsinore area and inside the burned area. They will be using heavy equipment and helicopters to transport and place these poles. Operations will be scheduled during times of minimal highway use. All motorists should be aware that fire equipment is still working on the roads and traffic delays occur for extended periods. Please plan accordingly.

An interactive map for both counties may be found at: https://bit.ly/3TtJBW9.

All evacuation orders and warnings have been lifted.

Additional fire information can be found here.

3D Map

Airport Fire Daily Map Products

Airport Fire Photos and Videos

Road Closures

Highway 74 is now open. There is still infrastructure repair occurring through Highway 74 please use caution and slow to a safe speed. Commuters should expect intermittent lengthy delays due to ongoing repair of infrastructure along the highway. Be aware that several roads off of Ortega Highway in or near the fire area in both Riverside and Orange Counties remain closed.

Hard Road Closures

- Trabuco Creek Road
- Maple Springs Road

- North Main Divide Road at Ortega Highway
- Long Canyon Road at Ortega Highway

Forest Closure

The Cleveland National Forest has a temporary closure of the Trabuco Ranger District. This closure prohibits going into or, being upon any National Forest System lands, roads, and trails within the boundaries of the Trabuco Ranger District. The closure will be in effect from September 18, 2024 until September 17, 2025, to provide for public health and safety concerns related to the Airport Fire. To view the Forest Orders and Maps, visit our website at: https://www.fs.usda.gov/alerts/cleveland/alerts-notices/?aid=90727

Damage Assessment

Confirmed Damage to Property, Injuries, and Fatalities.

34	160	2	20
Structures Damaged Residential, Commercial and Other	Structures Destroyed Residential, Commercial and Other	Confirmed Civilian Injuries	Confirmed Firefighter Injuries

Contact Information

Public Information Email
2024.airport@firenet.gov

Fire Information
(949)384-8736

Agency Information

CAL FIRE, US Forest Service, Orange County Sheriff Department, California Highway Patrol, CAL OES, Orange County Public Works, Riverside County Sheriff Department, Southern California

Edison.

Social Media

OCFireAuthority

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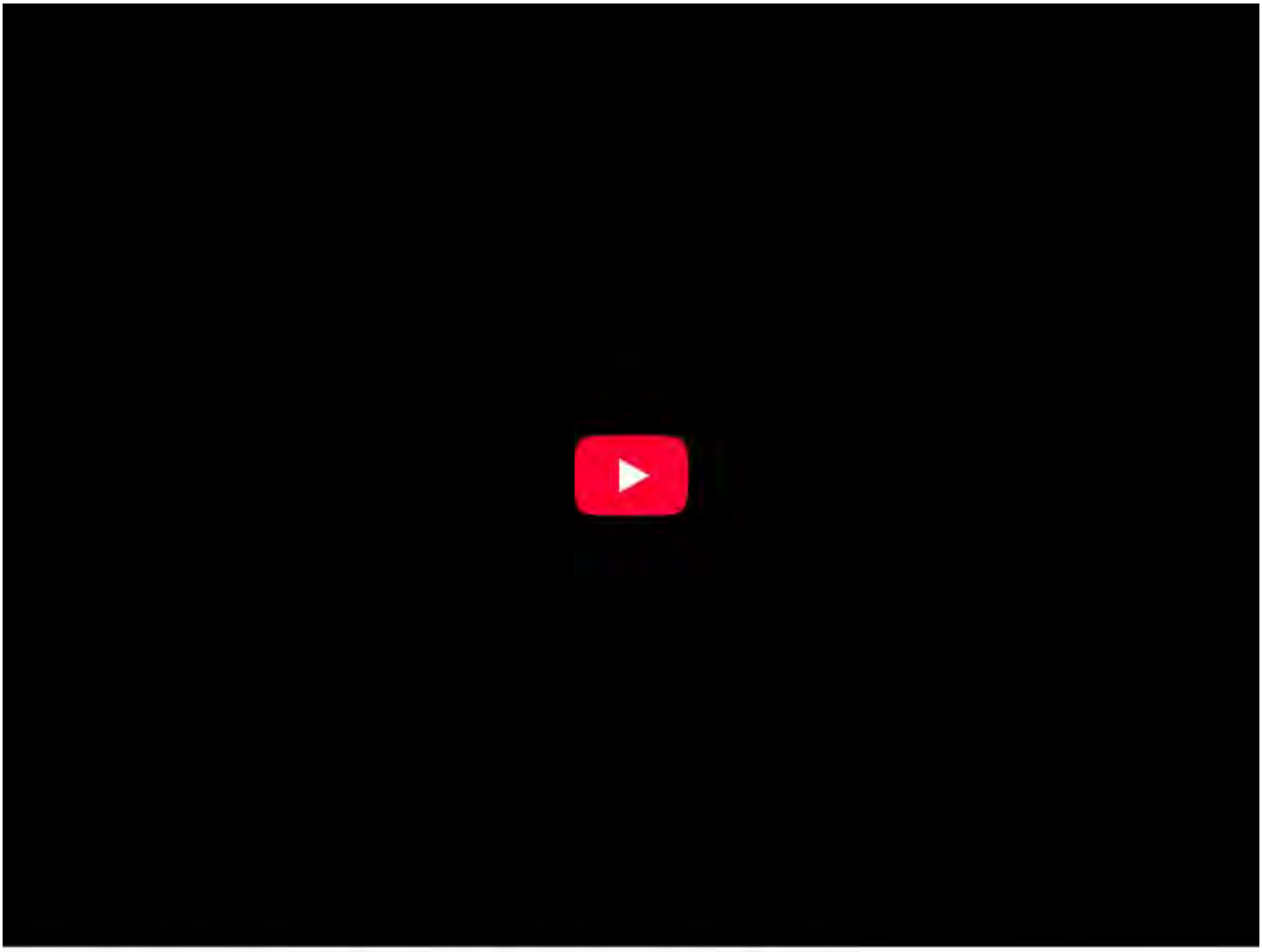
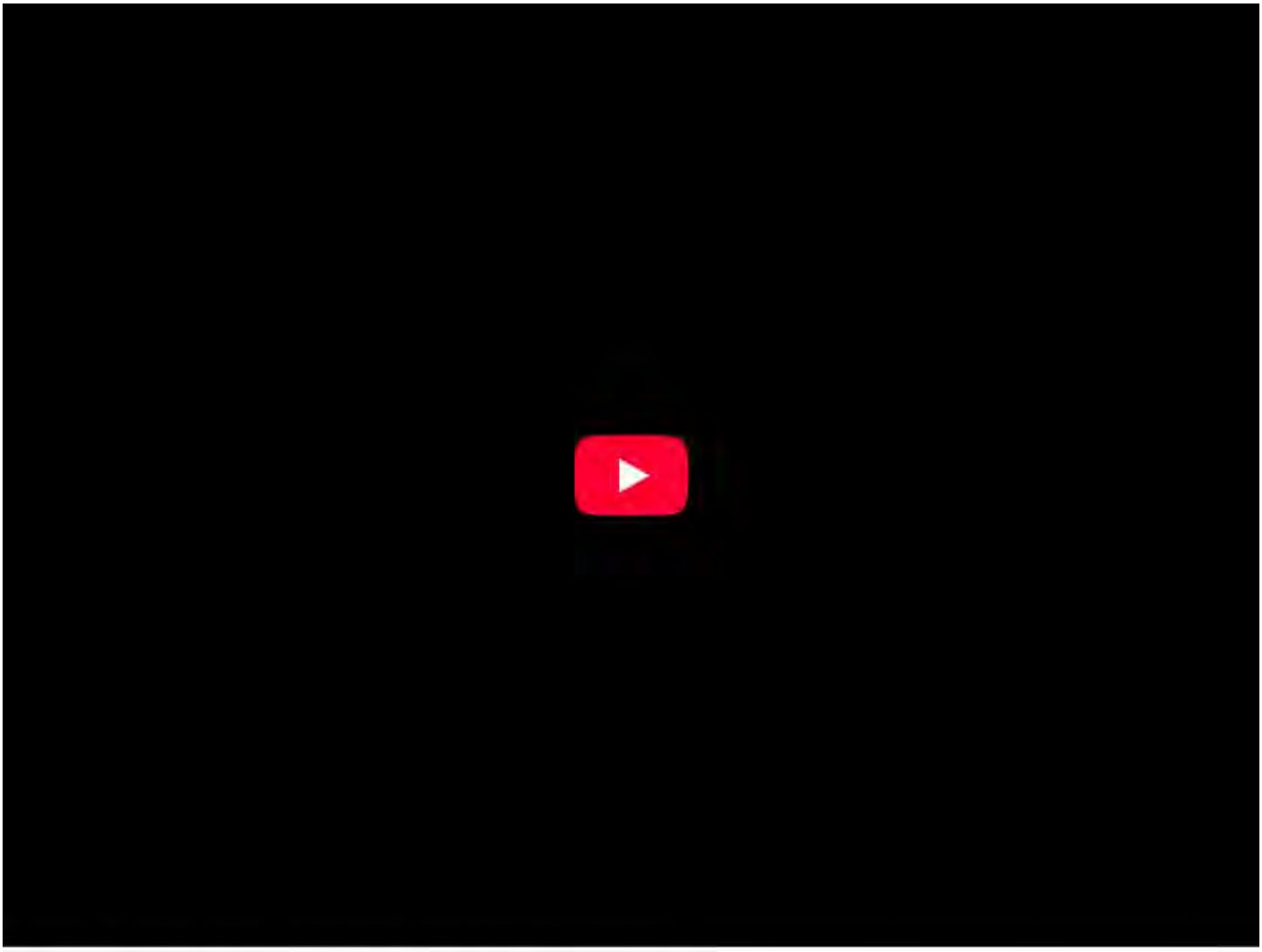
Fire Hazard Severity Zones

California's seasonally dry Mediterranean climate lends itself to wildfires, and in an effort to better prepare, CAL FIRE is required to classify the severity of fire hazard in areas of California.



The History of Fire Hazard Severity Zone Maps

Fire Hazard Severity Zone maps arose from major destructive fires, prompting the recognition of these areas and strategies to reduce wildfire risks. Legislative response led to mandated mapping across California under the California Public Resources Code 4201-4204, encompassing all State Responsibility Areas (SRA).

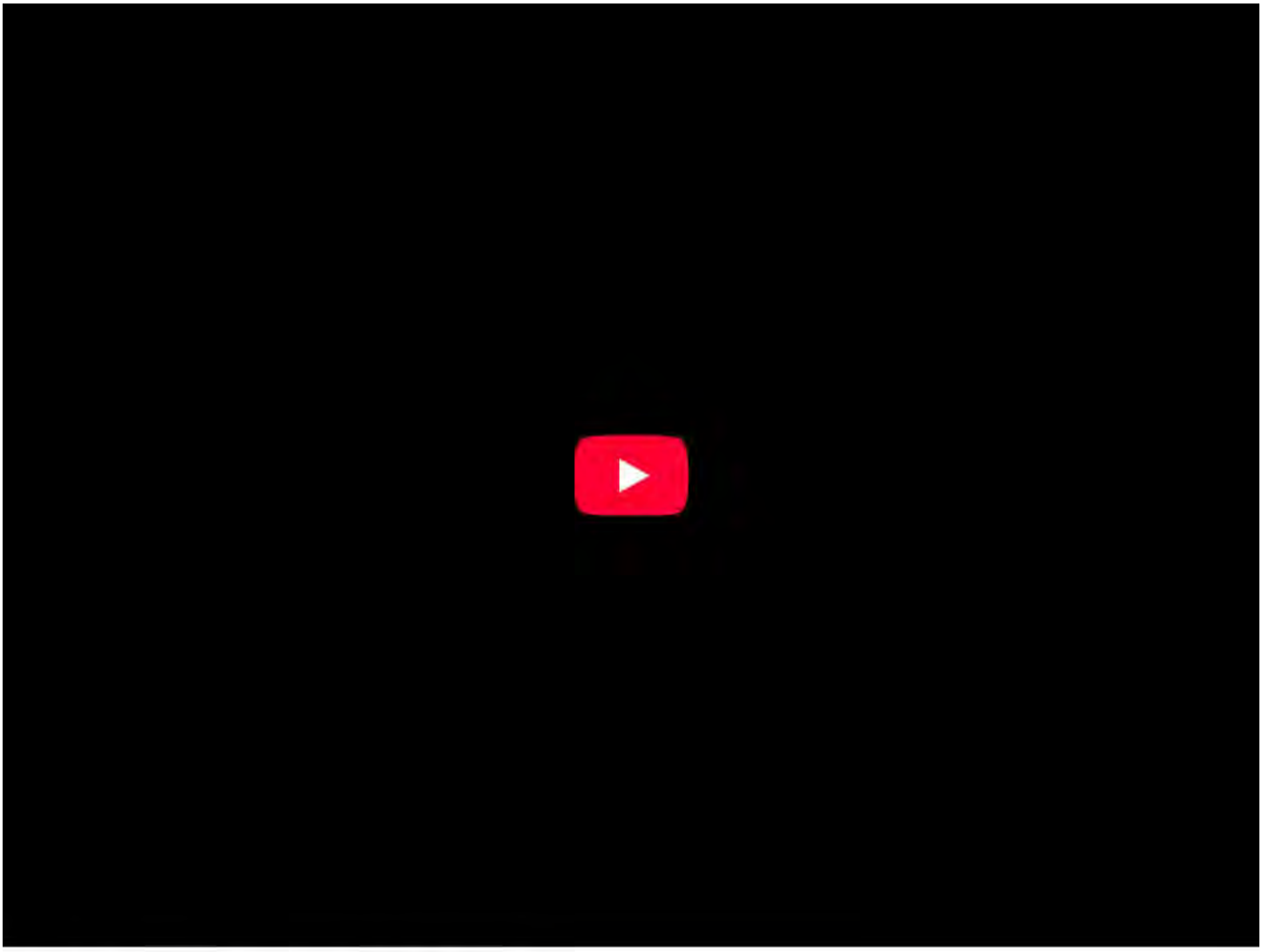


What are Fire Hazard Severity Zones?

The State Fire Marshal is mandated to classify lands within State Responsibility Areas into Fire Hazard Severity Zones (FHSZ). Fire Hazard Severity Zones fall into one of the following classifications:

- Moderate
- High
- Very High

The California laws that require Fire Hazard Severity Zones include California Public Resources Code 4201-4204, California Code of Regulations Title 14, Section 1280 and California Government Code 51175-89.



Frequently Asked Questions

FAQ DOCUMENT (PDF)

FAQ DOCUMENT (PDF) (SPANISH)

EXAMPLES OF FHSZ STATE MINIMUM MITIGATION REQUIREMENTS

Explore Fire Hazard Severity Zones

The Fire Hazard Severity Zone (FHSZ) maps are developed using a science-based and field-tested model that assigns a hazard score based on the factors that influence fire likelihood and fire behavior. Many

factors are considered such as fire history, existing and potential fuel (natural vegetation), predicted flame length, blowing embers, terrain, and typical fire weather for the area. There are three levels of hazard in the State Responsibility Areas: moderate, high, and very high.

Fire Hazard Severity Zone maps evaluate "hazard," not "risk". They are like flood zone maps, where lands are described in terms of the probability level of a particular area being inundated by floodwaters, and not specifically prescriptive of impacts. "Hazard" is based on the physical conditions that create a likelihood and expected fire behavior over a 30 to 50-year period without considering mitigation measures such as home hardening, recent wildfire, or fuel reduction efforts. "Risk" is the potential damage a fire can do to the area under existing conditions, accounting for any modifications such as fuel reduction projects, defensible space, and ignition resistant building construction.

View Map on Cell/Tablet Device

Find your Fire Hazard Severity Zone (FHSZ) and local public contacts

CLICK TO COMPARE OLD & NE...

App that feeds the FHSZ/PIO lookup component of the Fire Hazard Severity Zone and Local PIO Viewer App on the CAL FIRE website.

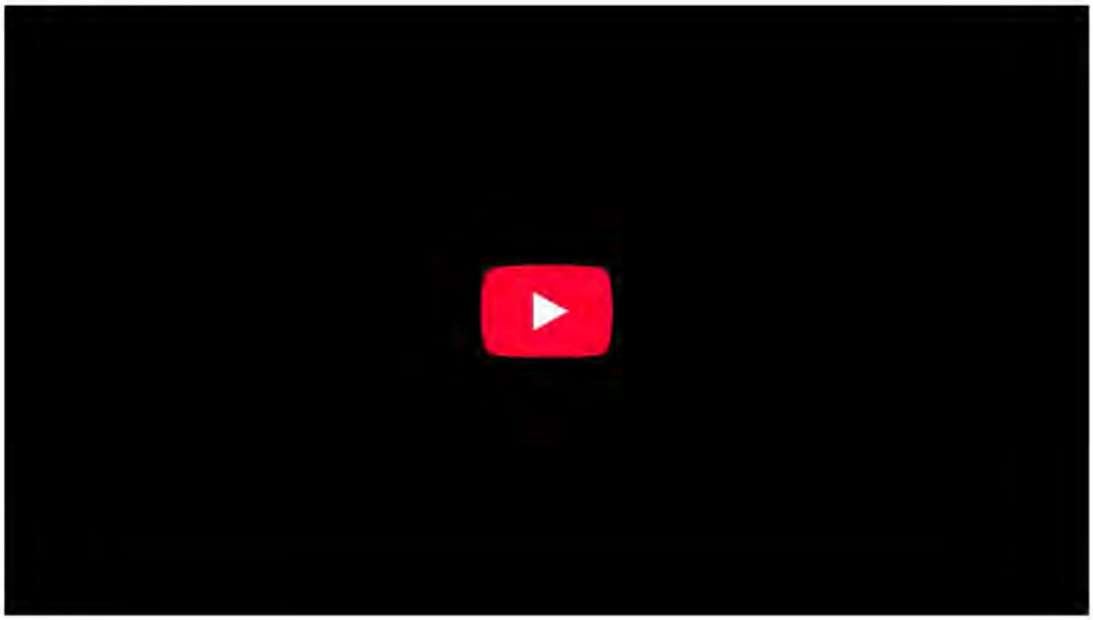
Powered by Esri

FHSZ ACRE CHANGES IN SRA AND LRA

Local Responsibility Area Fire Hazard Severity Zone Maps +

State Responsibility Area Fire Hazard Severity Zone Maps +

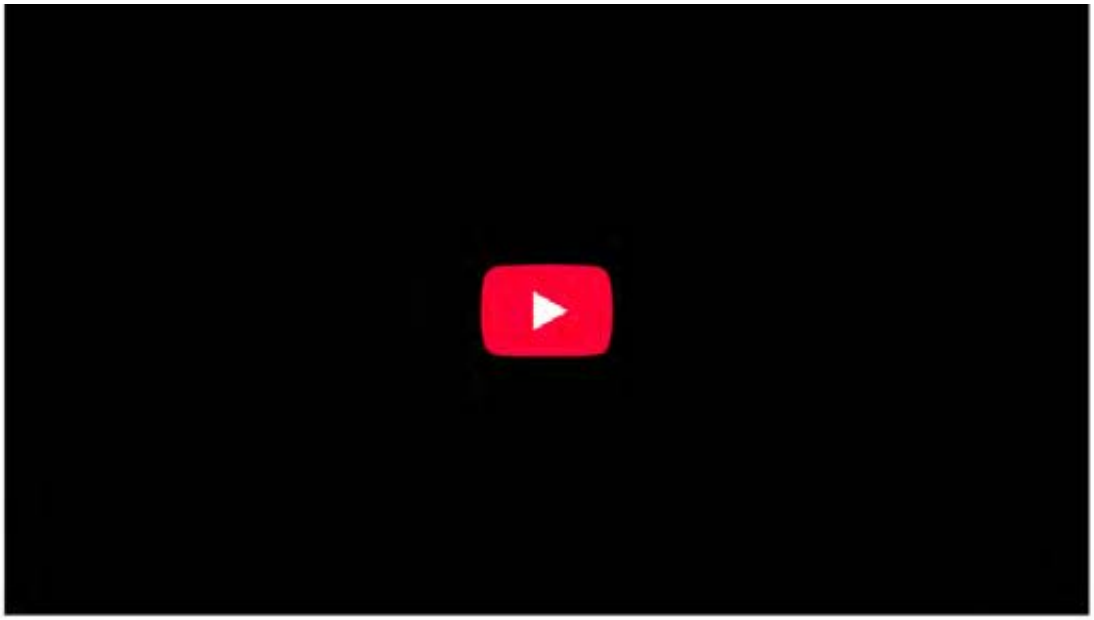
Methods for Creating Fire Hazard Severity Zone Maps



Enhance your Property's Fire Safety

It is your responsibility to prepare yourself, your family, and your home for when wildfire strikes. Creating and maintaining defensible space and hardening your home by retrofitting it with ignition-resistant or noncombustible materials to protect against the threat of flying embers, direct flame contact, and radiant heat exposure will dramatically increase your safety and the survivability of your home.

DEFENSIBLE SPACE | HOME HARDENING



Science and Method +

Definitions +

California Department of Insurance Information +

Contact Information

FHSZinformation@fire.ca.gov
916-633-7655

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ROB BONTA
ATTORNEY GENERAL

Best Practices for Analyzing and Mitigating Wildfire Impacts of Development Projects Under the California Environmental Quality Act

I. Introduction

Wildfires are part of California's present, and with the effects of climate change, an increasing part of our future. Development in fire-prone areas increases the likelihood that more destructive fires will ignite, fire-fighting resources will be taxed, more habitat and people will be put in harm's way or displaced, and more structures will burn. It is therefore imperative that local jurisdictions making decisions to approve new developments carefully consider wildfire impacts as part of the environmental review process, plan where best to place new development, and mitigate wildfire impacts to the extent feasible.

This guidance is designed to help lead agencies[1] comply with the California Environmental Quality Act, Public Resources Code, section 21000 et seq. (CEQA), when considering whether to approve projects in wildfire-prone areas. These areas are often in the wildland-urban interface, generally defined as the area where the built environment meets or intermingles with the natural environment.[2] The California Department of Forestry and Fire Protection (CAL FIRE) has classified lands based on fire risk, the highest being those classified as high or very high fire hazard severity zones. It has also identified areas where the State (as opposed to a local agency) has responsibility for fire-fighting.[3] Particularly in these high-risk areas, but also throughout the

---

[1] Lead agencies are any public agencies with "principal responsibility for carrying out or approving a project which may have a significant effect upon the environment." (Pub. Resources Code, § 21067.)

[2] CAL FIRE has published an instructive map on the wildland-urban interface in California: https://frap.fire.ca.gov/media/10300/wui_19_ada.pdf. The wildland-urban interface is defined differently by different agencies for different purposes, but the most widely used definition for wildfire purposes include the intermix and interface areas mapped by Radeloff et al. 2005, 2018. See Volker C. Radeloff, et al., *Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk.* PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES USA, 115(13):3314-3319 (2018), available at https://www.pnas.org/doi/10.1073/pnas.1718850115.

[3] See https://osfm.fire.ca.gov/divisions/community-wildfire-preparedness-and-mitigation/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/. Note that areas mapped by CAL FIRE as high or very high fire risk are not always coextensive with the wildland-urban interface. In addition, CAL FIRE's maps are currently in the process of being updated and lead agencies should consult with CAL

wildland-urban interface, wildfire risks must be considered during the environmental review process for individual development projects.

This guidance provides suggestions for how best to comply with CEQA when analyzing and mitigating a proposed project's impacts on wildfire ignition risk, emergency access, and evacuation.[4] This guidance is aimed at proposed development projects, such as residential, recreational, or commercial developments.[5] The extent to which it applies will inherently vary by project, based on project design and location. This document does not impose additional requirements on local governments or alter any applicable laws or regulations. Rather, it is intended to provide guidance on some of the issues, alternatives, and mitigation measures that should be considered during the environmental review process. This guidance is based on the Office of the Attorney General's experience reviewing, commenting on, and litigating CEQA documents for projects in high wildfire prone areas, and is intended to assist lead agencies with their planning and approval of future projects. The guidance reflects current requirements and conditions and may need to be updated as changes occur.

II. Background

Although wildfires are and have been an important natural process throughout California's history, recent changes in fire frequency, intensity, and location are posing increasing threats to the residents and environment of California. More acres of California have burned in the past decade than in the previous 90 years[6] and eight of the State's ten largest fires since 1932 have occurred in the last decade.[7] While lightning is a common cause of some of the State's largest

---

FIRE before relying on the classifications listed on this map. CAL FIRE's list of state responsibility areas (defined as areas where the State of California, as opposed to a local agency, is financially responsible for prevention and suppression of wildfires) can be found at: https://calfire-forestry.maps.arcgis.com/apps/webappviewer/index.html?id=468717e399fa4238ad86861638765ce1. Each county should have a map of the very high or high fire hazard severity zones in its jurisdiction, and they are also included on the CAL FIRE zone map: https://egis.fire.ca.gov/FHSZ/.

[4] Readers who want to determine their legal obligations under CEQA should consult their own attorney for legal advice.

[5] This guidance is not intended to apply to state and local agency fire management activities, such as prescribed burns, approval of vegetation management plans to reduce wildfire risk, and review of timber harvesting plans.

[6] CAL FIRE, Top 20 Largest California Wildfires (Jan. 13, 2022), available at https://www.fire.ca.gov/media/4jandlhh/top20_acres.pdf. See also Hugh D. Safford et al., *The 2020 California Fire Season: A Year Like No Other, a Return to the Past or a Harbinger of the Future?* (Apr. 17, 2022) GLOBAL ECOLOGY AND BIOGEOGRAPHY, available at https://onlinelibrary.wiley.com/doi/10.1111/geb.13498?af=R.

[7] Paul Rogers, *Map: 1 of Every 8 acres in California has Burned in the Last 10 Years. Here's Where the Biggest Fires Spread—and are Burning Now*, Mercury News (Sept. 29, 2021), available at https://www.mercurynews.com/2021/09/29/top-10-california-wildfires-megafires-map/. Notably, the large fires of late are not unprecedented in the State's history with similarly large fires occurring specifically during the 1920s. See Jon E. Keeley & Alexandra D. Syphard, *Large California Wildfires: 2020*

fires, in recent years, many of the State's most destructive fires have been caused by human activity, such as downed powerlines or electrical sources associated with residential development or industrial facilities.[8]

Wildfires can have dramatic, adverse ecological impacts. Frequent wildfires can result in habitat loss and fragmentation, shifts in vegetative compositions, reductions in small mammal populations, and accelerated loss of predatory species.[9] Wildfire can also have adverse impacts on erosion and water quality. During active burning, ash and associated contaminants can enter water supplies. Later, after large burns, rainstorms can flush vast amounts of sediment from exposed soils into those same water supplies.[10]

Wildfires also have tragic consequences for California's residents. Since 2010, wildfires have killed nearly 150 people in California[11] and, since 2005, wildfires have destroyed over 97,000 structures,[12] requiring mass evacuations and exacerbating the State's already-pressing need for more housing. In addition, wildfire smoke is unhealthy to breathe and is a public health concern.[13] Further, wildfire losses are not experienced equally. Lower-income households are more likely to lose all of their assets and less likely to have adequate insurance to cover their losses.[14] Meanwhile, the costs of wildfire suppression and resiliency have become significant. In

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Fires in Historical Context (Aug. 25, 2021) FIRE ECOLOGY, available at https://fireecology.springeropen.com/articles/10.1186/s42408-021-00110-7.

[8] See CAL FIRE, Top 20 Largest California Wildfires (Jan. 13, 2022), available at https://www.fire.ca.gov/media/4jandlhh/top20_acres.pdf; CalFire, Top 20 Most Destructive California Wildfires (Jan. 13, 2022), available at https://www.fire.ca.gov/media/t1rdhizr/top20_destruction.pdf.

[9] See Alexandra D. Syphard, et al., *Human Influence on California Fire Regimes.* ECOLOGICAL APPLICATION 17:1388-1402 (2007).

[10] United States Environmental Protection Agency, Wildfires: How do They Affect Our Water Supplies? (Aug. 13, 2019), available at https://www.epa.gov/sciencematters/wildfires-how-do-they-affect-our-water-supplies#:~:text=Vegetation%20that%20holds%20soil%20in,%2C%20rivers%2C%20and%20downstream%20reservoirs.

[11] CAL FIRE, Top Deadliest California Wildfires (Oct. 22, 2021), available at https://www.fire.ca.gov/media/lbfd0m2f/top20_deadliest.pdf.

[12] Headwaters Economics, Wildfires Destroy thousands of structures each year (Nov. 2020, updated Aug. 2022), available at https://headwaterseconomics.org/natural-hazards/structures-destroyed-by-wildfire/.

[13] See Kurtis Alexander, *California Ranks Worst in Nation for Air Pollution Because of Wildfire Smoke*, S.F. Chronicle (June 23, 2022), available at https://www.sfchronicle.com/bayarea/article/california-air-quality-17259687.php. See also Lora Kolodny, *The West Coast Is Suffering from Some of the Worst Air in the World — These Apps Show How Bad it Is*, CNBC (Sept. 13, 2020), available at https://www.cnbc.com/2020/09/12/air-quality-apps-purpleair-airnow-iqair-essential-in-western-us.html; and California Air Resources Board, *Protecting Yourself from Wildfire Smoke*, available at https://ww2.arb.ca.gov/protecting-yourself-wildfire-smoke.

[14] California Council on Science and Technology, The Costs of Wildfire in California (Oct. 2020), at p. 69, available at https://ccst.us/reports/the-costs-of-wildfire-in-california/.

2021, the State invested $1.5 billion in wildfire resiliency efforts, and the 2022-2023 budget includes an additional $1.2 billion to support wildfire and forest resilience.[15] The changing nature of wildfires, under various metrics—frequency, area burned, adverse ecological impacts, the number of Californians displaced—is a worsening crisis that will unfortunately be part of California's future.[16]

As of 2010, about one-third of California's housing units were located within the wildland-urban interface.[17] Residential developments in the wildland-urban interface and other wildfire prone areas can significantly increase the risks of wildfires and the risk to public safety for several reasons. First, introducing more people—via additional development—into a flammable landscape increases the likelihood of: (1) a wildfire igniting due to the increased presence of people; and (2) the ignition becoming a wildfire because of the placement of homes amongst the flammable vegetation.[18] Second, building housing units in the wildland-urban interface puts more people in harm's way.[19] Wildfires, particularly those that impact developments in relatively remote locations, may impede the evacuation of communities and emergency access, making it more difficult to ensure public safety and to limit, control, or extinguish wildfires. Finally, fires in remote locations require significant fire-fighting resources and mobilization of fire-fighters from all over the State—putting a major strain on the State's fire-fighters and the State's budget. Put simply, bringing more people into or near flammable wildlands leads to more frequent, intense, destructive, costly, and dangerous wildfires.[20]

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[15] Gavin Newsom, California State Budget (2022-2023), at p. 61, available at https://www.ebudget.ca.gov/FullBudgetSummary.pdf; California State Budget, Budget Addendum (2021-2022), at p. 3, available at https://www.ebudget.ca.gov/BudgetAddendum.pdf.

[16] See California Council on Science and Technology, *The Costs of Wildfire in California* (Oct. 2020), at p. 17, available at https://ccst.us/reports/the-costs-of-wildfire-in-california/.

[17] Community Wildfire Planning Center, Land Use Planning Approaches in the Wildland-Urban Interface (Feb. 2021), at p. 7, available at https://www.communitywildfire.org/wp-content/uploads/2021/02/CWPC_Land-Use-WUI-Report_Final_2021.pdf; see also Heather Anu Kramer, et al., *High Wildfire Damage in Interface Communities in California* (2019) INTERNATIONAL JOURNAL OF WILDLAND FIRE, available at https://www.fs.usda.gov/nrs/pubs/jrnl/2019/nrs_2019_kramer_001.pdf. At the current rate of growth and under current growth patterns, it is anticipated that an additional 645,000 housing units will be developed in areas designated by CAL FIRE as very high fire hazard severity zones by 2050. Next 10, Rebuilding for a Resilient Recovery: Planning in California's Wildland Urban Interface (June 2021), at p. 9, available at https://www.next10.org/publications/rebuilding-resilient.

[18] See Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) Fremontia, *47*(2), at p. 29; Volker C. Radeloff, et al., *Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk.* PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES USA, 115(13):3314-3319 (2018).

[19] See Heather Anu Kramer, et al., *High Wildfire Damage in Interface Communities in California* (2019) International Journal of Wildland Fire, available at https://www.fs.usda.gov/nrs/pubs/jrnl/2019/nrs_2019_kramer_001.pdf; Volker C. Radeloff, et al., *Rapid growth of the US wildland-Urban interface raises wildfire risk.* PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES USA, 115(13):3314-3319 (2018).

[20] See Michael L. Mann, et al., *Incorporating Anthropogenic Influences into Fire Probability Models: Effects of Human Activity and Climate Change on Fire Activity in California* (Apr. 28, 2016) PLOS ONE

III. Wildfire and Land Use Planning

While this guidance is focused on best practices to disclose, analyze, and mitigate wildfire impacts in compliance with CEQA, it is important to note that general planning also provides a critical opportunity for local jurisdictions to think proactively about how to accommodate their housing and development needs while reducing the risks of wildfire.[21] In the last ten years, new legislation has passed requiring local jurisdictions to consider wildfire risks in their general planning processes.[22] The Governor's Office of Planning and Research (OPR) recently published comprehensive guidance to help local agencies comply with these requirements.[23] We encourage local jurisdictions to consult this guidance and to thoughtfully plan for new development given the increasing risk of wildfires throughout the state.[24]

11(4), available at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0153589; Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at pp. 28-35, available at https://pubs.er.usgs.gov/publication/70215982; Alexandra D. Syphard, et al., *Land Use Planning and Wildfire: Development Policies Influence Future Probability of Housing Loss* (2013) PLOS ONE, available at https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0071708&type=printable; see also Final Statement of Reasons for Regulatory Action re Amendments to the State CEQA Guidelines OAL Notice File No. Z-2018-0116-12 ("Statement of Reasons"), at p. 87, available at https://resources.ca.gov/CNRALegacyFiles/ceqa/docs/2018_CEQA_Final_Statement_of%20Reasons_111218.pdf.

[21] See Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at p. 33, available at https://pubs.er.usgs.gov/publication/70215982 [concluding that "the most effective strategy at reducing future structure loss would focus on reducing the extent of low-density housing via careful land planning decisions"].

[22] See Sen Bill No. 1241 (2011-2012 Reg. Sess.), amending and/or adding Gov. Code, §§ 65302, subd. (g)(3), 65302.5, subd. (b), and 66474.02) [requiring local jurisdictions within state responsibility areas or very high fire hazard severity zones to address wildfire risk when updating their safety elements and to submit their draft updates to the State Board of Forestry and Fire Protection for review]; Sen. Bill No. 99 (2019-2020 Reg. Sess.), amending Gov. Code, § 65302, subd. (g)(5) [requiring updated safety elements to identify residential developments within hazard areas that do not have at least two evacuation routes]; Assem. Bill No. 747 (2019-2020 Reg. Sess.), adding Gov. Code, § 65302.15 [requiring local jurisdictions to update their safety element to address the capacity of evacuation routes under a range of various emergency scenarios]; Assem. Bill No. 1409 (2020-2021 Reg. Sess.), amending Gov. Code, § 65302.15 [requiring that safety elements identify locations where people can evacuate to].

[23] Governor's Office of Planning and Research, Fire Hazard Planning Technical Advisory, 2022 Update (Aug. 2022), available at https://opr.ca.gov/docs/20220817-Fire_Hazard_Planning_TA.pdf; and Wildland-Urban Interface Planning Guide: Examples and Best Practices for California Communities (Aug. 2022), available at https://opr.ca.gov/docs/20220817-Complete_WUI_Planning_Guide.pdf.

[24] Local jurisdictions that have complied with their general planning obligations, including incorporating wildfire and evacuation planning considerations into their general plans, may benefit from streamlined CEQA requirements at the project approval level. If a development project is consistent with an updated general plan and an environmental impact report (EIR) was prepared for that plan, the CEQA review for the project may be limited to the parcel-specific impacts of the project or impacts that new information,

IV. Analyzing and Mitigating Wildfire Risk Impacts Under CEQA

A. **CEQA's** requirements for analyzing wildfire risks

CEQA requires local jurisdictions considering development projects to prepare an environmental impact report (EIR) or a mitigated negative declaration[25] if the project may potentially have a significant impact on the environment and is not otherwise exempt from CEQA.[26] Under CEQA, local jurisdictions may act as lead agencies with responsibility for preparing the EIR (or other CEQA document), or as responsible agencies relying on an EIR prepared by a lead agency. CEQA provides a critical process for local jurisdictions to understand how new developments will exacerbate existing wildfire risks, allowing them to consider project design features, alternatives, and mitigation measures that provide for smarter development and the protection of existing communities.

The CEQA Guidelines[27] require that an EIR include a description of the physical environmental conditions in the vicinity of the project, at the time the notice of preparation is published, or if no notice of preparation is published, at the time environmental analysis is commenced.[28] This "baseline" of existing environmental conditions is generally used to determine the significance of project-related impacts. In the EIR's discussion of the existing environmental conditions, lead agencies should include information about open space areas and habitats within the project area that may be fire prone, as well as a discussion of fire history and fuels on the project site. Including a discussion of existing available water supplies for fire-fighting is also critical. Providing detail about existing environmental conditions at the project site that may exacerbate or minimize wildfire impacts will help ensure that the EIR fully considers the project's impacts on wildfire risk.

The CEQA Guidelines require an analysis of "any significant environmental effects the project might cause or risk exacerbating by bringing development and people into the area affected," including by locating development in wildfire risk areas.[29] The "environmental checklist form" in Appendix G of the CEQA Guidelines, Section XX, directs lead agencies to assess whether

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arising since adoption of the general plan, shows will be more significant than described in the prior EIR. (Pub. Resources Code, § 21083.3; CEQA Guidelines, § 15193).

[25] Where "EIR" is used in this guidance it should also be considered to refer to a mitigated negative declaration.

[26] Pub. Resources Code, § 21067; CEQA Guidelines, §§ 15050 and 15367.

[27] The CEQA Guidelines are found at California Code of Regulations, title 14, section 15000, et seq.

[28] CEQA Guidelines, § 15125.

[29] CEQA Guidelines, § 15126.2.

projects located *in or near* state responsibility areas or lands classified as very high fire hazard severity zones,[30] would:

a) Substantially impair an adopted emergency response plan or emergency evacuation plan;
b) Due to slope, prevailing winds, and other factors, exacerbate wildfire risks, and thereby expose project occupants to pollutant concentrations from a wildfire or the uncontrolled spread of a wildfire;
c) Require the installation or maintenance of associated infrastructure (such as roads, fuel breaks, emergency water sources, power lines or other utilities) that may exacerbate fire risk or that may result in temporary or ongoing impacts to the environment; or
d) Expose people or structures to significant risks, including downslope or downstream flooding or landslides, as a result of runoff, post-fire slope instability, or drainage changes.[31]

In addition to the four questions above, Section IX(g) of the checklist broadly directs lead agencies to consider whether a project will "expose people or structures, either directly or indirectly, to a significant risk of loss, injury or death involving wildland fires."[32] In answering these questions, lead agencies must consider both on- and off-site impacts.[33]

B. Analyzing a p**roject's** impact on wildfire risks

Several variables should be considered in analyzing a project's impact on wildfire risk, including:

- Project Density: Project density influences how likely a fire is to start or spread, and how likely it is that the development and its occupants will be in danger when a fire starts. Fire spread and structure loss is more likely to occur in low- to intermediate-density developments.[34] This is because there are more people present to ignite a fire (as compared to undeveloped land), and the development is not concentrated enough

[30] See footnote 1 for more information on state responsibility areas and very high fire hazard severity zones.

[31] CEQA Guidelines, Appendix G, XX.

[32] CEQA Guidelines, Appendix G, IX(g). This Guidance focuses on these key wildfire-related questions in Sections IX(g) and XX of the checklist, but in conducting environmental review, lead agencies must continue to thoroughly address the other questions identified in Section XX and the checklist more generally.

[33] CEQA Guidelines, § 15360 [defining the environment to be considered as "the area in which significant effects would occur either directly or indirectly as a result of the project"].

[34] Alexandra D. Syphard, *The Relative Influence of Climate and Housing Development on Current and Projected Future Fire Patterns and Structure Loss Across Three California Landscapes* (2019) GLOBAL ENVIRONMENTAL CHANGE; Alexandra D. Syphard, et al., *Housing Arrangement and Location Determine the Likelihood of Housing Loss Due to Wildfire* (Mar. 28, 2012) PLOS ONE, available at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0033954.

(as compared to high-density developments) to disrupt fire spread by removing or substantially fragmenting wildland vegetation.[35] "Isolated clusters of development and low housing density mean that homes are embedded within, and more exposed to, a matrix of wildland vegetation."[36] Moreover, fire-fighters may have difficulty accessing more remote and disconnected developments.[37]

- Project Location in the Landscape: Project placement in the landscape relative to fire history, topography and wind patterns also influences wildfire risk. Although wildfire ignitions are primarily human-caused in California, wildfire behavior is largely driven by topography, fuel, climatic conditions, and fire weather (such as low humidity and high winds). How a development project is planned within the landscape determines to what extent it will influence fire risk.[38] For example, if a project site is located in a wind corridor, above-ground power lines may become a source of ignition. Similarly, siting residential structures in rugged terrain or on the top of steep hills may increase the wildfire risk. By contrast, if a project site includes landscape features that could prevent or slow the spread of fire, such as a lake or an irrigated golf course, the development may be strategically located so as to capitalize on that feature as a natural fuel break.[39]

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[35] See generally Alexandra D. Syphard, et. al., *Multiple-Scale Relationships between Vegetation, the Wildland-Urban Interface, and Structure Loss to Wildfire in California* (Mar. 12, 2021) MDPI FIRE 2021.
[36] Max A. Moritz, et al., *Learning to Coexist with Wildfire* (2014) NATURE 515(7525), at p. 64; see also Alexandra D. Syphard, et. Al., *Multiple-Scale Relationships between Vegetation, the Wildland-Urban Interface, and Structure Loss to Wildfire in California* (March 12, 2021) MDPI FIRE 2021.

[37] See Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at p. 31.

[38] See generally Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020) University of California Agriculture and Natural Resources, Publication 8680, available at https://escholarship.org/uc/item/6n12m6pn; Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at pp. 28-35, available at https://pubs.er.usgs.gov/publication/70215982.

[39] See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020) University of California Agriculture and Natural Resources, Publication 8680, at p. 10, available at https://escholarship.org/uc/item/6n12m6pn; see also Conservation Biology Institute, *Paradise Nature-Based Fire Resilience Project Final Report* (June 2020), available at https://d2k78bk4kdhbpr.cloudfront.net/media/reports/files/CBI_Paradise_Final_Report_for_Posting_Online.pdf [An examination of how siting and greenbelts may have protected homes during the Paradise fire]. Siting of a new fire-resistant development between wildlands and existing development may even serve as a protective barrier for the existing development. But there can still be some risk of ember spread if the new development succumbs to fire. See Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at pp. 28-35, available at https://pubs.er.usgs.gov/publication/70215982; California Council on Science and Technology, The Costs of Wildfire in California (Oct. 2020), at p. 67, available at https://ccst.us/reports/the-costs-of-wildfire-in-california/.

- Water Supply and Infrastructure: As part of evaluating a project's wildfire risk impacts, an EIR should analyze the adequacy of water supplies and infrastructure to address fire-fighting within the project site.[40] This analysis should consider the potential loss of water pressure during a fire, which may decrease available water supply[41] and the potential loss of power, which may eliminate the supply.[42]

To understand how a project may exacerbate the risk of wildfire, an EIR should qualitatively assess these variables and also use fire modeling and other spatial and statistical analyses to quantify the risks to the extent feasible. Experts should utilize fire models to account for various siting and design elements, as well as a variety of different fire scenarios. The modeling should include scenarios for fires that start in, near, and far from the project site, as well as extreme weather conditions that exacerbate fire spread.

Lead agencies are encouraged to develop thresholds of significance that either identify an increase in wildfire risk as a significant impact or determine, based on substantial evidence, that some increase in the risk of wildfires is not considered a significant impact. Relevant factors should include the project's impact on ignition risk, the likelihood of fire spread, and the extent of exposure for existing and new residents based on various fire scenarios. Modeling the various scenarios enables local agencies to quantify increased wildfire risks resulting from a project adding more people to wildfire prone areas and to assess the risks according to the threshold of significance.

Some EIRs have concluded that the conversion of some wildland vegetation into paved development reduces or does not increase wildfire risk. This conclusion is contrary to existing evidence and the well-accepted understanding that the fundamental driver of increased wildfire risk is the introduction of people into a flammable landscape.[43] Accordingly, the conversion of vegetation into developed land does not obviate the need for lead agencies to carefully consider and model how the addition of development into wildfire prone areas contributes to the risk of wildfire.

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[40] See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020) University of California Agriculture and Natural Resources, Publication 8680, at p. 19 and Appendix B, available at https://escholarship.org/uc/item/6n12m6pn.

[41] See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020), at p. 19, University of California Agriculture and Natural Resources, Publication 8680, available at https://escholarship.org/uc/item/6n12m6pn.

[42] See Alexandra D. Syphard, *Nexus Between Wildfire, Climate Change and Population Growth in California* (2020) FREMONTIA, *47*(2), at p. 26.

[43] See Heather Anu Kramer, et al., *High Wildfire Damage in Interface Communities in California* (2019) INTERNATIONAL JOURNAL OF WILDLAND FIRE, available at https://www.fs.usda.gov/nrs/pubs/jrnl/2019/nrs_2019_kramer_001.pdf; see also Exhibit A to the Final Statement of Reasons for Regulatory Action re Amendments to the State CEQA Guidelines, OAL Notice File No. Z-2018-0116-12, at p. 212, available at https://resources.ca.gov/CNRALegacyFiles/ceqa/docs/2018_CEQA_ExA_FSOR.pdf.

C. Analyzing the p**roject's** impact on evacuation and emergency access

The addition of new development into high wildfire risk or adjacent areas may impact the evacuation of project residents, as well as the existing population (e.g., residents, workers, students, visitors, and possibly livestock) in the area and the ability of emergency responders to simultaneously access the area to fight wildfire. This can, in turn, impact the risk and extent of large-scale fire spread and community safety within and around the new development. The EIR should evaluate these impacts both during construction and over the life of the project. The required analysis is relative to a project's impacts and risks; e.g., a higher density infill project within an already developed area would likely not require the same level of analysis as a new low-density development within the wildland-urban interface and surrounded largely by open space.[44]

For projects located in high wildfire risk areas that present an increased risk of ignition and/or evacuation impacts, evacuation modeling and planning should be considered and developed at the time of project review and approval—when there is greater flexibility to modify a project's design, density, siting, and configuration to address wildfire considerations—rather than deferred to a later stage of the development process. Lead agencies will be best-positioned to ensure proposed development projects facilitate emergency access and ease constraints on evacuation with this information in hand prior to project approval. The ultimate objective is to allow for informed decision-making that minimizes the environmental and public safety hazards associated with new developments that increase the risk of ignition and impede evacuation in high wildfire prone areas.

Evacuation modeling and analysis should include the following:

- Evaluation of the capacity of roadways to accommodate project and community evacuation and simultaneous emergency access.
- Assessment of the timing for evacuation.
- Identification of alternative plans for evacuation depending upon the location and dynamics of the emergency.
- Evaluation of the project's impacts on existing evacuation plans.
- Consideration of the adequacy of emergency access, including the project's proximity to existing fire services and the capacity of existing services.
- Traffic modeling to quantify travel times under various likely scenarios.

[44] See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020), University of California Agriculture and Natural Resources, Publication 8680, at p. 5, available at https://escholarship.org/uc/item/6n12m6pn [describing the benefits of infill development].

In considering these evacuation and emergency access impacts, lead agencies may use existing resources and analyses, but such resources and analyses should be augmented when necessary. For example, agencies should:

- Utilize information from the EIR's analysis of traffic/transportation impacts, but they should not limit themselves to that information, which may not reflect the impact of emergency conditions on travel times.
- Consult with local fire officials and ensure that assumptions and conclusions regarding evacuation risk are substantiated with sound facts. Emergency conditions may not allow for ideal evacuation scenarios—staggered, staged, or targeted evacuation in response to a wildfire may sometimes be possible, but human behavior is difficult to predict and wildfires can be erratic, unpredictable, and fast-moving.[45]
- Consider impacts to existing evacuation plans, but recognize that, depending on the scope of an existing evacuation plan, additional analyses or project-specific plans may be needed. Community evacuation plans often identify roles and responsibilities for emergency personnel and evacuation routes, but do not necessarily consider the capacity of roadways, assess the timing for community evacuation, or identify alternative plans for evacuation depending upon the location and dynamics of the emergency.
- Avoid overreliance on community evacuation plans identifying shelter-in-place locations. Sheltering in place, particularly when considered at the community planning stage,[46] can serve as a valuable contingency, but it should not be relied upon in lieu of analyzing and mitigating a project's evacuation impacts.[47]

Local jurisdictions are encouraged to develop thresholds of significance for evacuation times. These thresholds should reflect any existing planning objectives for evacuation, as well as

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[45] See FEMA and U.S. Fire Administration, *Wildland Urban Interface: A Look at Issues and Resolutions* (June 2022), available at https://www.usfa.fema.gov/downloads/pdf/publications/wui-issues-resolutions-report.pdf.

[46] FEMA, *Planning Considerations: Evacuation and Shelter-in-Place* (July 2019), available at https://www.fema.gov/sites/default/files/2020-07/planning -considerations-evacuation-and-shelter-in-place.pdf. The distinction between temporary shelter-in-place locations and buildings designed or retrofitted for longer term shelter-in-place should also be considered. See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020) University of California Agriculture and Natural Resources, Publication 8680, at p. 17, available at https://escholarship.org/uc/item/6n12m6pn [discussing the difference between "safety zones"—areas with little flammable vegetations, such as golf courses—versus buildings that are designed to provide protection from heat and embers while the front of a fire passes, typically for a duration of at least 30-60 minutes].

[47] See Mejia, *Pepperdine University Defends 'Shelter in Place' Decision During Woolsey Fire*, Los Angeles Times (Nov. 13, 2018), available at https://www.latimes.com/local/lanow/la-me-ln-pepperdine-shelter-20181113-story.html; Chandler, *Am I Going to Stay in the Parking Lot . . . While the Fires Burn Around Me?*, Record Searchlight (Dec. 12, 2019), available at https://www.redding.com/in-depth/news/2019/04/25/california-wildfire-shelter-place-plans-questioned-evacuation-preparation/3427075002/.

informed expert analysis of safe and reasonable evacuation times given the existing and proposed development. Local jurisdictions should consider whether any increase in evacuation times for the local community would be a significant impact. A conclusion that an increase in evacuation times is a less than significant impact should be based on a threshold of significance that reflects community-wide goals and standards.

In establishing thresholds, local jurisdictions should consider referring to successful evacuations from prior emergencies within their community or similarly situated communities. The thresholds should include, but not be limited to, whether the project creates an inconsistency with: (1) an adopted emergency operations or evacuation plan; (2) a safety element that has been updated per the requirements in Government Code sections 65302(g)(5) and 65302.15 to integrate wildfire and evacuation concerns; or (3) recommendations developed by the California Board of Forestry and Fire Protection regarding the safety of subdivisions pursuant to Public Resources Code section 4290.5.

D. Mitigating wildfire risk, evacuation, and emergency access impacts

If a project presents significant increased wildfire risks and/or evacuation and access impacts, CEQA requires the lead agency to consider and adopt feasible alternatives and mitigation measures to avoid or reduce the project's impacts (or make a finding of overriding consideration).[48] Not all project design features or mitigation measures will achieve the same reduction in impacts for every project—the effects and effectiveness of measures will vary geographically and by project. An EIR that baldly concludes that certain project design features or mitigation measures will reduce or eliminate all potential wildfire risks, without first describing those risks, fails to fully analyze the project's impacts. Compressing the analysis of impacts and mitigation deprives decision makers of a full description of the project's adverse impacts and, therefore, fails to equip the decision makers with the necessary information to properly address the impacts by adopting project design features, mitigation measures, or alternatives. To avoid this error and provide for better project design, the project EIR should first analyze the increased wildfire risks and evacuation impacts, and then consider feasible mitigation and alternatives to avoid or reduce those impacts.

Set forth below are some examples of potential mitigation measures and design alternatives that may reduce wildfire risk impacts. This list is not exclusive and a lead agency's adoption of some or all of these mitigation measures for a particular project may not be sufficient to comply with CEQA's requirement to adopt all feasible mitigation measures.

- Increasing housing density and consolidated design, relying on higher density infill developments as much as possible.
- Avoidance and minimization of low-density exurban development patterns or leapfrog-type developments (i.e., those with undeveloped wildland between developed areas).

[48] Pub. Resources Code, § 21081.

- Decreasing the extent and amount of "edge," or interface area, where development is adjacent to undeveloped wildlands.
- Creation of buffer zones and defensible space within and adjacent to the development, with particular attention to ensuring that vegetation will not touch structures or overhang roofs.[49] It is also important that legal obligations are structured so that defensible space measures are retained over time.[50]
- Siting projects to maximize the role of low-flammability landscape features that may buffer the development from fire spread.
- Undergrounding power lines.
- Limiting development along steep slopes and amidst rugged terrain, so as to decrease exposure to rapid fire spread and increase accessibility for fire-fighting.
- Placement of development close to existing or planned ingress/egress and designated evacuation routes to efficiently evacuate the project population and the existing community population, consistent with evacuation plans, while simultaneously allowing emergency access.
- Placement of projects close to adequate emergency services.
- Construction of additional points of ingress and egress and modification of evacuation routes to minimize or avoid increasing evacuation times or emergency access response times.
- Fire hardening structures and homes—upgrading the building materials and installation techniques to increase the structure's resistance to heat, flames, and embers—beyond what is required in applicable building codes, both for new structures and existing structures in proximity to the new development.
- Requiring fire-hardened communication to the project site including high-speed internet service.
- Enhanced communication to the project population about emergency evacuation plans and evacuation zones.
- Parking limitations to ensure access roads are not clogged with parked vehicles.
- On-site water supply/storage to augment ordinary supplies that may be lost during a wildfire.

In all situations, mitigation measures should be combined and tailored to the specifics of the project, the surrounding landscape, and nearby existing uses. In some contexts, the mitigation measure itself may have an adverse impact that should be evaluated in an EIR. In addition,

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[49] Note, however, that defensible space around homes does not alone tend to account for structural survival. See Alexandra D. Syphard, *Why Are so Many Structures Burning in California?* (2020) FREMONTIA, *47*(2), at p. 32, available at https://pubs.er.usgs.gov/publication/70215982; Alexandra D. Syphard et al., *The Role of Defensible Space for Residential Structure Protection During Wildfires* (Oct. 14, 2014) INTERNATIONAL JOURNAL OF WILDLAND FIRE, available at http://dx.doi.org/10.1071/WF13158.

[50] See Max Moritz, et al., *Building to Coexist with Fire: Community Risk Reduction Measures for New Development in California* (Apr. 2020), at p. 12, University of California Agriculture and Natural Resources, Publication 8680, available at https://escholarship.org/uc/item/6n12m6pn.

mitigation measures may not provide the same level of protection or mitigation in all scenarios.[51] For example, home hardening has been shown to be an extremely effective measure for preventing structure loss during a wildfire. The California Building Code was updated in 2008 to require more advanced fire hardening and homes built to the revised standards were shown to be 40 percent less likely to be destroyed by a wildfire than similarly situated homes built prior to the update.[52] However, home hardening by itself may not be an adequate mitigation measure in all situations. During the Camp Fire, which swept through Paradise in 2018, homes built before and after the 2008 Building Code update were destroyed at roughly equal rates.[53] Home hardening in conformance with the 2008 Building Code alone did not meaningfully effect survivability; rather, proximity to other destroyed structures, the extent of vegetative overstory, and defensive space around homes was more relevant to whether or not a home survived.[54] While home hardening may be a worthy measure, this highlights the importance of combining measures, with an awareness to overall landscape conditions, to maximize public safety and minimize wildfire-related losses. It also demonstrates that defensive measures can improve but do not guarantee survivability, which highlights the continued importance of planning for evacuation and emergency access.

VII. Conclusion

As climate change and housing pressure continue to impact the State's landscape, wildfire risks, and development needs, local agencies need to thoroughly evaluate where and how new development is planned and constructed. With careful forethought during the various planning processes and thoughtful environmental review at the individual project development stage, new development can be designed and positioned to minimize future wildfire risks, enhance fire resiliency of our communities, and protect the health and safety of California's residents and natural resources. While the applicable rules, requirements, and analytical tools to reduce wildfire risk are evolving, this guidance is intended to provide suggestions for how best to comply with CEQA when analyzing and mitigating the wildfire risks of development projects in the wildland-urban interface and other fire prone areas.

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[51] See Alexandra D. Syphard, et. al., *Multiple-Scale Relationships between Vegetation, the Wildland-Urban Interface, and Structure Loss to Wildfire in California* (Mar. 12, 2021), at p. 13, MDPI FIRE 2021 [noting that "the most effective fire risk reduction approach will account for multiple factors at multiple scales and will incorporate simultaneous strategies"].

[52] Patrick W Baylis, et al., *Mandated vs. Voluntary Adaptation to Natural Disasters: the Case of U.S. Wildfires* (Dec. 2021), National Bureau of Economic Research, available at https://www.nber.org/papers/w29621.

[53] Eric E. Knapp, et al., *Housing Arrangement and Vegetation Factors Associated with Single-Family Home Survival in the 2018 Camp Fire, California* (2021) FIRE ECOLOGY 17:25, available at https://fireecology.springeropen.com/track/pdf/10.1186/s42408-021-00117-0.pdf [37 percent of homes built between 1997 and 2008 survived, while 44 percent of homes built between 2008 and 2018 survived].

[54] Eric E. Knapp, et al., *Housing Arrangement and Vegetation Factors Associated with Single-Family Home Survival in the 2018 Camp Fire, California* (2021) FIRE ECOLOGY 17:25, available at https://fireecology.springeropen.com/track/pdf/10.1186/s42408-021-00117-0.pdf.

CALIFORNIA FISH AND GAME COMMISSION
NOTICE OF FINDINGS

Mountain Lion
(*Puma concolor*)

NOTICE IS HEREBY GIVEN that, pursuant to the provisions of Section 2074.2 of the Fish and Game Code, the California Fish and Game Commission (Commission), at its April 15-16, 2020 teleconference meeting, accepted for consideration the petition submitted to list an evolutionarily significant unit (ESU) of mountain lions (*Puma concolor)* in southern and central coastal California as threatened or endangered under the California Endangered Species Act.

Pursuant to subdivision (e)(2) of Section 2074.2 of the Fish and Game Code, the Commission determined that the amount of information contained in the petition, when considered in light of the California Department of Fish and Wildlife's (Department) written evaluation report, the comments received, and the remainder of the administrative record, would lead a reasonable person to conclude there is a substantial possibility the requested listing could occur.

Based on that finding and the acceptance of the petition, the Commission is also providing notice that the Southern California/Central Coast ESU of mountain lions is a candidate species as defined by Section 2068 of the Fish and Game Code.

Within one year of the date of publication of this notice of findings, the Department shall submit a written report, pursuant to Section 2074.6 of the Fish and Game Code, indicating whether the petitioned action is warranted. Copies of the petition, as well as minutes of the April 15-16, 2020 Commission meeting, are on file and available for public review from Melissa Miller-Henson, Executive Director, California Fish and Game Commission, 1416 Ninth Street, Suite 1320, Sacramento, California 95814, phone (916) 653-4899.

Written comments or data related to the petitioned action should be directed to the Department contact via email (Esther.Burkett@wildlife.ca.gov); include “Mountain Lion ESU” in the subject line. Comments may also be submitted by mail, addressed to: California Department of Fish and Wildlife, Wildlife Branch, Attn: Esther Burkett/Mountain Lion ESU, P.O. Box 944209, Sacramento, CA 94244-2090. Submission of information via email is preferred.

April 21, 2020

Fish and Game Commission

Melissa Miller-Henson
Executive Director

BEFORE THE CALIFORNIA FISH AND GAME COMMISSION

A Petition to List the Southern California/Central Coast Evolutionarily Significant Unit (ESU) of Mountain Lions as Threatened under the California Endangered Species Act (CESA)

A Mountain Lion in the Verdugo Mountains with Glendale and Los Angeles in the background.
Photo: NPS

Center for Biological Diversity and the Mountain Lion Foundation
June 25, 2019

Notice of Petition

For action pursuant to Section 670.1, Title 14, California Code of Regulations (CCR) and Division 3, Chapter 1.5, Article 2 of the California Fish and Game Code (Sections 2070 *et seq*.) relating to listing and delisting endangered and threatened species of plants and animals.

I. SPECIES BEING PETITIONED:

Species Name: Mountain Lion (*Puma concolor*). Southern California/Central Coast Evolutionarily Significant Unit (ESU)

II. RECOMMENDED ACTION: Listing as Threatened or Endangered

The Center for Biological Diversity and the Mountain Lion Foundation submit this petition to list mountain lions (*Puma concolor*) in Southern and Central California as Threatened or Endangered pursuant to the California Endangered Species Act (California Fish and Game Code §§ 2050 et seq., "CESA"). This petition demonstrates that Southern and Central California mountain lions are eligible for and warrant listing under CESA based on the factors specified in the statute and implementing regulations. Specifically, petitioners request listing as Threatened an Evolutionarily Significant Unit (ESU) comprised of the following recognized mountain lion subpopulations:

1. Santa Ana Mountains
2. Eastern Peninsular Range
3. San Gabriel/San Bernardino Mountains
4. Central Coast South (Santa Monica Mountains)
5. Central Coast North (Santa Cruz Mountains)
6. Central Coast Central

Alternatively, as detailed in the petition, in the event the Commission determines that these six populations collectively either do not comprise a single Southern California/Central Coast ESU or otherwise do not meet the criteria for listing as Threatened, petitioners request the Commission consider whether any of these populations, singularly or in combination, comprise one or more ESUs and meet the criteria for listing as Threatened or Endangered pursuant to CESA.

III. AUTHORS OF PETITION:

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I hereby certify that, to the best of my knowledge, all statements made in this petition are true and complete.

Signature: _____ Date: ____6/25/19_____

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Executive Summary

The Center for Biological Diversity and the Mountain Lion Foundation submit this petition to list mountain lions (*Puma concolor;* cougar, puma) in Southern and Central Coastal California as "threatened" or "endangered" pursuant to the California Endangered Species Act (CESA) (California Fish and Game Code §§ 2050 et seq.). Following Section 670.1, Title 14, California Code of Regulations, petitioners present scientific information regarding life history, population trend, range, distribution, abundance, kind of habitat necessary for survival, factors affecting the ability to survive and reproduce, degree and immediacy of threat, impact of existing management efforts, suggestions for future management, availability of sources and information, and a detailed distribution map.

Specifically, petitioners request listing as a "threatened species" an evolutionarily significant unit (ESU) comprised of the following recognized mountain lion subpopulations:

1. Santa Ana Mountains
2. Eastern Peninsular Range
3. San Gabriel/San Bernardino Mountains
4. Central Coast South (Santa Monica Mountains)
5. Central Coast North (Santa Cruz Mountains)
6. Central Coast Central

As demonstrated in this petition, mountain lions in these areas comprise an ESU (referred to as the "Southern California/Central Coast ESU") and meet the statutory definition of a "threatened species."

The California Fish and Game Commission has long recognized that ESUs can be designated and listed under CESA, and this interpretation of CESA has been upheld by the courts. *See California Forestry Assn. v. California Fish & Game Com.* (2007) 156 Cal.App.4th 1535, 1540 ("Consistent with the policy of the CESA, we will hold that the term 'species or subspecies' includes evolutionarily significant units"); *Central Coast Forest Assn. v. Fish & Game Com.* (2018) 18 Cal.App.5th 1191, 1197, fn. 4 [*"CCFA II*"] ("An ESU is included within the term 'species or subspecies' in sections 2062 and 2067."). While the ESU concept has primarily been applied to fish, the Commission recently listed an ESU of a mammal, the Pacific Fisher, as a "threatened species." *See* 14 C.C.R. 670.5(b)(6)(J) ("Fisher (*Pekania pennant*) Southern Sierra Nevada Evolutionarily Significant Unit").

Under CESA, a "threatened species" is "a native species or subspecies of a … mammal… that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts . . . ." Cal. Fish & Game Code § 2067. An animal is an "endangered species" when it is "in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease." Cal. Fish & Game § 2062.

Certain populations of the Southern California/Central Coast mountain lion ESU are already "in serious danger of becoming extinct" (*e.g*. Santa Ana and Santa Monica mountains), and if assessed separately, would individually meet the definition of an "endangered species." When considered as a whole, the Southern California/Central Coast ESU is not at imminent risk of extinction but still faces significant and growing threats that ultimately threaten the viability of the entire ESU; it consequently meets the definition of a "threatened species."

Currently, there is no reliable estimate of mountain lion abundance in California. In 1984 the California Department of Fish and Wildlife (CDFW) estimated between 4,000-6,000 adult mountain lions in the state (Mansfield and Weaver 1984). However, CDFW acknowledges that this estimate is outdated and likely overestimates mountain lion abundance. CDFW is currently undertaking a large-scale research effort to estimate mountain lion numbers throughout California.

While reliable absolute abundance estimates are unavailable, recent genetic research has led to estimates of effective population size for California mountain lion populations.[1] These estimates highlight the genetic isolation among California mountain lion populations and raise significant concerns for the continued viability of mountain lions in Southern California and along the Central Coast.

Researchers have recently identified 10 genetically distinct mountain lion populations in California (Figure ES-1) (derived from Gustafson et al. 2018). Nine of these populations occur almost exclusively in California, while one is centered in Nevada but extends into the northeastern corner of California.

The abundance of mountain lions in the North Coast and inland populations (Western Sierra Nevada, Eastern Sierra Nevada, and the genetic cluster centered in the state of Nevada) is not well established; however, these populations are better connected than Southern California and Central Coast mountain lions, and they show relatively high levels of genetic diversity. Gustafson et al. (2018) suggest that these four populations may comprise an ESU. While these populations should be monitored and managed to ensure their continued viability, petitioners do not seek protection of these populations as an ESU under CESA at this time.

Considering the genetic source-sink dynamics among the remaining six populations, petitioners demonstrate that the populations along the Central Coast and in Southern California collectively comprise an ESU that warrants protection under CESA.[2] The Southern California/Central Coast ESU is comprised of six genetically distinct mountain lion populations: Central Coast North (CC-N, which includes mountain lions in the Santa Cruz Mountains and East Bay), Central Coast

[1] At its simplest, effective population size is the number of animals contributing offspring to the next generation. It is an important measure of the genetic health of a population.

[2] As explained *infra* at Section 3.0, these remaining populations can be grouped into one or several potential ESUs. Petitioners believe that for purposes of listing under CESA, treating them as a single ESU is supported by the best available science. Moreover, a single ESU also is the most pragmatic from a management perspective, as recovery of the individual populations ultimately depends upon maintaining and/or reestablishing connectivity between them. *See CCFA II,* 18 Cal.App.5th 1191, 1237 ("[T]he nature of the ESU designation is such that genetics alone are not determinative: One must look beyond genetics to questions of policy to determine which populations to include in an ESU.")(quotations omitted).

Central (CC-C), Central Coast South (CC-S, which includes the mountain lions in the Santa Monica Mountains), San Gabriel/San Bernardino Mountains (SGSB), Santa Ana Mountains (SAM), and Eastern Peninsular Range (EPR) (Gustafson et al. 2018).

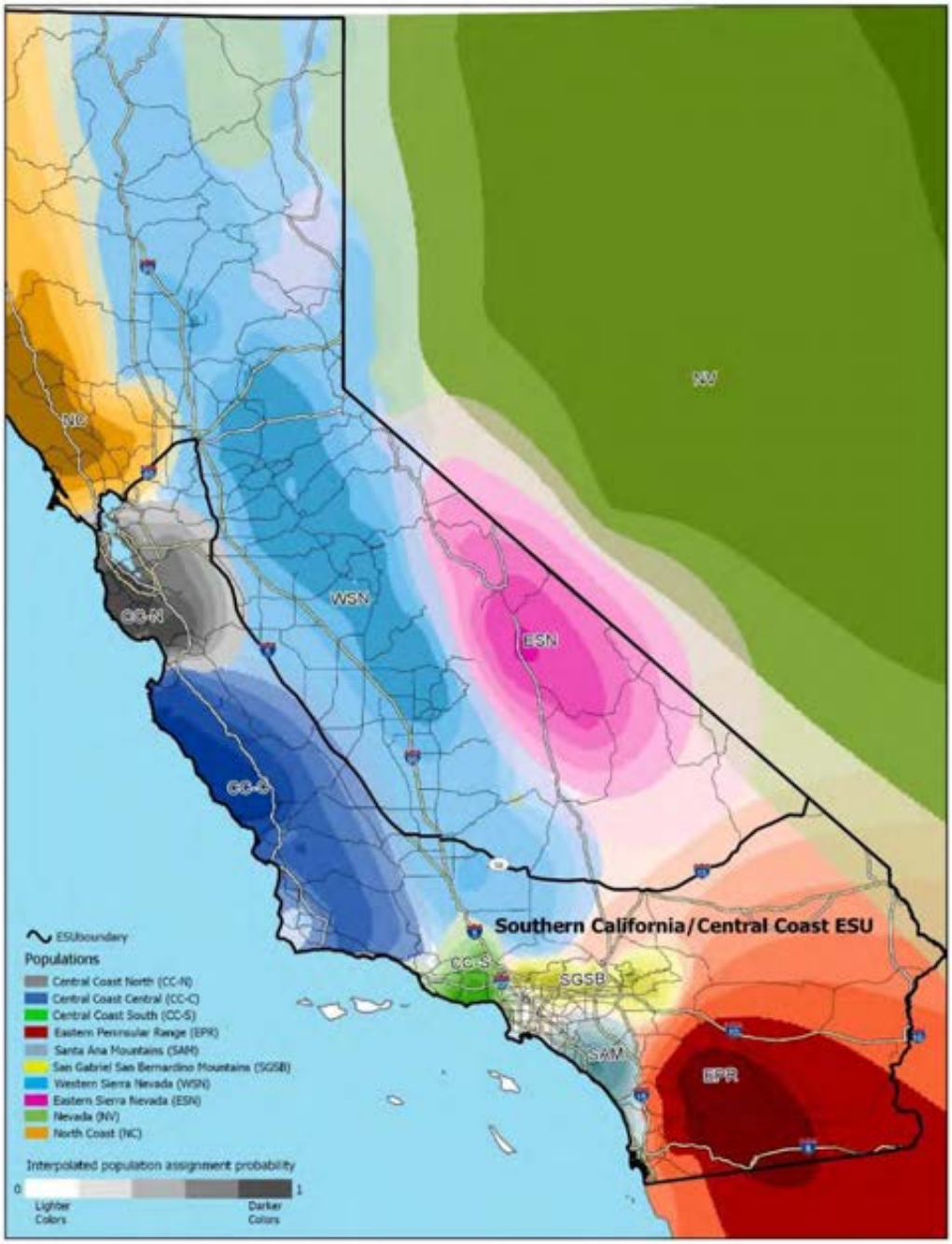

Figure ES-1. Map of genetically distinct mountain lion populations and major roadways in California based on data collected from 1992-2016 (the division and status of these populations could change over time and with further research). The black lines show the proposed Southern California/Central Coast ESU boundary. Derived from Gustafson et al. (2018). Genetics data source: Kyle Gustafson, PhD, Department of Biology and Environmental Health, Missouri Southern State University, and Holly Ernest, DVM, PhD, Department of Veterinary Sciences, Program in Ecology, University of Wyoming, Laramie. Roads data source: ESRI.

The boundary of the Southern California/Central Coast ESU is proposed in Figure ES-1, and includes mountain lions that occur south of the San Francisco Bay and I-80, west of I-5 to the intersection of I-5 and SR-58, south of SR-58 to I-15, south of the I-15 from the SR-58 intersection to the California-Nevada border, and, for the purposes of CESA, as far south as the California-Mexico border. These boundaries are recommended as they include virtually all mountain lions associated with the six populations comprising the ESU and are also unambiguous and readily discernable for purposes of management. We recommend including mountain lions in the Tehachapi and Sierra Pelona Mountains south of SR-58 in this ESU. While most mountain lions sampled from this region share some genetic affinities with Western Sierra Nevada (WSN) animals, many also show genetic connections with CC-S, SAM, EPR and SGSB mountain lions. This area serves not just as a connecting link between mountain lion populations comprising the Southern California/Central Coast ESU, but also between this ESU and all other California mountain lions and is therefore essential for the overall genetic health of mountain lions in the state.

While Southern California and Central Coast mountain lions face a multitude of threats, the greatest challenges stem from habitat loss and fragmentation and the consequent impact on their genetic health. Most of the populations comprising the ESU have low genetic diversity and effective population sizes, which puts them at increased risk of extinction (Ernest et al. 2003; Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016; Gustafson et al. 2018; Benson et al. 2019). The populations most at risk are the SAM, CC-S, SGSB, and CC-N populations. Due to extreme isolation caused by roads and development, the SAM and CC-S, populations exhibit high levels of inbreeding, and, with the exception of the endangered Florida panther, have the lowest genetic diversity observed for the species globally (Ernest et al. 2014; Riley et al. 2014; Gustafson et al. 2018; Benson et al. 2019). The SGSB and CC-N similarly have low observed genetic diversity and effective population sizes, and they reside in areas of significant isolation and habitat fragmentation, which also puts them at increased risk (Gustafson et al. 2018). And although the CC-C and EPR populations have slightly higher levels of genetic diversity and effective population sizes, high rates of development, habitat loss and fragmentation, and human-caused mortalities in both areas could lead to a similar fate of isolation, genetic drift, low effective population size, and increased risk of extinction in the foreseeable future.

Although minimum viable effective population size has been found to vary depending on the species (Frankham 1995; Traill et al. 2010), general conservation management practice over the past few decades has followed a 50/500 rule, under which an effective population size of 50 is assumed sufficient to prevent inbreeding depression in the short term (over the duration of five generations) and an effective population size of 500 is sufficient to retain evolutionary potential in perpetuity (Traill et al. 2010; Frankham et al. 2014). It is clear that Central Coast and Southern California mountain lion populations are genetically compromised and face significant risk of extinction in both the short- and long-term. Five of the six populations have effective population sizes well below 50 (from lowest to highest: CC-S, SGSB, SAM, CC-N, EPR), and one population (CC-C) is just barely above that threshold at $N_e = 56.6$ (Table ES-1) (Gustafson et al. 2018).

Table ES-1. Effective population size from Gustafson et al. (2018) and estimated total adult population of Central Coast and Southern California Mountain Lion Populations.

Population	Effective Population Size (N_e)	Estimated Total (Adult) Population (N)[1]
Central Coast North (CC-N)	16.6	33-66
Central Coast Central (CC-C)	56.6	113-226
Central Coast South (CC-S)	2.7[2]	5-10
Santa Ana Mountains (SAM)	15.6[3]	31-62
San Gabriel/ San Bernardino Mountains (SGSB)	5	10-20
Eastern Peninsular Range (EPR)	31.6	63-126
Total		255-510

[1]Calculations are based on the estimated ratio of effective to total adult population size (N_e/N) of Florida panthers being 0.25 to 0.5 (Ballou et al. 1989). This ratio was used in the USFWS Florida Panther Recovery Plan (USFWS 2008). Petitioners recognize that these derived population estimates, while informative, are not definitive and will likely be superseded by new population estimates being developed by CDFW.
[2]Benson et al. (2019) calculated an N_e of 4 for the Santa Monica Mountains population within the CC-S. Applying the Ballou et al. (1989) factors would lead to an estimate of 8-16 mountain lions in this area, which is roughly consistent with current estimates of this well-monitored population.
[3]Several studies provide N_e calculation for the SAM population. Ernest et al. (2014) calculated an N_e of 5.1 and Benson et al. (2019) calculated an N_e of 6. Applying the Ballou et al. (1989) factors to the most recent calculation would lead to an estimate of 12-24 mountain lions in the SAM, which is roughly consistent with current estimates.

Although low effective population sizes standing alone are cause for conservation concern for Southern California and Central Coast mountain lion populations, there are other human-caused factors that further limit their long-term persistence. Habitat loss and fragmentation due to roads and development have led to extreme levels of isolation and high mortality rates. With low genetic diversity and high risk of inbreeding depression due to genetic isolation, vehicle strikes on roads, increased conflicts with humans that lead to depredation kills, high levels of intraspecific strife likely due to limited space and lack of connectivity, rodenticide and other environmental toxicant poisoning, and impacts of more frequent human-caused wildfires and climate change, the small isolated mountain lion populations of Southern California and the Central Coast will likely not persist without the restoration and enhancement of functional connectivity between populations and large blocks of heterogeneous habitats**.**

Loss of mountain lions in Southern California and the Central Coast would be devastating not just for the mountain lions themselves but also the many species that directly and indirectly rely on them. These top predators are important ecosystem engineers that facilitate healthy ecosystems and allow biodiversity to thrive (Ripple and Beschta 2006; Ripple and Beschta 2008;

Ripple et al. 2014; Ruth and Elbroch 2014; Barry et al. 2019; Elbroch and Quigley 2019). As keystone species mountain lions help support plant recruitment in riparian areas, stabilize stream banks, and sustain healthy habitats for a myriad of aquatic and terrestrial species, including plants, invertebrates, fish, amphibians, reptiles, birds, and mammals (Ripple and Beschta 2006; Ripple and Beschta 2008; Ripple et al. 2014). Their kills are also an important source of food for multiple terrestrial and avian scavengers (Ruth and Elbroch 2014; Barry et al. 2019; Elbroch and Quigley 2019).

Existing laws and regulations have proven to be inadequate to protect Southern California and Central Coast mountain lions. Although the California Wildlife Protection Act of 1990 (Proposition 117) prohibits hunting of mountain lions and has funded the acquisition of important habitat for preservation, the Act alone does not ensure that core habitats and connectivity are protected from development, highways, or other threats. Moreover, numerous mountain lions are killed each year pursuant to depredation authorizations issued under this regime, and there is no limit to the number of depredation permits a property owner can request or any limit to the number of depredation permits which can be issued for any population. And while CDFW has proactively issued a bulletin detailing a new depredation policy for mountain lions in the CC-S and SAM that requires property owners to first implement non-lethal measures prior to being issued a kill permit, this policy does not apply to other vulnerable populations.

Other environmental laws also are insufficient. State and local agencies continue to interpret the California Environmental Quality Act (CEQA) as allowing for the construction of highways and other development in mountain lion habitat and essential corridor areas without adequate mitigation despite severe impacts of such projects on mountain lions. Agencies likewise have generally interpreted CEQA and the federal National Environmental Policy Act as not requiring implementation of connectivity measures when projects fragment or destroy mountain lion habitat. And perhaps most importantly, Caltrans lacks a clear affirmative mandate to design, build, or improve crossings for mountain lions on existing highways, despite the undisputed role of transportation infrastructure in preventing connectivity and gene flow.

Future human population growth and associated development will further diminish and fragment remaining mountain lion habitat, driving Southern California and Central Coast mountain lions closer to extinction and undermining any chance of recovery. Should state and local agencies continue to build and expand roads and highways and permit construction in wildlife habitat and corridors without ensuring adequate habitat connectivity, the genetic health of mountain lion populations will continue to decline while the number of mountain lions killed by vehicle strikes and other human activity will increase.

Ultimately, without a reversal of these trends, mountain lions will disappear from Southern and Central Coastal California in the coming decades, representing a loss of the species from a significant portion of its range in the state. Nevertheless, most of the threats facing mountain lions can be halted or sufficiently reduced if CDFW is provided with adequate resources and all relevant state and local agencies sufficiently prioritize mountain lion conservation in their decision-making. Legal protection of mountain lions under CESA, along with the attention and resources that such listing will generate, can help ensure the long-term survival of this iconic and ecologically significant species in Southern and Central Coastal California.

The Southern California/Central Coast Evolutionarily Significant Unit (ESU) of Mountain Lions Warrants Listing as Threatened under the California Endangered Species Act (CESA)

1 Introduction

This petition summarizes available scientific information regarding the natural history of mountain lions, their distribution and abundance in California, population trends and threats, describes the proposed ESU, and discusses the limitations of existing management measures in protecting the species. As demonstrated below, mountain lions in Southern California and along the Central Coast meet the criteria for protection as a threatened species under the California Endangered Species Act (CESA), and would benefit greatly from such protection.

2 Life History

2.1 Species Description

Adult female mountain lion (left) and kittens (right). Photos: NPS.

The mountain lion (*Puma concolor*) is also commonly called a puma (from the Inca language Quechua) or cougar (corrupted from cuguacuarana from the indigenous Guarani people in Paraguay, Argentina, Bolivia, and Brazil). Adults are large, slender cats with short, muscular limbs and a long tail that is about one third of the animal's total length. Their hind limbs are longer than their fore limbs, which makes them highly adapted for jumping through rugged terrain or pouncing on their prey. They have tawny pelage that can be lighter/whitish on their belly and the undersides of their legs and they have areas of white around the muzzle, throat and chest. They have black fur on the backs of their rounded ears, the tip of their tail, and outlining their muzzle. Their eyes are a grayish brown to golden color, and the nose is pink with a black outline.

Adult body size and weight can vary depending on the geographic range (Iriarte et al. 1990). Mountain lions are smaller and weigh less near the equator and are larger and heavier towards the poles, which likely reflects the size of available prey and the presence of sympatric carnivores (Iriarte et al. 1990). Males are typically larger than females. Males generally weigh 55-65kg with a length of 2.2-2.3m from the nose to the tip of the tail, and females generally weigh 35-45kg with a length of 2.0-2.1m (Currier 1983).

Mountain lion kittens are born weighing approximately 400g, and their eyes and ear canals remain closed for one to two weeks after birth (Currier 1983). They have light coats with dark spots and a white muzzle, chest, and belly. Like the adults, they have black fur on the backs of their rounded ears, the tip of their tail, and outlining their muzzle. Their eyes are initially blue, change to mostly brown within four months, and then change to a golden color at around nine months (Currier 1983). The dark spots on their coat start to fade at 12-14 weeks of age, presumably when a kitten starts to accompany its mother on hunts, but the spots are still distinguishable until the animal is about one year old (Currier 1983). Adult weight is typically reached between the second and fourth year.

2.2 Taxonomy and Population Genetics

The mountain lion is in the order Carnivora and is a member of the cat family Felidae. Unlike the large, roaring cats of the subfamily Pantherinae (*e.g*., lions, tigers, and leopards), mountain lions are categorized with small, purring cats in the subfamily Felinae (*e.g*., bobcats, lynxes, ocelots, cheetahs, and jaguarundi). Their scientific name is *Puma concolor*, formerly called *Felis concolor*. Based on molecular and morphological features, it is thought that mountain lions share a common ancestor with cheetahs (*Acinonyx jubatus*) and jaguarundi (*Puma yaguaroundi*).

Mountain lion fossil records in North America date back 300,000 years (Pierce and Bleich 2003); however, they were likely extirpated during a massive extinction event at the end of the Pleistocene, which eliminated about 80% of large vertebrates in North America (Culver et al. 2000; Caragiulo et al. 2013). Genetic studies suggest that after this extinction event, a small number of Central and South American mountain lions migrated north and repopulated North America (Culver et al. 2000; Caragiulo et al. 2013). As a result, existing North American mountain lions exhibit founder effects and have less genetic diversity compared to mountain lions in Central and South America (Culver et al. 2000; Caragiulo et al. 2013).

There is some debate regarding the number of subspecies of mountain lions. Two subspecies are “tentatively” recognized by the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) Cat Specialist Group: *Puma concolor concolor* (Linnaeus, 1771) in South America and *Puma concolor couguar* (Kerr, 1792) in North and Central America and possibly northern South America west of the Andes Mountains (Kitchener et al. 2017). However, there are various studies that suggest the divergence of multiple subspecies of mountain lions. About 30 subspecies of mountain lions throughout the Americas have been referenced in the literature, with about 15 subspecies in North America (Young and Goldman 1946; Currier 1983; Pierce and Bleich 2003).

Based on more recent genetic analyses of mitochondrial DNA (mtDNA) from mountain lions throughout the Americas, Caragiulo et al. (2013) found that the mountain lions they sampled could be separated into three broad groupings: North America, Central America, and South America, with North American mountain lions having the least variation in mtDNA compared to populations in Central and South America. Although that study genotyped 601 specimens, the distribution of sampling within the broad geographic range was limited compared

to a study conducted by Culver et al. (2000), which analyzed mtDNA from 315 mountain lions sampled from more locations throughout the species' geographic distribution. Culver et al. (2000) found six phylogeographic groupings or subspecies throughout the Americas.

Despite this ongoing debate, the United States Fish and Wildlife Services (USFWS) has long recognized mountain lion subspecies under the federal Endangered Species Act (ESA). Two of these subspecies have been protected under the ESA due to low population sizes: the eastern cougar (*Puma concolor couguar*), which was listed as endangered and is now thought to be extinct, with the last recorded occurrence in 1938 (USFWS 2018), and the endangered Florida panther (*Puma concolor coryi*), which is an isolated population that is now restricted primarily to the cypress swamps of southern Florida. In addition, the California mountain lion (*Puma concolor californica*) was recognized by USFWS in response to a 1994 petition by the Mountain Lion Foundation to list the population of California mountain lions in the Santa Ana Mountains as endangered, as those populations that occur within most of California, southern Oregon, western Nevada, and northern Baja California, Mexico (USFWS 1994). Additionally, the California Department of Fish and Wildlife (CDFW) recognizes the Yuma Puma (*Puma concolor browni*) as a (sub)species of special concern that occurs in the desert plains and low mountains along the Colorado River in southeastern California, southwestern Arizona, northeastern Baja California, Mexico, and northwestern Sonora, Mexico (CDFW 1990).

In California, researchers have recently identified 10 genetically distinct mountain lion populations in California and Nevada, nine of which have core areas in California (Figure 1) (Gustafson et al. 2018). In the study, 992 mountain lions from throughout California and Nevada were genotyped using 42 microsatellite loci to identify regional populations and evaluate functional connectedness between the populations (Gustafson et al. 2018). The divergence of these populations is likely the result of habitat fragmentation caused by roads and development (Ernest et al. 2003; Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2017; Gustafson et al. 2018; Benson et al. 2019). According to Gustafson et al. (2018), mountain lions in the North Coast and inland populations (Nevada, Eastern Sierra Nevada, Western Sierra Nevada) appear to be better-connected than those in the south and along the central coast, with relatively larger effective population sizes and higher levels of genetic diversity. The authors suggest that these populations may comprise an evolutionarily significant unit (ESU). Considering the genetic source-sink dynamics among the remaining populations (Gustafson et al. 2018), petitioners demonstrate that the populations in Southern California and along the Central Coast collectively comprise an ESU (referred to as the "Southern California/Central Coast ESU"). See *Section 3.0 Southern California and Central Coast Mountain Lions Comprise and Evolutionarily Significant Unit* for more discussion.

The Southern California/Central Coast ESU is comprised of six genetically distinct mountain lion populations: Central Coast North (CC-N, which includes mountain lions in the Santa Cruz Mountains), Central Coast Central (CC-C), Central Coast South (CC-S, which includes mountain lions in the Santa Monica Mountains), San Gabriel/San Bernardino Mountains (SGSB), Santa Ana Mountains (SAM), and Eastern Peninsular Range (EPR) (Figure 1) (Gustafson et al. 2018). Most of these populations appear to be struggling with low genetic diversity and effective population sizes, which puts them at increased risk of extinction (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2018;

Benson et al. 2019). The populations struggling the most include the SAM, CC-S, SGSB, and CC-N populations. Although the CC-C and EPR have slightly higher levels of genetic diversity and effective population sizes, high rates of development in both areas could lead to a similar fate of isolation, genetic drift, low effective population size, and increased risk of extinction in the foreseeable future.

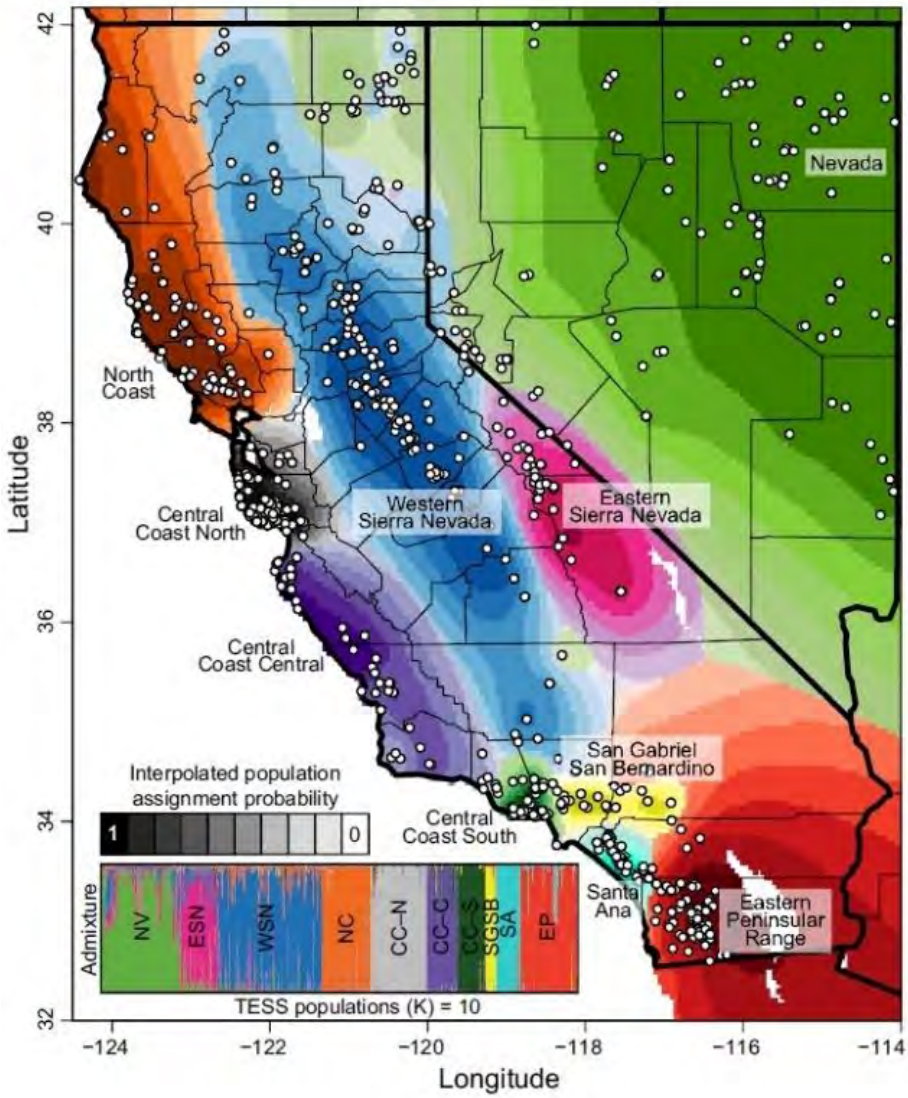

Figure 1. Map of genetically distinct mountain lion populations in California. The Central Coast North (CC-N), Central Coast Central (CC-C), Central Coast South (CC-S), San Gabriel/San Bernardino (SGSB), Santa Ana Mountains (SAM), and Eastern Peninsular Range (EPR) mountain lion populations should be considered an evolutionarily significant unit (ESU). Each color represents a genetically distinct mountain lion population. White dots are individual animals sampled. Source: Gustafson et al. (2018).

Although discrete populations have been identified in Southern California mountain ranges, other mountain lions have been regularly observed outside of the CC-S, SAM, SGSB, and EPR core areas, including transient and resident mountain lions in the Mojave and Colorado deserts and along the Lower Colorado River (*i.e.*, Yuma mountain lion [*Puma concolor browni*], a recognized subspecies of special concern). These populations presumably occur in low

densities due to limited resources, such as lower prey abundance/vulnerability or less suitable habitat. In fact, Kucera (1998) states that habitat within the Yuma mountain lion range is generally considered to be of low or no suitability for mountain lions. Relatively low density populations are inferred by the larger ranges of mountain lions in desert environments; four individual Yuma mountain lions had home ranges of 389km^2 to 1621km^2, which is much larger than other California mountain lion home ranges (Grigione et al. 2002; Riley et al. 2014; Zeller et al. 2017; see *Section 2.5 Habitat Requirements* for more details) but similar to those estimated for other desert mountain lions (Kucera 1998). This petition considers these low-density transients and resident lions as included within the Southern California/Central Coast ESU.

2.2.1 Effective Population Size and Extinction Risk

It has been established that genetic factors play a critical role in extinction risk. Inbreeding depression, loss of genetic diversity, and accumulation of deleterious mutations can lead to elevated extinction risk due to reduced reproductive fitness and evolutionary potential (*i.e.*, the ability to adapt to change) (Spielman et al. 2004; Frankham 2005; Traill et al. 2010). Effective population size (N_e) is a key metric used to assess a population's genetic viability and its chances of long-term persistence. Effective population size is an estimate of the size of an idealized population that would lose heterozygosity (*i.e.*, genetic diversity) at the same rate as the observed population; it indicates a population's rates of inbreeding and genetic drift (changes in allele frequencies over generations based purely on chance). A lower effective population size indicates a higher risk of inbreeding depression. Factors that affect effective population size include census population size (*i.e.*, the total number of individuals within a population), breeding sex ratio, variance in reproductive success, and population density. Several characteristics of these mountain lion populations, including small census population size, low density, female-biased sex ratios, and skewed male reproductive success, reduce effective population size, which suggests that these populations have an increased risk of inbreeding depression and extinction (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019).

The minimum effective population size for a population to persist has been debated (*e.g.*, Jamieson and Allendorf 2012; Frankham et al. 2014). Although minimum viable effective population size has been found to vary depending on the species (Frankham 1995), general conservation management practice over the past few decades has followed a 50/500 rule, which purports that an effective population size of 50 is sufficient to prevent inbreeding depression in the short term (over the duration of five generations) and an effective population size of 500 is sufficient to retain evolutionary potential in perpetuity (Frankham et al. 2014). In a 2012 review, Jamieson and Allendorf (2012) concluded that the 50/500 rule is a useful guiding principle in conservation management when genetic concerns are likely to affect the short- and long-term viability of populations. However, Frankham et al. (2014) later revised the 50/500 rule and recommended an effective population size of 100 to limit the loss of total fitness to <10% in the short-term and an effective population size of 1,000 to retain evolutionary potential for fitness in perpetuity, while recognizing that fragmented populations should be evaluated on a case-by-case basis.

Whether the 50/500 or 100/1,000 rule is considered, it is clear that Central Coast and Southern California mountain lion populations are genetically imperiled and face extinction in both the short- and long-term. Five of the six populations have effective population sizes well below 50 (from lowest to highest, according to Gustafson et al. 2018: CC-S, SGSB, SAM, CC-N, EPR), and the remaining population (CC-C) is just barely above that threshold at $N_e = 56.6$ (Table 1) (Ernest et al. 2014; Riley et al. 2014; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019). Although the ratio of effective to total adult population size (N_e/N) varies by species, the effective population size is often much lower than the total adult population size (Frankham 1995). Several studies indicate that the N_e/N in wild vertebrate populations ranges from 0.2 to 0.5 (Ballou et al. 1989; Mace and Lande 1991; Spong et al. 2000; Laundré and Clark 2003). Ballou et al. (1989) estimated the N_e/N to be 0.25-0.5 in their population viability assessment of the Florida Panther, which aligns with other studies on big cats (Frankham 1995; Spong et al. 2000). This range was used in the USFWS's Florida Panther Recovery Plan (USFWS 2008), and, if applied to the Central Coast and Southern California mountain lion populations, the total number of mountain lions in the areas combined would be 255 to 510 individuals (Table 1). This is well below the recommended minimum viable population size of at least 5,000 adult individuals for the long-term persistence of a population (Frankham 1995; Reed et al. 2003; Traill et al. 2010).

Table 1. Effective population size and estimated total adult population of Central Coast and Southern California Mountain Lion Populations from Gustafson et al. (2018).

Population	Effective Population Size (N_e)	Estimated Total (Adult) Population (N)[1]
Central Coast North (CC-N)	16.6	33-66
Central Coast Central (CC-C)	56.6	113-226
Central Coast South (CC-S)	2.7[2]	5-10
Santa Ana Mountains (SAM)	15.6[3]	31-62
San Gabriel/ San Bernardino Mountains (SGSB)	5	10-20
Eastern Peninsular Range (EPR)	31.6	63-126
Total		255-510

[1]Calculations are based on the estimated ratio of effective to total adult population size (N_e/N) of Florida panthers being 0.25 to 0.5 (Ballou et al. 1989). This ratio was used in the USFWS Florida Panther Recovery Plan (USFWS 2008). Petitioners recognize that these derived population estimates, while informative, are not definitive and will likely be superseded by new population estimates being developed by CDFW.

[2]Benson et al. (2019) calculate an N_e of 4 for the Santa Monica Mountains population within the CC-S. Applying the Ballou et al. (1989) factors would lead to an estimate of 8-16 mountain lions in this area, which is roughly consistent with current estimates of this well-monitored population.

[3]Several studies provide N_e calculation for the SAM population. Ernest et al. (2014) calculated an N_e of 5.1 and Benson et al. (2019) calculated an N_e of 6. Applying the Ballou et al. (1989) factors to the most recent calculation would lead to an estimate of 12-24 mountain lions in the SAM, which is roughly consistent with current estimates

Habitat loss and fragmentation due to roads and development have led to extreme levels of isolation in these populations, which have lowered their effective population sizes and, ultimately, their ability to survive and reproduce with a diverse gene pool (Ernest et al. 2014; Riley et al. 2014; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019). However, re-establishing gene flow among isolated subpopulations of a species can increase effective population size and reduce extinction risk (Frankham et al. 2014). Thus, the implementation of wildlife crossing infrastructure at existing barriers along with the preservation of intact, heterogeneous habitats would facilitate connectivity among Central Coast and Southern California mountain lion populations and significantly improve their chances of long-term survival.

2.2.2 Central Coast North (CC-N) Mountain Lion Population

In a statewide study, Gustafson et al. (2018) found that the CC-N population clustered genetically with the CC-C and CC-S populations. The population exhibited evidence of a previous genetic bottleneck and was found to have low genetic diversity and a low effective population size (N_e = 16.6). There is some evidence, though weak, that suggests the CC-N population is a source population, with limited gene flow with the other Central Coast populations and the Western and Eastern Sierra Nevada populations (Gustafson et al. 2018). CDFW has identified that the Santa Cruz Mountains population, which occurs within the CC-N area, is struggling due to fragmentation from roads and development as well as lack of protected habitat (Dellinger 2019). The low genetic diversity and effective population size threaten both the short- and long-term survival of the CC-N population.

2.2.3 Central Coast Central (CC-C) Mountain Lion Population

The CC-C mountain lion population has been found to exhibit a previous genetic bottleneck (Gustafson et al. 2018). It has intermediate levels of genetic diversity and the highest effective population size (N_e = 56.6) among the Central Coast and Southern California populations (Gustafson et al. 2018). Although this effective population size exceeds the older standard of 50 to prevent in-breeding depression in the short-term, it falls well below the recommended newer standard of 100 and is insufficient for the long-term persistence of the population. This population was found to be clustered genetically with the CC-N and CC-S populations and identified as a source population with limited gene flow with other Central Coast populations, the Western and Eastern Sierra Nevada populations, and the SGSB population (Gustafson et al. 2018). Although the CC-C population appears to be the healthiest population in the Central Coast and Southern California, the lack of sufficient protected lands and high rates of development and habitat fragmentation in the area threaten the persistence of this population (Dellinger 2019).

2.2.4 Central Coast South (CC-S) Mountain Lion Population

The CC-S mountain lion population has been found to exhibit a prior genetic bottleneck, with low genetic diversity and an extremely low effective population size (N_e = 2.7 to 4) (Riley et al. 2014; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019). This population was

found to be clustered genetically with the CC-N and CC-C populations and identified as a genetic sink population, with limited gene flow from mountain lions along the Central Coast and in the Sierra Nevada (Gustafson et al. 2018).

A recent population viability analysis focused on the Santa Monica Mountains population, a subpopulation within the CC-S that has been severely isolated due to roads and development, found that if the population remains isolated with little or no immigration (similar to what is currently being observed in the area), the population could experience high levels of genetic erosion, with 40-57% loss of predicted heterozygosity within 50 years (Benson et al. 2016a). When considering just demographic processes with little or no immigration and no inbreeding depression, the population was predicted to have a 15-22% chance of extinction within 50 years (Benson et al. 2016a; Benson et al. 2019). However, if inbreeding depression occurs, which is a strong possibility given the predicted substantial loss of genetic diversity and the documentation of father-daughter, grandfather-granddaughter, and grandmother-grandson inbreeding within the population (*e.g.*, Riley et al. 2014)[3], population growth will likely decline and chances of extinction within 50 years is predicted to be 99.7%, with a median time to extinction of 15.1 years (Benson et al. 2016a; Benson et al. 2019).

2.2.5 Santa Ana Mountains (SAM) Mountain Lion Population

The SAM mountain lion population has been found to have the lowest genetic diversity of all populations in California, with levels nearly as low as the endangered Florida panther (Ernest et al. 2014; Gustafson et al. 2017; Gustafson et al. 2018; Benson et al. 2019). This population is also estimated to have a low effective population size (N_e = 5.1 to 15.6) and high levels of relatedness and inbreeding (Ernest et al. 2014; Gustafson et al. 2018; Benson et al. 2019). The SAM population was found to be a genetic sink population, with limited gene flow with the EPR population (Gustafson et al. 2018). In a 16-year study (2001-2016) seven migrants (out of 146 sampled animals), were detected via genetics and GPS collar tracking to have crossed the I-15 between the EPR and SAM (three males from the EPR to SAM, four males from the SAM to the EPR); only one migrant is known to have reproduced (Gustafson et al. 2017). Low genetic diversity and effective population size in the SAM are indicative of a genetic bottleneck that is estimated to have occurred 40-80 years ago, around the time when urban development and multi-lane highway construction boomed in Southern California (Ernest et al. 2014; Gustafson et al. 2018). This population was also found to be largely disconnected from all the other California populations, along with the EPR population.

A recent population viability analysis found that if the population remains isolated with little or no immigration (similar to what is currently being observed in the area), the population could experience further genetic erosion, with 28-49% loss of predicted heterozygosity within 50 years (Benson et al. 2019). When considering just demographic processes with little or no immigration and no inbreeding depression, the population was predicted to have a 16-21% chance of extinction within 50 years. However, to avoid inbreeding depression in wild populations, loss in heterozygosity should be less than 5-10% over 100-200 years (Soule et al. 1986; Benson et al. 2016a), which suggests that inbreeding depression in the SAM population is

[3] Inbreeding has been documented in the SMM population in Riley et al. 2014 and in ongoing studies by the NPS. More information from the NPS is available here: https://www.nps.gov/samo/learn/nature/puma-profiles.htm

a strong possibility. In addition, evidence of potential inbreeding depression has been observed in the population (*e.g.*, kinked tails coupled with low genetic diversity, Figure 2, Ernest et al. 2014). When inbreeding depression was considered in the population viability analysis, population growth will likely decline and chances of extinction within 50 years is predicted to be 100%, with a median time to extinction of 11.7 years (Benson et al. 2019).

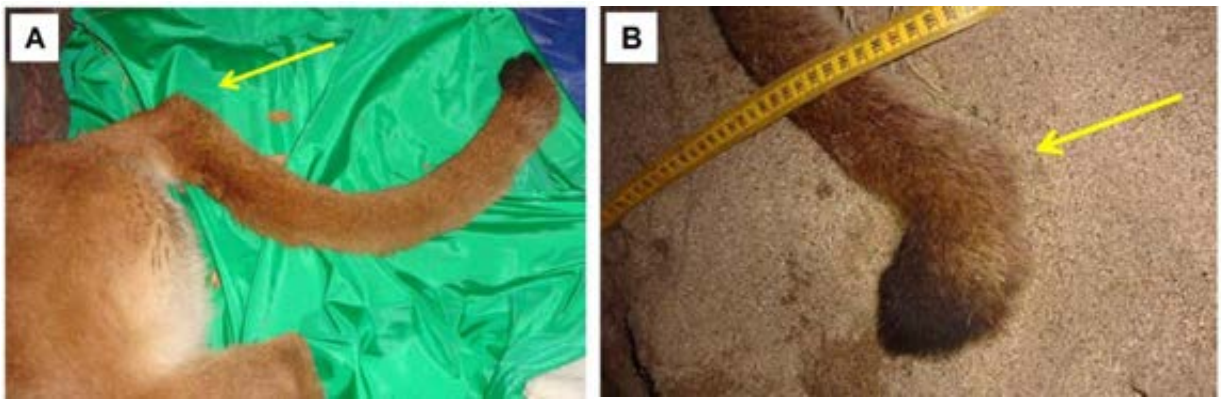

Figure 2. Two SAM mountain lions with a kink at the base of the tail (A) and near the tip of the tail (B). These individuals had among the lowest genetic diversity measured in the study. Source: Ernest et al. 2014.

2.2.6 San Gabriel/San Bernardino Mountains (SGSB) Mountain Lion Population

According to Gustafson et al. (2018), the SGSB mountain lion population exhibits extremely low genetic diversity and effective population size ($N_e = 5$), though the sample size from SGSB was low. They were also found to be a sink population, with limited gene flow with populations in the Western Sierra Nevada, CC-C, and the EPR (Gustafson et al. 2018). Although genetic studies on this population are limited, patterns of isolation, loss of genetic diversity, and low effective population size are similar to those of the SAM and CC-S populations and likely indicate a high risk of extinction. Not only is the population's long-term survival at stake, but the geographic location of the SGSB population is paramount. Despite only limited gene flow between the SGSB population and the Western Sierra Nevada, CC-C, and EPR, this population represents a critical linkage between mountain lion populations in the northern, central coast, and southern mountain ranges of California (Gustafson et al. 2018). Restoration and enhancement of connectivity is key for the continued survival of the SGSB population as well as the Central Coast and Southern California mountain lion populations.

2.2.7 Eastern Peninsular Range (EPR) Mountain Lion Population

Gustafson et al. (2018) found that the EPR population exhibits a prior genetic bottleneck. Although the population was found to have a higher effective population size than the other Southern California mountain lion populations ($N_e = 31.6$), this is still well below the older standard of 50 to prevent in-breeding depression in the short-term and is insufficient for the long-term persistence of the population. In addition, the EPR population was found to be largely disconnected from all the other California populations, with limited gene flow and low connectivity with the SAM and SGSB populations (Gustafson et al. 2018). With continued development in San Diego, Riverside, and Imperial Counties, the EPR population could have a

similar fate of isolation, genetic drift and inbreeding, and risk of extinction as the other Central Coast and Southern California populations.

As mentioned previously, there are records for mountain lions outside of the core mountain ranges in Southern California, which are likely transients or residents of smaller populations. For example, the Yuma mountain lion has been recognized by CDFW as a subspecies of special concern, and likely occurs in low density in the desert plains and low mountains of the Colorado River Valley. Genetic studies on the Yuma mountain lion are limited, and no samples were obtained from that area for the study conducted by Gustafson et al. (2018). However, the low densities of transients and smaller populations in areas where roads and development threaten connectivity make them part of the EPR and larger Southern California population, and as such, they are considered a conservation concern and are included in this petition.

2.3 Reproduction and Growth

Dens are often in rocky outcrops (left) or in dense vegetation (right). Photos: NPS.

Mountain lions are polygamous breeders, and mates likely locate each other with auditory and olfactory signals (Currier 1983). They may reproduce at any time of year, though seasonal pulses have been documented and the timing of reproduction may be affected by prey abundance or climate (Pierce and Bleich 2003). In North America, kitten births are most common between April and September (Currier 1983; Beier 1995; Pierce and Bleich 2003).

Pairs generally mate for about 2-5 days (Beier et al. 1995), though there are instances in which pairs have been recorded traveling together for up to 16 days (Seidensticker et al. 1973). During this time they vocalize frequently, travel little, will sometimes share a kill, and copulate up to 70 times per day (Seidensticker et al. 1973; Beier et al. 1995; Pierce and Bleich 2003). Female estrous cycles last an estimated 4-12 days, and it is hypothesized that numerous acts of copulation stimulate ovulation and improve chances of successful fertilization (Pierce and Bleich 2003, Kitchener 1991). If the litter is born dead or removed within 24 hours of birth, females will go into estrous within a few weeks (Currier 1983). In addition, competing males have been

known to commit infanticide[4], presumably to trigger estrous in females, though scientists are still investigating what drives this behavior.

Gestation lasts 82-96 days (Young and Goldman 1946; Currier 1983). Litter size ranges from 1-6, though 2-4 kittens per litter are typical (Pierce and Bleich 2003; Beier et al 2010; Riley et al. 2014). Females average larger litters during their first year of reproduction and tend towards smaller litters when they are older (Pierce and Bleich 2003). The sex ratio of litters has generally been found to be equal (Pierce and Bleich 2003). Females keep their kittens in dens located in rocky terrain or in dense vegetation that provide cover (Young and Goldman 1946), and they may move their young to several different dens until the young are weaned at about 2-3 months old (Pierce and Bleich 2003). Denning mountain lions have been found to avoid roads and stay at a distance from human disturbance four times greater (~600m) than non-reproductive mountain lions (~150m) (Wilmers et al. 2013).

Females care for their young for 1-2 years, at which point the mother comes into estrous and either abandons the cubs or acts aggressively towards them to prevent them from following her, as older males will kill cubs (Young and Goldman 1946; Seidensticker et al. 1973; Currier 1983; Beier 1995; Pierce and Bleich 2003). Newly independent young have been found to stay in the area where the mother leaves them for 2-3 weeks, and then disperse away from the direction their mother left (Beier 1995). Typically 50% of females stay in their natal range and 50% disperse while all males disperse, and siblings sometimes travel for a short time together (Pierce and Bleich 2003; Logan and Sweanor 2010). Subadult mountain lions may disperse up to 500km from their natal home ranges as they explore and establish their own territories (Pierce and Bleich 2003).

Mountain lions reach sexual maturity at 2-4 years of age. Although they are rarely known to mate until they have an established home range, transient males may occasionally breed with resident females (Hornocker 1970; Seidensticker et al. 1973; Currier 1983).

2.4 Diet and Foraging Ecology

Mountain lion cub feasting on a deer kill in the Santa Monica Mountains. Photo: NPS.

[4] Infanticide has been documented in the Santa Monica Mountains mountain lion population. More information from the NPS is available here: https://www.nps.gov/samo/learn/nature/puma-profiles.htm

Large ungulates, especially deer, are the preferred prey of mountain lions, making up about 70% of their diet (Currier 1983; Iriarte et al. 1990). Hornocker (1970) estimated that the average adult mountain lion consumes 860-1,300kg of large prey annually. However, mountain lions are opportunistic predators, and they have been documented eating a wide variety of other large and smaller prey, including moose, elk, wild horses, burros, pronghorn, bighorn sheep, mountain goats, wild hogs, coyotes, bobcats, porcupines, badgers, rabbits, raccoons, rodents, turkeys, and livestock (Currier 1983; Iriarte et al. 1990; Garcelon unpublished data).

Their diet can vary by prey availability, prey vulnerability, the presence of sympatric carnivores, the season, and the age and sex of the mountain lion (Currier 1983; Iriarte et al. 1990; Knopff et al. 2010; Allen et al. 2014a). For example, deer have been found to make up >90% of the diet in mountain lions in the Santa Monica Mountains and in Northern California (Allen et al. 2014a; Riley et al. 2014), while in Florida wild hogs were found to be the most common prey (Maehr et al. 1990), and in northwestern Sonora, Mexico bighorn sheep were found to be the primary prey (Rosas-Rosas et al. 2003). These observed patterns were likely due to the availability of different prey in different geographic regions. A study conducted in Alberta, Canada, Knopff et al. (2010) found that while adult females were more likely to kill small ungulates (*e.g.*, deer), adult males were more likely to kill larger ungulates (*e.g.*, elk), and subadults relied on both small ungulates and nonungulate prey (*e.g.*, beavers, snow hares). A similar pattern was found in a mountain lion population in the Greater Yellowstone Ecosystem, in which older, larger individuals hunted larger prey and younger, smaller individuals hunted smaller prey (Elbroch and Quigley 2019). In addition, mountain lions were found to prey upon female ungulates in the spring before and during the birthing period, and they would more often prey upon male ungulates in the fall during the rut, highlighting that prey vulnerability may play a role in mountain lion predation (Knopff et al. 2010).

Mountain lion preying on a coyote in Joshua Tree, California. Photo: Brendan Cummings

Mountain lions roam through expansive home ranges in search of prey, often hunting between dusk and dawn. Although they are generally most active at dusk and dawn, their peak activities have been observed to shift to more nocturnal patterns when they are closer to human

disturbance (Van Dyke et al. 1986). Mountain lions are primarily solitary animals and will repeatedly move and wait as they stalk and ambush their prey (Beier et al. 1995). Once within close proximity, mountain lions will lunge at their prey and kill the animal by crushing the trachea and suffocating it or by breaking its neck at the base of the skull with a bite (Currier 1983; Pierce and Bleich 2003). Instead of eating their kill right away, mountain lions drag their kill to a secluded spot to feed. They cover it with brush and other debris and return to feed at night for up to five days (Currier 1983; Beier et al. 1995). However, the presence or perceived presence of humans has been found to reduce overall feeding time (Smith et al. 2015; Smith et al. 2017).

Deer kill rates vary depending on the sex of the mountain lion, whether or not the female has cubs, and surrounding human land use. Male kill rates have been found to range from 35 to 47 ungulates per year, regardless of housing density (Anderson , Jr . and Lindzey 2003; Cooley et al. 2008; Knopff et al. 2010; Smith et al. 2015). However, kill rates for females differ depending on human disturbance. In lower density housing areas, kill rates of solitary females and females with kittens have been found to be 52-60 and 57-68 ungulates per year, respectively, while females in high density housing areas were found to have a kill rate of 81 ungulates per year (Anderson , Jr . and Lindzey 2003; Cooley et al. 2008; Knopff et al. 2010; Smith et al. 2015). This pattern could be driven by reduced time spent at kill sites in more developed areas, indicating that females are not consuming as much of each carcass and therefore need to kill more prey (Smith et al. 2015). This may reflect a trade-off made by females to choose feeding sites closer to human-disturbed areas and expend more energy killing prey in order to reduce potential encounters with males that pose a threat to themselves or their kittens (Benson et al. 2016b). Another factor that may be contributing to higher kill rates in developed areas is that mountain lions expend more energy traveling faster and farther in human-dominated landscapes and therefore require increased caloric intake compared to mountain lions away from developed areas (Wang et al. 2017).

2.5 Habitat Requirements

Mountain lions are primarily solitary (except in certain situations, such as when breeding, when females are rearing cubs, or when dispersing with siblings), territorial cats that occur in low density. They require large areas of relatively undisturbed habitats with adequate connectivity to allow for dispersal and gene flow. They have large home ranges that include heterogenous habitats. In the United States these often consist of pine forests, riparian and oak woodlands, streams, chaparral, and grasslands, though they are also known to occur in desert habitats (*e.g.*, Figure 3).

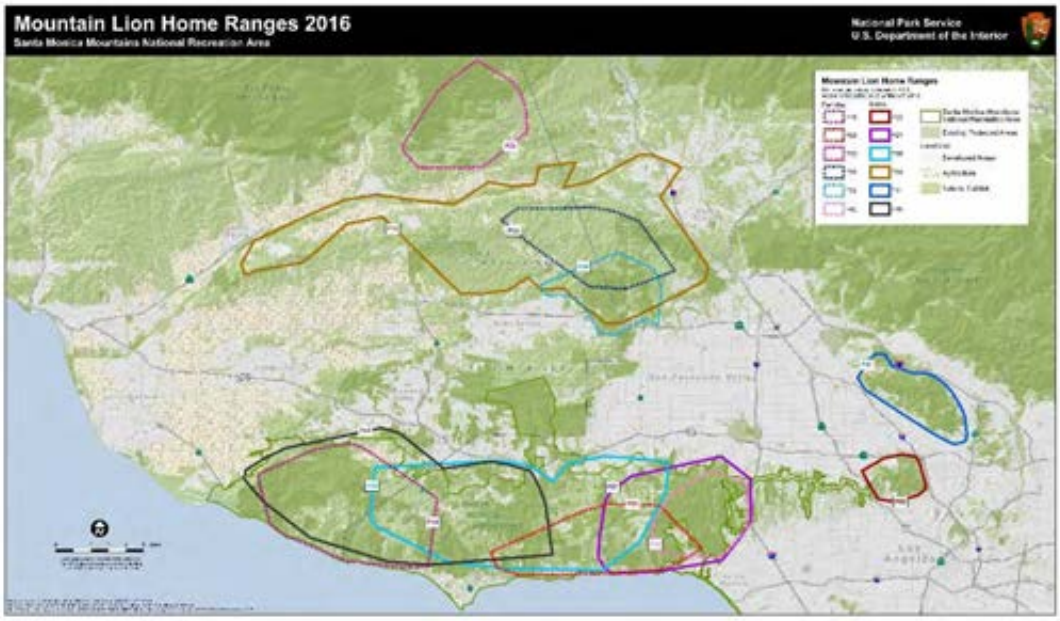

Figure 3. Home ranges of mountain lions being actively studied in 2016 by NPS in and near the Santa Monica Mountains. Source: NPS.

Mountain lions have been found to utilize different habitats within a 24-hour period (Dickson and Beier 2002; Dickson et al. 2005; Dickson and Beier 2006; Kertson et al. 2011; Zeller et al. 2017). Riparian habitats were found to be preferred over grasslands and human-disturbed areas during the day, which likely represents the animals resting in areas with understory vegetation for cover (Dickson and Beier 2002; Dickson et al. 2005). However, nocturnal movement patterns showed that mountain lions utilize a broad range of habitats as they travel through their home ranges and hunt (Dickson et al. 2005). Although riparian vegetation was the highest ranked habitat for nocturnal use, usage of riparian areas was not statistically different from the use of scrub, chaparral, grasslands, or woodlands (Dickson et al. 2005).

Nocturnal patterns of movement and stasis suggest that mountain lions generally avoid areas with human disturbance (*i.e.*, residential developments and two-lane paved roads) and use a variety of habitats to stalk and pursue their prey (Dickson and Beier 2002; Dickson et al. 2005). In addition, Dickson and Beier (2006) found that when mountain lions were traveling or hunting, they preferred canyon bottoms and gentle slopes and used steeper slopes and ridgelines to a lesser extent. And Benson et al. (2016b) found that mountain lions tend to choose feeding sites on steeper slopes in habitats with dense understory vegetation, such as chaparral, scrub, and upland forest. Although mountain lions will use moderately disturbed areas as they travel and hunt (Wilmers et al. 2013; Gray et al. 2016), occupancy is lower in developed areas and they are more likely to use developed areas if they border open spaces (Wang et al. 2015). Thus, mountain lions require a habitat mosaic that provides sufficient room to roam away from human-disturbed areas and connected to expansive, intact, heterogeneous habitats (Beier 1995; Dickson and Beier 2002; Dickson et al. 2005; Kertson et al. 2011; Zeller et al. 2017).

Home range size can vary depending on geographic area, season, sex, reproductive status, and prey density (Currier 1983; Grigione et al. 2002; Riley et al. 2014). Males generally have

much larger home ranges than females, and females with cubs tend to have even smaller home ranges (Beier et al. 1995; Grigione et al. 2002). Male home ranges tend to include partially or entirely overlapping female home ranges, and to a limited extent, they may partially overlap with other male home ranges (Figure 3) (Seidensticker et al. 1973; Currier 1983; Pierce and Bleich 2003). Mountain lions mark their home ranges with scrapings in the ground, often containing urine or feces (Seidensticker et al. 1973). Males make scrapings more often than females (Allen et al. 2014b), and females may only make scrapings when they are in estrous (Seidensticker et al. 1973; Currier 1983; Pierce and Bleich 2003).

Seasonal variation in home range size can differ depending on geographic area. Grigione et al. (2002), found strong influences of seasonality in average mountain lion home ranges in the Sierra Nevada mountains, with much larger home ranges in the summer (541km^2 for females, 723km^2 for males) compared to those in the winter (349km^2 for females, 569km^2 for males). These patterns likely reflect the abundance and distribution of deer – during the winter deer would be concentrated at lower elevations, which allowed mountain lions to reduce their home ranges, while in the summer deer could disperse to higher elevations and the mountain lions would expand their ranges accordingly (Grigione et al. 2002). However, seasonal variation was not as pronounced and had the reverse trend in Coastal California mountain ranges, including in the SAM, where the average area of winter home ranges was slightly larger (100km^2 for females, 350km^2 for males) than summer home ranges (90km^2 for females, 300km^2 for males) (Grigione et al. 2002). These differences were not statistically significant, and this pattern is likely due to the moderate year-round climate in the coastal ranges, where prey abundance and distribution does not exhibit as extreme shifts as those in the Sierra Nevada (Grigione et al. 2002). This generally aligns with Zeller et al. (2017), who found that mountain lion home ranges in the SAM and EPR ranged from 41-497 km^2, with mean home range sizes of 188km^2 for females and 316 km^2 for males. And Riley et al. (2014) found that CC-S mountain lions had home ranges similar in size to the SAM and EPR mountain lions, with female home ranges being 100-200km^2 and male home ranges being 300-500 km^2. According to the Santa Cruz Puma Project, in the Santa Cruz Mountains female home ranges are on average about 100 km^2 and male home ranges are about 230 km^2 (Santa Cruz Puma Project 2015). Although studies are limited regarding the home range size of the CC-C and SGSB mountain lions, given their close proximity and similar seasonality to other Central Coast and Southern California populations, they are likely similar.

2.6 Survivorship and Mortality

According to the National Park Service (NPS), mountain lions can live up to 13 years in the wild. As a top carnivore with no natural predators, conspecifics and humans are the main drivers of mountain lion survivorship and mortality. Although studies regarding kitten (<18 months), subadult (18-30 months), and adult (>30 months) survivorship are limited, some long-term studies of radio-collared mountain lions on the CC-S, SAM, and EPR provide valuable insights for these Central Coast and Southern California populations (Beier and Barrett 1993; Riley et al. 2014; Vickers et al. 2015).

In a study conducted in the CC-S area (which encompasses the Santa Monica Mountains, Simi Hills, and Santa Susana Mountains) that included 42 mountain lions from 2002 to 2012, Riley et al. (2014) found an annual adult survival of ≥ 75%, though Benson et al. (2016a) found

lower subadult survival rates. Although adult survival in the CC-S is similar to previous studies conducted in California and the southwestern US (Beier 1993; Logan and Sweanor 2001), it is higher than what was found in the SAM and EPR populations during the same time period. From following 74 radio-collared mountain lions from 2001 to 2013, Vickers et al. (2015) found an annual survival rate across all age groups of 56.5% and 55.4% in the SAM and EPR, respectively.

In the Santa Monica Mountains: Female mountain lion P-23 hunted down a deer on Mulholland Drive (left). In 2018 she was killed by a vehicle strike on Malibu Canyon Road. An uncollared mountain lion killed by a vehicle strike on Malibu Canyon Road in 2004 (right). Photos: NPS

Vehicle strikes, depredation kills, and intraspecific strife (including male aggression towards conspecifics and infanticide) are the primary causes of mortality in the Central Coast and Southern California populations (Beier 1993; Riley et al. 2014; Vickers et al. 2015). Other known causes of death in California mountain lion populations include rodenticide poisoning, disease, poaching/illegally killing, starvation/abandonment, public safety removal, and human-caused wildfires (Beier 1993; Riley et al. 2014; Vickers et al. 2015). Causes of mortality will be discussed more in depth in *Section 5.0 Abundance and Population Trends* and *Section 6.0 Factors Affecting Ability to Survive and Reproduce*.

3 Southern California and Central Coast Mountain Lions Comprise an Evolutionarily Significant Unit

3.1 CESA Provides for Listing of ESUs

CESA defines an "endangered species" as a species or subspecies of animal or plant that is in serious danger of becoming extinct through either all or "a significant portion" of its range. (Cal. Fish & Game Code § 2062.) A "threatened species" is likely to become an endangered species in the foreseeable future in the absence of special protection and management efforts. (Cal. Fish & Game Code § 2067.) CDFW has concluded—and appellate courts have upheld—that the term "range" is construed to refer to the range of a species or subspecies *within* California, not the worldwide range of the species or subspecies. (*California Forestry Assn. v. California Fish & Game Com.* (2007) 156 Cal.App.4th 1535, 1550-551.) This means that a species or subspecies which may not be endangered in other states or countries may still be endangered within California. Courts also have confirmed that the phrase "significant portion" of

a range authorizes CDFW to designate certain populations of a species or subspecies as "evolutionarily significant units" or "ESUs" and list such populations as endangered under CESA. (*Id.* at 1549; *Central Coast Forest Assn. v. Fish & Game Com.* (2018) 18 Cal.App.5th 1191, 1236-37 [*"CCFA II*"].) In other words, ESUs are a population of a species or subspecies "that is considered distinct for purposes of conservation." (*Central Coast Forest Assn. v. Fish & Game Com*. (2012) 211 Cal.App.4th 1433, 1439 fn 5 [depublished] ["*CCFA I*"].)

CDFW has confirmed that the use of ESUs to evaluate the status of species pursuant to CESA is appropriate.[5] In the *Status Review of Fisher*, CDFW designated fishers in northern California and the southern Sierra Nevada as two separate ESUs based upon the reproductive isolation of these fisher populations and the degree of genetic differentiation between them. In designating these ESUs, CDFW highlighted the need to maintain "geographically widespread and genetically diverse" populations of the species.

3.2 Southern California and Central Coast Mountain Lions are Significantly Reproductively Isolated from Other Populations and Form an ESU

Southern California and Central Coast mountain lion populations could be grouped into one or several potential ESUs. However, petitioners believe that for purposes of listing under CESA, treating the CC-N, CC-C, CC-S, SAM, SGSB, and EPR populations as a single Southern California/Central Coast ESU is both supported by the best available science and makes sense from a management perspective. Gustafson et al. (2018) suggest that the North Coast and inland populations (Nevada, Eastern Sierra Nevada, and Western Sierra Nevada) may form an ESU (hereinafter "North Coast/Inland ESU") given that they were found to be genetically diverse and well-connected. Due to extreme isolation and high levels of human-caused mortalities, functional connectivity between Southern California and Central Coast mountain lion populations and the healthier North Coast/Inland ESU has become severely impaired (Gustafson et al. 2018, see further discussion in *Section 2.2 Taxonomy and Population Genetics* and *Section 6.0 Factors Affecting Ability to Survive and Reproduce*). There is a tenuous link made up of small mountain ranges (*i.e*., Tehachapi and Sierra Pelona Mountains) that connect the North Coast/Inland ESU with the proposed Southern California/Central Coast ESU. Thus, although there is some (limited) connectivity between the North Coast/Inland ESU and the proposed ESU, as a practical matter under current management the two ESUs are functionally isolated.

Southern California and Central Coast populations have lower levels of genetic diversity and are relatively disconnected from each other compared to North Coast and inland populations. The Central Coast populations form a genetic cluster while the SAM and EPR populations form a second, less connected genetic cluster (Figure 4) (Gustafson et al. 2018). The SGSB population, though isolated, is most genetically similar to the Western Sierra Nevada, CC-C, and EPR populations, which indicates that it is an important intersection for statewide genetic connectivity (Figure 4) (Gustafson et al. 2018).

Genetic source-sink dynamics are informative in determining gene flow among the populations and how they are connected. Five genetic source populations were identified: the

[5] California Department of Fish and Wildlife, *Status Review of Fisher* (June 10, 2015), available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=101470.

Eastern and Western Sierra Nevada populations, CC-N, CC-C, and EPR (Gustafson et al. 2018). The Sierra Nevada populations were the greatest genetic source populations and the CC-N population had only weak evidence of being a source population (Gustafson et al. 2018). The CC-S, SGSB, and SAM were identified as genetic sink populations with limited connectivity to source populations (Figure 4) (Gustafson et al. 2018). Maintaining and reestablishing genetic connectivity with source populations like the CC-C, EPR, and Western Sierra Nevada populations are important for the long-term viability of Southern California and Central Coast populations (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gray et al. 2016; Gustafson et al. 2017). This underscores the importance of the Tehachapi and Sierra Pelona Mountains as the key remaining linkage, though tenuous, for statewide genetic connectivity.

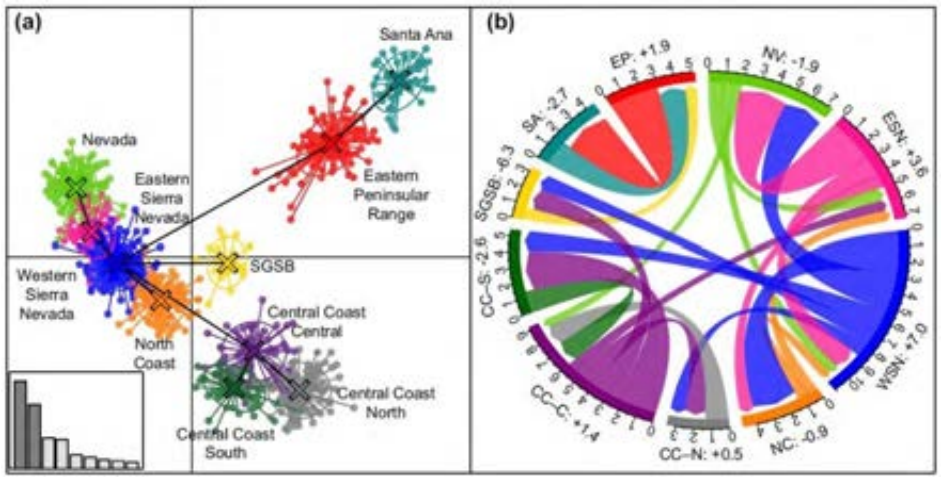

Figure 4. Functional connectedness of California mountain lion populations. Each color represents a genetically distinct population. In (a), the results of the discriminant analysis of principal components shows connectivity among California mountain lions. The x-axis represents latitude with north to the left and south to the right. The y-axis represents longitude, separating the Central Coast populations from Southern California populations. In (b), estimated migration rates between populations are shown. Source-sink dynamics are indicated by positive (source) or negative (sink) net migration rates. Source: Gustafson et al. (2018).

While genetics as currently understood could support several different ESU formulations, petitioners believe a single Southern California/Central Coast ESU is the most pragmatic from a management perspective, as recovery of the individual subpopulations ultimately depends upon maintaining and/or reestablishing connectivity between them. *See CCFA II,* 18 Cal.App.5th 1191, 1237 ("[T]he nature of the ESU designation is such that genetics alone are not determinative: One must look beyond genetics to questions of policy to determine which populations to include in an ESU.") (quotations omitted). Designating Southern California and Central Coast mountain lions as an ESU would help ensure "geographically widespread and genetically diverse" populations of mountain lions in California.

While petitioners believe that listing of a single Southern California/Central Coast ESU as threatened is both a permissible and prudent course of action for the Commission, petitioners also request that as additional data become available over the course of CDFW conducting its status review that the agency also assess other possible ESU formulations for Southern California and Central Coast mountain lions. One such formulation would be to group all three Central Coast populations (CC-N, CC-C and CC-S) into one ESU, with the remaining three

populations placed into a second ESU (SAM, EPR and SGSB). Alternatively, the Central Coast populations could be treated as one ESU, SAM and EPR as a second ESU, and SGSB separately listed as a third ESU. Petitioners believe the genetic data in Gustafson et al. (2018) could support each of these alternative formulations. Lastly, given each of the six populations at issue are themselves already genetically distinguishable and occupy significant portions of the range of mountain lions in California, each could be separately treated as an ESU. Under this formulation, the SAM and CC-S populations would clearly warrant endangered listing, the CC-C and EPR populations would warrant threatened listing, and the CC-N and SGSB populations would warrant at least threatened and likely endangered listing.

3.3 Proposed Boundary of the Southern California/Central Coast ESU

We propose the Southern California/Central Coast ESU to include mountain lions that occur in areas east of the Pacific Ocean, south of the San Francisco Bay Area waters and I-80, west of I-5 to the intersection of I-5 and SR-58 at Bowerbank/Buttonwillow, south of SR-58 to I-15, south of the I-15 from the SR-58 intersection to the California-Nevada border, and, for the purposes of CESA, north of the California-Mexico border (Figure 5). These boundaries are recommended as they include virtually all mountain lions associated with the six populations comprising the ESU and are also unambiguous and readily discernable for purposes of management.[6]

[6] In the event the Commission determines that the proposed ESU should instead be treated as separate Southern California (SAM, EPR, SGSB) and Central Coast (CS-N, CS-C, CS-S) ESUs, we propose the boundary between them to be delimited by I-5 and I-710.

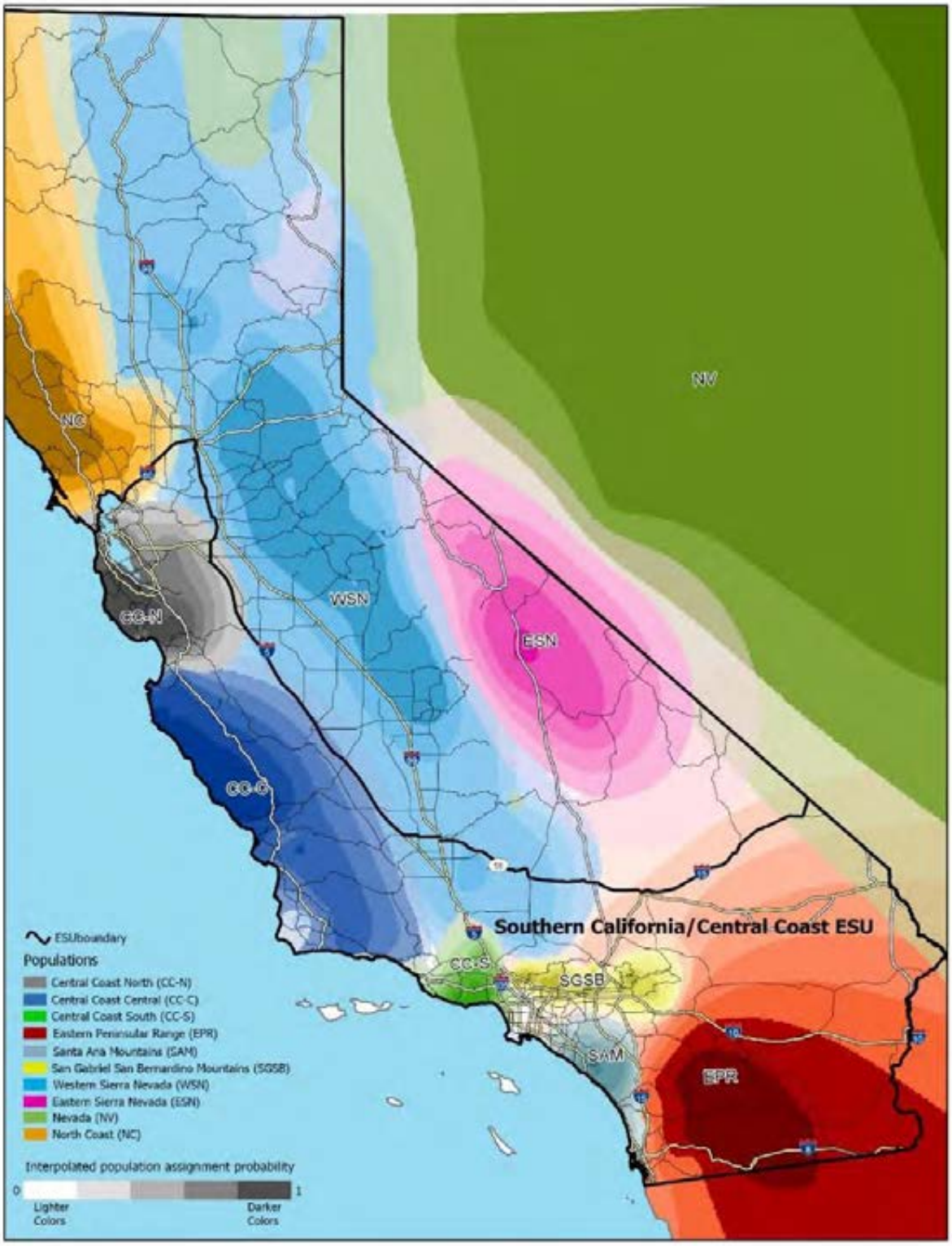

Figure 5. Map of the Southern California/Central Coast ESU boundary. Derived from Gustafson et al. (2018). Genetics data source: Kyle Gustafson, PhD, Department of Biology and Environmental Health, Missouri Southern State University, and Holly Ernest, DVM, PhD, Department of Veterinary Sciences, Program in Ecology, University of Wyoming, Laramie. Roads data source: ESRI.

We recommend including mountain lions in the Tehachapi and Sierra Pelona Mountains south of SR-58 in the Southern California/Central Coast ESU. While most mountain lions sampled from this region share some genetic affinities with Western Sierra Nevada (WSN) animals, individuals sampled in the Tehachapi Mountains and surrounding areas, including the Sierra Pelona Mountains in the Angeles National Forest and the Los Padres National Forest, had genetic structures made up of multiple genetic populations from the northern, central coastal, and southern populations (Figure 6). This area serves not just as a connecting link between mountain lion populations comprising the Southern California/Central Coast ESU, but also between this ESU and all other California mountain lions. The Tehachapi and Sierra Pelona Mountains are the last remaining linkages for statewide genetic connectivity and are critical for the overall genetic health of Southern California and Central Coast mountain lions. Consequently, mountain lions in these areas should be considered part of the listed entity.

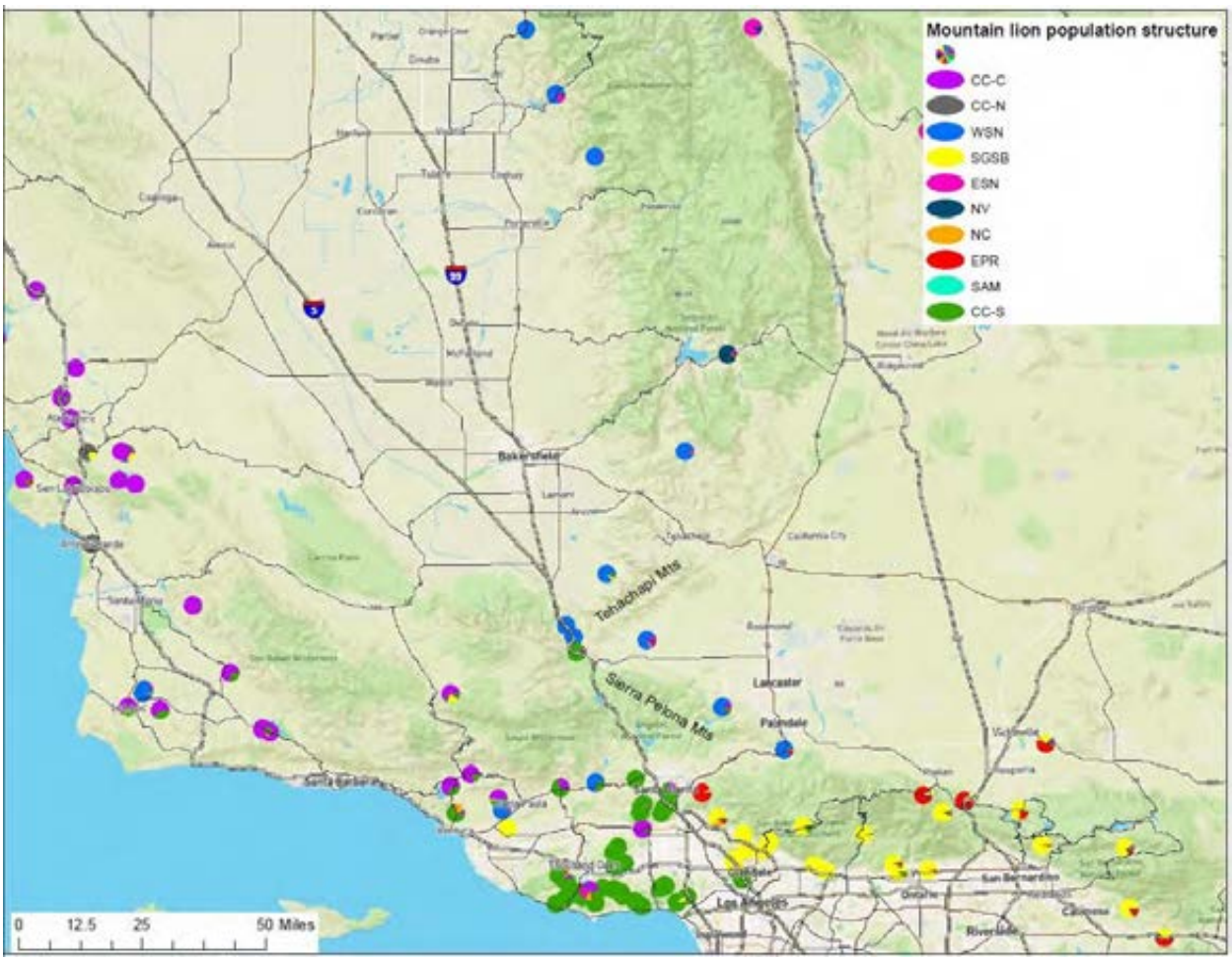

Figure 6. Map of mountain lion genetic structure in and surrounding the Tehachapi and Sierra Pelona Mountains, the last remaining linkage between the coastal, southern, and northern populations. Data source: Kyle Gustafson, PhD, Department of Biology and Environmental Health, Missouri Southern State University, and Holly Ernest, DVM, PhD, Department of Veterinary Sciences, Program in Ecology, University of Wyoming, Laramie.

3.4 Southern California and Central Coast Mountains Lions are Essential to the Region's Biodiversity

Additional support for designation of a Southern California/Central Coast ESU is provided by the fact that mountain lions are a keystone species critical to maintaining biodiversity in coastal California's ecosystems. The loss of these mountain lions—which are the only remaining large predator in the region—would lead to a trophic cascade wherein deer populations would increase and overgraze vegetation due to the lack of predation and lack of risk of predation, causing other repercussions to other species and habitats (Ripple and Beschta 2006; Ripple and Beschta 2008; Ripple et al. 2014). In addition, their kills are an important source of food for multiple terrestrial and avian scavengers (Ruth and Elbroch 2014; Elbroch et al. 2017; Barry et al. 2019).

Ripple and Beschta (2006) highlighted the critical role of mountain lions in western ecosystems by comparing habitat quality and the levels of biodiversity in two separate areas of Zion National Park – Zion Canyon, which mountain lions generally avoid due to high human presence, and North Creek, which mountain lions inhabit due to less human presence. The sustained lack of mountain lions in Zion Canyon has led to an unnaturally high density of deer, which has had profound impacts on Zion Canyon ecosystems. Ripple and Beschta (2006) observed Zion Canyon had low numbers of hydrophytic plants, wildflowers, amphibians, lizards, and butterflies while North Creek had significantly higher numbers in each of these categories.

North Creek riparian areas had well vegetated and stable banks while Zion Canyon lacked bank vegetation and its banks were continuing to erode (Ripple and Beschta 2006). The study noted that such geomorphic transformation of stream channels where mountain lions were absent were caused by plant loss on stream banks, which led to high levels of erosion and sedimentation, less shading and higher water temperatures, a larger width:depth ratio in streams, loss of hydrologic connectivity with historical floodplains, and loss of a wide variety of species, including native plants, benthic invertebrates, butterflies, fish, amphibians, and reptiles (Ripple and Beschta 2006).

The study concluded that removing a large carnivore from an ecosystem "appears to have [] profound effects on lower trophic levels, as well as multiple indicators of ecosystem status and native species abundance." (Ripple and Beschta 2006.) A similar study found that in Yosemite Valley—where mountain lions are largely absent due to high human presence—deer populations have expanded leading to a lack of oak recruitment and a decrease in biodiversity (Ripple and Beschta 2008). And their kills support disproportionately high levels of mammal, bird, and invertebrate diversity (Ruth and Elbroch 2014; Elbroch et al. 2017; Barry et al. 2019) and may even play a role in tree and other vegetation growth (Ruth and Elbroch 2014). In sum, extinction of Southern California and Central Coast mountain lions would result in degraded habitats and reduced abundance and diversity of other species, likely undermining the biological diversity, ecosystem function, and resilience of California's coastal regions.

3.5 Californians Derive Aesthetic, Recreational, and Economic Value from Southern California and Central Coast Mountain Lions

The people of California derive aesthetic, recreational, economic, spiritual, scientific, educational, and emotional value from Southern California and Central Coast mountain lions. For instance, the City of Los Angeles has designated October 22 as "P-22 day" to honor a young (and mate-less) male mountain lion that lives in Griffith Park and to acknowledge the importance of Southern California mountain lions to the region. Many people view mountain lions as a symbol of wildness and cherish landscapes that still are home to these predators. People from within and beyond the region choose to recreate, hike, bike, camp, fish, and hunt in California's wildlands in part because they enjoy exploring and sharing landscapes with mountain lions. And these activities are a significant economic driver for the state: A report commissioned for California State Parks found that direct outdoor recreation expenditures for Los Angeles, Southern California, the Central Coast and the San Francisco Bay Area totaled nearly $15 billion per year.[7] The Outdoor Industry Association concluded that outdoor recreation in California generates $92 billion of consumer spending annually and directly employs 691,000 Californians—more jobs than the wine and television industry combined.[8]

Mountain lions also provide an economic and social benefit because, by controlling deer populations, they reduce collisions between deer and automobiles. There are 1.2 million deer-vehicle collisions in the United States per year, incurring an estimated $1.66 billion in damages, 29,000 injuries, and 200 deaths (Gilbert et al. 2016). Impacts of deer-vehicle collisions are particularly severe in the eastern United States where white-tailed deer are overabundant. Gilbert et al. (2016) determined that if mountain lions recolonized the eastern United States, their presence would result in a 22 percent decline in deer-vehicle collisions over thirty years.

It is estimated that 7,000 to 23,000 wildlife vehicle collisions have occurred annually on California roads (Shilling et al. 2017; Shilling et al. 2018; State Farm Insurance Company 2016, 2018). These crashes result in human loss of life, injuries, emotional trauma, and property damages that can add up to $300-600 million per year (Shilling et al. 2018). If Southern California and Central Coast mountain lions became extinct, there would likely be a significant increase in deer-vehicle collisions in the region, along with associated human fatalities, injuries, and property damage.

An overabundance of deer in the eastern United States is also linked to an increase in ticks, which has led to increased incidences of Lyme disease among humans (Telford 2017; Côté et al. 2004). Lyme disease is now the most common vector-borne illness in the United States, with over 30,000 cases per year, primarily in the eastern United States.[9] Increases in deer abundance and attendant increases in ticks and tick-borne disease among humans would be

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[7] BBC Research & Consulting, *California Outdoor Recreation Economic Study: Statewide Contribution and Benefits* (2010), available at https://www.parks.ca.gov/pages/795/files/ca%20outdoor%20rec%20econ%20study-statewide%2011-10-11%20for%20posting.pdf.

[8] Outdoor Industry Association, *California Recreation Report*, available at https://outdoorindustry.org/wp-content/uploads/2017/07/OIA_RecEcoState_CA.pdf.

[9] Centers for Disease Control and Prevention, *Lyme Disease Data and Surveillance*, available at https://www.cdc.gov/lyme/datasurveillance/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Flyme%2Fstats%2Findex.html.

expected if Southern California and Central Coast mountain lions became extinct. Loss of Southern California and Central Coast mountain lions would have far-reaching effects not only on California's ecology, but also on public health and the region's economy.

Protection of Southern California and Central Coast mountain lions under CESA would confirm that this species is a vital member of our ecosystems which is worthy of protection. Conservation of these mountain lions would provide compelling evidence that large carnivores and abundant human populations can co-exist, even in densely populated landscapes (Benson et al. 2019).

4 Historical and Current Distribution

Mountain lions once had the most expansive range of any New World terrestrial mammal (Seidensticker 1991). They roamed most of the Americas (excluding most of Alaska and the northern areas of Canada) from approximately 50º N to 50ºS latitude and could be found from sea level to about 4,000m elevation (Young and Goldman 1946, Pierce and Bleich 2003) in habitats varying from dense forests, to dry deserts, savannahs, and swamp lands.

Due to habitat loss and hunting after the arrival of European colonists, the mountain lion's current range has been reduced to one third of its historical range in North America (Figure 7) (Culver et al. 2000; Pierce and Bleich 2003). In the United States, the species' range has been reduced to 15 western states and a small remnant population in Florida (endangered Florida panthers [*Puma concolor coryi*]), with isolated animals occasionally appearing in additional states. Continued hunting pressure and changes in land management practices have pushed most populations into mountainous, relatively unpopulated areas, though isolated populations are known to occur in more urban areas (Currier 1983; Gustafson et al. 2018).

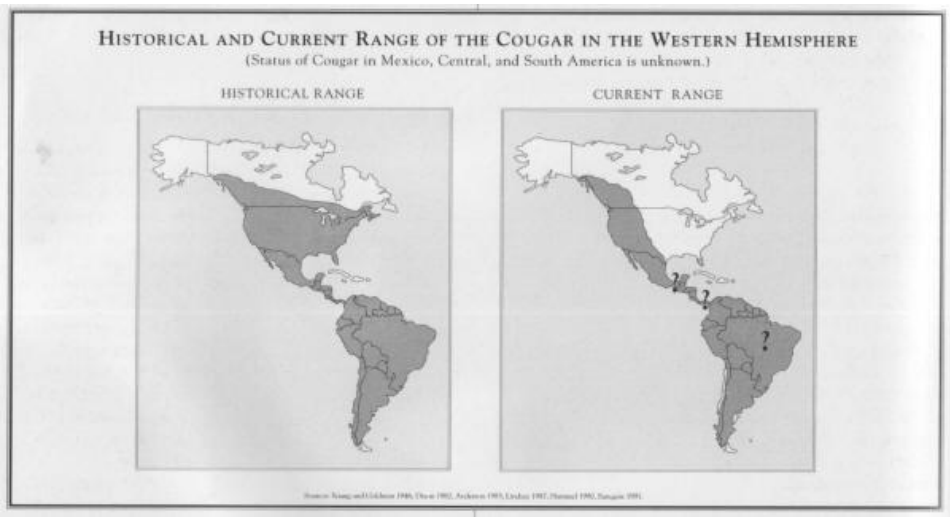

Figure 7. Historical and current range of mountain lions. Source: Hansen 1992.

In California, habitat fragmentation from roads and development has led to highly fragmented, divergent populations (Ernest et al. 2003; Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Gustafson et al. 2018). As mentioned in *Section 2.2 Taxonomy and Population Genetics*, nine genetically distinct populations have been identified within California

(Gustafson et al. 2018), with Southern California and Central Coast populations being the most constrained populations (and a tenth population centered in Nevada but extending slightly into California). Those located in highly urbanized areas of Southern California coastal mountain ranges, including the CC-S, SAM, and SGSB populations are especially restricted (Figure 8) (Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019).

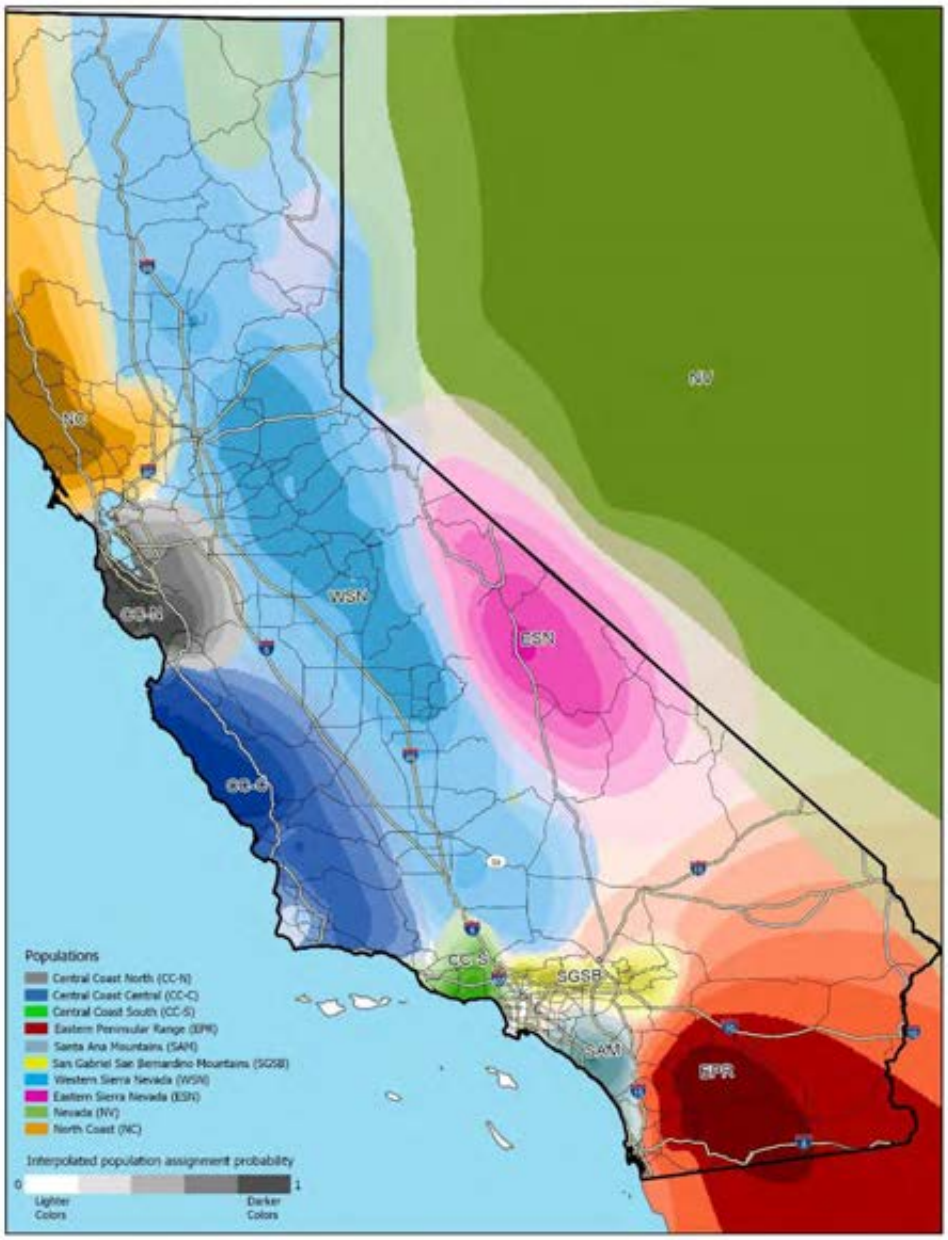

Figure 8. Map of genetically distinct mountain lion populations and major roads in California. The CC-S (which includes the Santa Monica Mountains), SGSB, and SAM populations are exceptionally constrained. The map is based on data collected from 1992-2016 (the division and status of these populations could change over time and with further research. Derived from Gustafson et al. (2018). Genetics data source: Kyle Gustafson, PhD, Department of Biology and Environmental Health, Missouri Southern State University, and Holly Ernest, DVM, PhD, Department of Veterinary Sciences, Program in Ecology, University of Wyoming, Laramie. Roads data source: ESRI.

4.1 Central Coast North (CC-N) Mountain Lion Population

The CC-N mountain lion population occurs mostly within the counties of Alameda, Contra Costa, San Mateo, Santa Clara, and Santa Cruz (Figure 8). The area is almost divided into two portions: an eastern half and a western half. The Santa Cruz Mountains make up the core area of the CC-N, bound by the Pacific Coast to the west, development lining the San Francisco Bay to the north and north west, and Highway 101 to the south. The eastern portion of the CC-N consists of various open space and nature preserves in the Berkeley Hills and Diablo Range bound by development lining the San Francisco Bay and Highway 101 and associated developments to the west, San Pablo Bay and Suisun Bay and associated developments to the north, I-5 to the east, and State Route 130 (SR-130) to the south. Interestingly, the CC-N seems almost bisected by the San Francisco Bay and Highway 101 and associated developments.

4.2 Central Coast Central (CC-C) Mountain Lion Population

The CC-C mountain lion population occurs mostly within the counties of Monterey, San Benito, San Luis Obispo, and Santa Barbara. The area encompasses the central and southern portions of the Southern Coast Ranges, including the Santa Lucia Range, Sierra de Salinas, the Temblor Range, and the Sierra Madre Mountains. It is bound by the Pacific Ocean to the west, Highway 101 and SR-156 and associated development to the north, the I-5 and San Joaquin Valley to the east, and SR-126 and associated developments to the south (Figure 8).

4.3 Central Coast South (CC-S) Mountain Lion Population

The CC-S mountain lion population is limited to the Santa Monica Mountains, Simi Hills, and the Santa Susana Mountains in Ventura and Los Angeles Counties (Figure 8). The Santa Monica Mountains population has the isolated area with about 660 km^2 within the Santa Monica Mountains National Recreation Area (Riley et al. 2014). The Pacific Ocean lies to the south while the cities of Oxnard, Thousand Oaks, San Fernando Valley, Los Angeles, and Santa Monica and major freeways including Highway 101, Interstate 5 (I-5) and Interstate 405 surround the area and create major movement barriers.

The Simi Hills is a smaller area of open space located north of the Santa Monica Mountains; the areas are bisected by Highway 101. This open space is mostly surrounded by development, including Simi Valley to the northwest, Thousand Oaks to the west, Agoura Hills to the southwest, Calabasas to the southeast, and Woodland Hills, Canoga Park, and Chatsworth to the east.

The Santa Susana Mountains are located north of the Santa Monica Mountains and Simi Hills. The area is generally bordered by freeways and the edges of development and agriculture. SR-118 borders the south and southwest, SR-126 borders the north and northwest, and I-5 borders the east.

4.4 San Gabriel/San Bernardino Mountains (SGSB) Mountain Lion Population

The SGSB mountain lion population occurs within the Transverse Ranges located northwest of the City of Los Angeles within Los Angeles, Kern, and San Bernardino Counties (Figure 8). The western and southern boundaries of the San Gabriel and San Bernardino Mountains are lined with urban developments and major freeways, including the San Fernando Valley, cities of San Bernardino, Rancho Cucamonga, and West Covina, and the I-5, I-210, and I-10 freeways. The northern and eastern boundaries of the area are abutted by agriculture, suburban development, high desert, and roads.

4.5 Santa Ana Mountains (SAM) Mountain Lion Population

The SAM mountain lion population inhabits about 1,533km^2 of undeveloped areas of the SAM within Orange, Riverside, and San Diego Counties (Beier and Barrett 1993; Benson et al. 2019). The area is mostly bound by major freeways and development (Figure 8). SR-241 creates the western boundary, SR-91 borders the northwest boundary, I-5 creates the eastern boundary, and agriculture and development border the southern extent. The closest intact habitat known to be used by other mountain lions is to the east/southeast, in the Peninsular Ranges.

4.6 Eastern Peninsular Range (EPR) Mountain Lion Population

The EPR mountain lion population occurs in mountain ranges east of the SAM and south of the San Bernardino Mountains. The EPR is a predominantly north to south range that runs through San Diego, Riverside, and Imperial Counties and the California-Mexico border. They include the San Jacinto, Laguna, and San Ysidro Mountains in California and continue south into the mountain ranges of Baja California, Mexico. The western boundary of the EPR population is lined with roads and urban development, including areas around the cities of Escondido, San Diego, and Chula Vista. Studies regarding the northern, southern, and eastern extent of the population are limited; however, movement patterns documented by Vickers et al. (2015) and Vickers et al. (2017) between 2001 and 2016 suggest that EPR mountain lions generally stay north of the U.S. – Mexico border, along the edges of the desert that borders the east side of the EPR, and south of I-10. Although the EPR population has been found to be largely disconnected from all other California populations, some mountain lion movement was documented traversing between the EPR and SGSB (Vickers et al. 2015), which would have occurred at the northern boundary of the EPR, and there is evidence of limited genetic exchange between the two populations (Gustafson et al. 2018). In addition, one young male mountain lion was documented to the south using the Parque-to-Park Linkage to cross the US-Mexico border several times (where the terrain is too rugged to install a border wall), but he was eventually killed in Mexico in a collision with a vehicle (Vickers et al. 2015; W. Vickers *unpublished data*). Little is known about the mountain lions south of the border, but the movement patterns of EPR mountain lions suggest that they may form a discrete population within the EPR north of the US-Mexico border (Vickers et al. 2015; Vickers et al. 2017).

5 Abundance and Population Trends

According to the International Union for Conservation of Nature (IUCN), mountain lion populations are decreasing throughout their remaining range (Nielsen et al. 2015). Mountain lion population densities are generally low, which may be driven by prey density, competition between males for access to females, and mutual avoidance (Pierce and Bleich 2003). In the United States, population densities for mountain lions have been found to range from 0.4 to 4.3 resident adults per 100km^2 and 0.4 to 7.1 total mountain lions per 100km^2, though it varies by population and the presence of human-induced pressures (*e.g*., hunting) (Pierce and Bleich 2003). In California, where hunting has been outlawed but other anthropogenic pressures such as roads and development are present, resident adult and total population densities have been found to be 1.1 and 3.6 per 100 km^2, respectively (Pierce and Bleich 2003). Adult sex ratio has been reported to be about 2-3:1 in favor of females (Hornocker 1970; Seidensticker et al. 1973; Beier 1993; Santa Cruz Puma Project 2015). These low population densities and female-biased sex ratios further highlight the species' need for expansive, connected, heterogeneous habitats to support viable populations.

It has been estimated that 4,000 to 6,000 adult mountain lions roam California (Mansfield and Weaver 1989). However, CDFW acknowledges that this estimate from 1984 is outdated and relied on density estimates from regional studies to derive a statewide abundance. The agency has since declared that the number of mountain lions throughout the state is unknown, and they have embarked on an intensive statewide research project to better understand mountain lion numbers regionally and throughout the state.[10] Working with other agencies, academic institutions, and non-profits, CDFW plans to have statewide and region-specific mountain lion population estimates by 2022 (Vaughan 2018).

As mentioned in *Section 2.2 Taxonomy and Population Genetics*, one way in which the abundance of mountain lions can be estimated is with the ratio of effective to total adult population size (N_e/N) of 0.25 to 0.5, as was used by USFWS to generate an abundance estimate for the endangered Florida panther (Ballou et al. 1989; USFWS 2008). Using this method with the estimated effective population sizes of the nine genetically distinct mountain lion populations centered in California from Gustafson et al. (2018) and Benson et al. (2019), the statewide total population would be 818 to 1,634 individuals (255 to 510 in the Central Coast and Southern California populations [Table 1], and 563 to 1,124 in the remaining Eastern Sierra Nevada, Western Sierra Nevada, and North Coast populations), which is much lower than the 4,000 to 6,000 estimate. This is also well below the recommended minimum viable population size of at least 5,000 adult individuals for the long-term persistence of a population (Frankham 1995; Reed et al. 2003; Traill et al. 2010). Petitioners recognize that the N_e/N methodology has limitations and is but one method of generating an overall abundance estimate. More studies are needed to determine regional and statewide mountain lion abundance, including CDFW's ongoing efforts which should produce a more scientifically robust statewide abundance estimate.

[10] CDFW 2018 - Commonly Asked Questions About Mountain Lions. Accessed on 11 April 2019 at: https://www.wildlife.ca.gov/Conservation/Mammals/Mountain-Lion/FAQ#359951241-how-many-mountain-lions-are-in-california

Despite unknown statewide population estimates, researchers have been closely tracking several of the Central Coast and Southern California populations. Through their published studies and reports they provide some insights regarding abundance and population trends for these populations.

5.1 Central Coast North (CC-N) Mountain Lion Population

Studies on the CC-N mountain lion population are limited, and abundance and population trends are unknown. However, with an effective population size of 16.6 (Gustafson et al. 2018), and an N_e/N of 0.25 to 0.5 (Ballou et al. 1989; USFWS 2008), the estimated total adult population would be 33 to 66 individuals (see Table 1). As mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, these numbers are grossly insufficient to prevent inbreeding depression in the short term or maintain evolutionary potential in the long term (Jamieson and Allendorf 2012; Frankham et al. 2014).

Gustafson et al. (2018) found that this population has low genetic diversity and a low effective population size, which suggests that it is at increased risk of inbreeding depression within five generations and eventual extinction. Ongoing studies in the Santa Cruz Mountains highlight high levels of human-caused mortalities. Depredation kills are the leading cause of death in collared mountain lions in the Santa Cruz Mountains (Wang et al. 2017), and CDFW reported 34 depredation kills between 2010 and 2016 in the CC-N counties of Alameda, Contra Costa, San Mateo, Santa Clara, and Santa Cruz (see Appendix A[11]). In addition, at least six mountain lions have been killed by vehicle strikes on Highway 17 in the Santa Cruz Mountains between 2008 and 2018 (Midpensinsula Regional Open Space 2017; Slade 2018) and news outlets reported at least three mountain lions killed by vehicle strikes on the I-280 in San Mateo County between 2014 and 2016 (Wilmers 2014, CBS SF 2015, Kamala 2016). The poor genetic health of the CC-N population is likely due to habitat fragmentation and isolation caused by roads and development combined with high levels of human-caused mortalities. CDFW has identified the Santa Cruz Mountains population as at risk due to current habitat and genetic concerns, at-risk internal habitat and connectivity, limited external connectivity, and lack of protected habitat (Dellinger 2019). Poor connectivity and continued development in the CC-N will likely lead to further isolation, increased human-caused mortalities, decreased genetic diversity, and increased risk of extinction in the foreseeable future.

5.2 Central Coast Central (CC-C) Mountain Lion Population

Studies on the CC-C mountain lion population are limited, and abundance and population trends are unknown. However, with an effective population size of 56.6 (Gustafson et al. 2018), and an N_e/N of 0.25 to 0.5 (Ballou et al. 1989; USFWS 2008), the estimated total adult population would be 113 to 226 individuals (see Table 1).

Although Gustafson et al. (2018) found that this population has intermediate levels of genetic diversity and the highest effective population size among the Central Coast and Southern

[11] These data were downloaded from the CDFW website; however, they no longer appear to be available online. These numbers have been shown to be low by a factor of two in some areas, likely due to incomplete reporting, and therefore should be considered absolute minimums (W. Vickers, *pers comm*).

California mountain lion populations, with an effective population size of 56.6, it just barely exceeds the older standard of 50 to prevent inbreeding depression in the short-term (Frankham et al. 2014; Gustafson et al. 2018). In addition, it falls well below the recommended newer standard of 100 and is insufficient for the long-term viability of the population (Frankham et al. 2014). And the lack of sufficient protected lands and high rates of development in the area threaten the persistence of this population (Dellinger 2019). Thus, although the CC-C population appears to be the healthiest population in the Central Coast and Southern California, it is still at increased risk of inbreeding depression and extinction, and connectivity to smaller adjacent areas should be improved (Dellinger 2019).

5.3 Central Coast South (CC-S) Mountain Lion Population

The NPS has been studying the CC-S population since 2002, though most studies regarding population dynamics focus on the Santa Monica Mountains mountain lions (Riley et al. 2014; Benson et al. 2019). Since 2002, NPS has collected data from 55 mountain lions within the Santa Monica Mountains and 19 mountain lions from the Simi Hills and Santa Susana Mountains.[12] There are currently 20-25 live mountain lions being tracked in the Santa Monica Mountains, 7-12 of which are adults (born in 2014 or earlier, the status of 5 adults are unknown) and 13 of which are juveniles or subadults (born in 2015 or later).[13] Given that the Santa Monica Mountains area is relatively small, adult survival rate is high (≥ 75%), and juvenile/subadult survival is low due to intraspecific strife and the inability to disperse, the Santa Monica Mountains population is likely space-limited and these numbers may represent the Santa Monica Mountains' carrying capacity (Riley et al. 2014; Benson et al. 2019). As mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, the extremely low effective population size and total adult population size are grossly insufficient to prevent inbreeding depression in the short term or maintain evolutionary potential in the long term (Jamieson and Allendorf 2012; Frankham et al. 2014). And CDFW has identified the CC-S population as at risk due to current habitat and genetic concerns, at-risk internal habitat and connectivity, limited external connectivity, and lack of protected habitat (Dellinger 2019).

The long-term survival of the Santa Monica Mountains population is severely threatened due to extreme habitat fragmentation and isolation caused by surrounding roads and development that impede movement in or out of the area (Riley et al. 2014). Limited space and lack of connectivity with suitable mountain lion habitat inhibit dispersal for subadults and likely drive unusually high levels of intraspecific strife, which is the most common cause of mortalities in the

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[12] The NPS provides puma profiles (last updated August-November 2018) of the marked animals (*i.e.*, tagged or radio-collared) they have been studying in the CC-S, which includes those studied in Riley et al. (2014). Some data presented in this section take these data into account. Accessed on 3 April 2019 at: https://www.nps.gov/samo/learn/nature/puma-profiles.htm.

[13] The adult population in the Santa Monica Mountains is generally consistent with the estimated 0.25 to 0.5 N_e/N; the Santa Monica Mountains was estimated to have an effective population size of four (Benson et al. 2019), which would suggest a total adult population size of 8 to 16. Interestingly, Gustafson et al. (2018) estimated an effective population size of 2.7 for the greater CC-S population, which would indicate a total adult population of 5 to 10 individuals throughout the Santa Monica Mountains, Simi Hills, and Santa Susana Mountains (see Table 1). There are currently 10 to 17 adult mountain lions being tracked throughout the CC-S area, which would put their N_e/N ratio at 0.16 to 0.27, which is still within the range of other species' N_e/N ratios (Frankham et al. 1995; Ballou et al. 1989; Mace and Lande 1991; Spong et al. 2000; Laundré and Clark 2003).

area (Riley et al. 2014). Although intraspecific strife is known to occur among mountain lions, there have been multiple cases of aggressive adult males killing their siblings, female offspring, and previous mates documented in the Santa Monica Mountains population, and researchers noted that "clearly this is rarely a sound evolutionary strategy as the survivorship of offspring or siblings is traded against the probability of future reproduction" (Riley et al. 2014). For 23 radio-collared individuals within the Santa Monica Mountains for which the cause of death is known, nine deaths were the result of instraspecific strife. Eight of the nine deaths (89%) were of animals less than four years old. In addition, three uncollared mountain lions in the Santa Monica Mountains less than four years old were found dead by intraspecific strife, which brings the total to 12 deaths by intraspecific strife documented in the Santa Monica Mountains between 2002 and 2018.

Although all subadult males and half of subadult females typically disperse from their natal areas (Logan and Sweanor 2010), only one subadult successfully dispersed from the Santa Monica Mountains between 2002 to 2012 – P-22, the famous male mountain lion who successfully crossed Highway 101 and I-405 freeways and established his home range in Griffith Park (Riley et al. 2014). Unfortunately, P-22 is extremely isolated with the smallest home range ever reported for an adult male (26km^2), and he has not had any opportunities to mate (Riley et al. 2014). In addition, vehicle strikes account for 17% (4/23) of known radio-collared mountain lion deaths in the Santa Monica Mountains. According to the NPS, most males in the Santa Monica Mountains do not live past the age of two. Thus, many healthy, young animals are not able to disperse from the Santa Monica Mountains, establish their own home ranges, and successfully reproduce.

Conversely, lack of connectivity also inhibits migrants coming from outside the Santa Monica Mountains and contributing to the population's gene pool. Only two outside mountain lions have been known to immigrate into the Santa Monica Mountains since 2002: P12 (from Simi Hills, alive as of August 2018, age 12) and P45 (from north of Highway 101, status unknown, age would be 6-7 if alive). While there has been no sign of P-45 since February, 2019 and no offspring from him have been detected, P-12 has been fairly prolific in the Santa Monica Mountains, fathering at least eight litters. Although P-12's appearance initially improved genetic diversity in the Santa Monica Mountains population, consistent immigration in small populations is needed so that the genetic diversity gains of immigrant mountain lions are not lost (Riley et al. 2014; Benson et al. 2016a; Benson et al. 2019). Subsequent inbreeding by P-12 with his daughters and granddaughters and inbreeding already occurring with other breeding adults in the Santa Monica Mountains have led to dangerously low genetic diversity (Riley et al. 2014; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019). With continued isolation, inbreeding, and loss of genetic diversity, there is increasing risk of inbreeding depression and extinction. With inbreeding depression, the probability of extinction within 50 years is predicted to be 99.7 %, with a median time to extinction of 15.1 years (Benson et al. 2016a; Benson et al. 2019).

5.4 Santa Ana Mountains (SAM) Population

Restricted habitat availability and high mortality rates in the SAM likely limits population size, and Benson et al. (2019) estimated that the SAM population is likely comprised of 16 adults and 13 juveniles (kittens and subadults). These numbers are slightly lower than the 31 to 62 adult mountain lions estimated from the SAM population's effective population size of 15.6 (Gustafson et al. 2018) (see Table 1). According to (Benson et al. 2019), high levels of human-caused adult mortalities may limit growth potential in the SAM, and it is uncertain if the population could be larger without as many anthropogenic pressures. In fact, although hunting is illegal in California, mountain lions in Southern California have a lower annual survival than many hunted populations (Vickers 2014). Interestingly, other studies calculated a much lower effective population size of 5.1 (Ernest et al. 2014) and four (Benson et al. 2019), which would align with the suggested carrying capacity. Regardless of which effective population size is used, they are all well below the frequently-used threshold of 50 and insufficient to prevent inbreeding depression in the short-term.

Although population trends are unclear, two long-term studies on radio-collared mountain lions in the SAM provide some insight (Beier 1993; Vickers et al. 2015). In a study that consisted of 32 radio-collared animals in the SAM from 1988 to 1993, researchers found a 75% adult survival rate (Beier and Barrett 1993), which is similar to adult survival rates in other populations, like the CC-S population (Riley et al. 2014). However, in a second, more recent study conducted in the area consisting of 31 marked mountain lions from 2001 to 2013, researchers found a 56.5% survival rate across all sexes and age groups (Vickers et al. 2015). The marked decrease in adult survival rate between the two studies coincides with an increase in the proportion of mortalities caused by vehicle strikes, with the 1988-1993 and the 2001-2013 studies resulting in 32% (10/31) and 46% (6/13) of deaths caused by vehicle strikes, respectively (Beier 1993; Vickers et al. 2015). It also parallels an upward trend of mountain lion mortalities caused by vehicle strikes throughout Southern California over time (Vickers et al. 2015). Other causes of death in the SAM population included depredation kills, illegal killing, disease, intraspecific strife, and human-caused wildfires (Beier and Barrett 1993; Vickers et al. 2015). Depredation kills were found to be 3.4 times more likely with males compared to females (Vickers et al. 2015).

The SAM mountain lion population's high adult mortality rates combined with isolation, small size, low genetic diversity, low effective population size, and limited immigration of new individuals cause demographic instability and put the population at high risk of extinction (Beier 1993; Beier and Barrett 1993; Ernest et al. 2014; Vickers et al. 2015; Gustafson et al. 2017; Gustafson et al. 2018; Benson et al. 2019). As mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, the extremely low effective population size and total adult population size are insufficient to prevent inbreeding depression in the short term or maintain evolutionary potential in the long term (Jamieson and Allendorf 2012; Frankham et al. 2014). Roads and development prevent dispersal and sustained immigration in the SAM, and lack of consistent gene flow has led to high levels of inter-relatedness and inbreeding (Ernest et al. 2014; Gustafson et al. 2017; Gustafson et al. 2018; Benson et al. 2019). Further genetic erosion is likely without improved connectivity to facilitate immigration (Benson et al. 2019). CDFW has identified the SAM population as at risk due to current habitat and genetic concerns, at-risk internal habitat and

connectivity, limited external connectivity, and lack of protected habitat (Dellinger 2019). If inbreeding depression occurs within this population, population growth will likely decline and the probability of extinction within 50 years is predicted to be 100%, with a median time to extinction of 11.7 years (Benson et al. 2019).

In 13 years, only one radio-collared individual crossed I-15, the major barrier between the SAM and the EPR, and that animal was killed 25 days after his crossing for depredating domestic sheep (Vickers et al. 2015). And although Gustafson et al. (2017) documented three males immigrating into the SAM from the EPR and four males emigrating from the SAM to the EPR over a 15-year period, only one of the males (M86, an immigrant to the SAM) is known to have successfully bred. While M86 improved the SAM population's genetic diversity (Gustafson et al. 2017), high levels of mortalities due to vehicle strikes and depredation/illegal killings likely reduce the number of immigrants that can successfully establish as breeding adults (Vickers et al. 2015). With high levels of adult mortalities due to vehicle strikes, depredation kills affecting 3.4 times more males than females, and a small population with a female-biased adult sex ratio, there is potential for occasional male extinction in the SAM, which could severely limit the short- and long-term viability of the population (Beier and Barrett 1993; Benson et al. 2019).

5.5 San Gabriel/San Bernardino Mountains (SGSB) Population

Studies on the SGSB mountain lion population are limited, and the abundance and population trends are unknown. However, with an effective population size of 5 (Gustafson et al. 2018), and an N_e/N of 0.25 to 0.5 (Ballou et al. 1989; USFWS 2008), the estimated total adult population would be 10 to 20 individuals (see Table 1). As mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, these numbers are grossly insufficient to prevent inbreeding depression in the short term or maintain evolutionary potential in the long term (Jamieson and Allendorf 2012; Frankham et al. 2014). And CDFW has identified the SGSB population as at risk due to current habitat and genetic concerns, at-risk internal habitat and connectivity, limited external connectivity, and lack of protected habitat (Dellinger 2019).

Although a population viability study has not been conducted for the SGSB population, given its low genetic diversity, low effective population size, and patterns of isolation due to roads and development creating movement barriers (Gustafson et al. 2018), the SGSB mountain lion population likely has high risk of inbreeding depression and extinction. The loss of this population could undermine genetic connectivity for mountain lions statewide because the SGSB population, along with the Tehachapi and Sierra Pelona Mountains, represents a critical linkage between mountain lion populations in the northern and southern mountain ranges of California (Gustafson et al. 2018). Restoration and enhancement of connectivity in the SGSB and surrounding mountain ranges are key for the continued survival of the SGSB population as well as all of the Central Coast and Southern California mountain lion populations.

5.6 Eastern Peninsular Range (EPR) Population

Studies on the EPR mountain lion population are limited and the abundance and population trends are unknown. However, with an effective population size of 31.6 (Benson et al. 2019), and an N_e/N of 0.25 to 0.5 (Ballou et al. 1989; USFWS 2008), the estimated total adult

population would be 63 to 126 individuals (see Table 1). As mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, these numbers are insufficient to prevent inbreeding depression in the short term or maintain evolutionary potential in the long term (Jamieson and Allendorf 2012; Frankham et al. 2014).

Vickers et al. (2015) followed 43 marked mountain lions in the EPR from 2001 to 2013, and their study provides some insight regarding survival rate and causes of mortality. Annual survival rate was found to be 55.4% in the EPR, which is similar to the SAM population (Vickers et al. 2015). The primary causes of death of marked mountain lions were depredation kills (26% [6/23]) and vehicle strikes (17% [4/23]). When assessing mountain lion death data from CDFW from 1981 to 2013, depredation and vehicle strikes accounted for about 70% of mountain lion deaths in the EPR: 40% (62/154) by depredation kills and 30% (46/154) by vehicle strikes (Vickers et al. 2015).

Although the EPR population was found to have the highest genetic diversity and effective population size among the Southern California mountain lion populations (Gustafson et al. 2018), movement and genetic studies have shown that the EPR population is largely disconnected from all other California populations (Ernest et al. 2014; Vickers et al. 2015; Vickers et al. 2017; Gustafson et al. 2018). And CDFW has identified the EPR population as at risk due to current habitat and genetic concerns, at-risk internal habitat and connectivity, limited external connectivity, and lack of protected habitat (Dellinger 2019). Thus, high human-caused mortality rates combined with continued development in San Diego, Riverside, and Imperial Counties could lead to further isolation, decreased genetic diversity, increased inbreeding depression, and increased risk of extinction.

6 Factors Affecting Ability to Survive and Reproduce

Female mountain lion, P-23, crossing a road in the Santa Monica Mountains. She was struck by a vehicle and found dead near Malibu Canyon Road in January 2018. Photo: NPS

Most, if not all, factors affecting the ability of the Southern California and Central Coast mountain lion populations to survive and reproduce are caused by humans. Lack of wildlife connectivity is the primary driver of their potential demise. Habitat loss and fragmentation due to roads and development have led to extreme levels of isolation and high mortality rates, which are driving these populations towards extinction. Continued development in current suitable

mountain lion habitat further threatens these populations. With low genetic diversity and high risk of inbreeding depression due to genetic isolation, vehicle strikes on roads, increased conflicts with humans that lead to depredation kills, high levels of intraspecific strife likely due to limited space and lack of connectivity, rodenticide and other environmental toxicant poisoning, and impacts of more frequent wildfires and climate change, Southern California and Central Coast mountain lions will likely not persist unless there is a concerted effort to restore and enhance functional connectivity between populations and large blocks of heterogeneous habitats.

The populations in Southern California are especially vulnerable to extinction, which is reflected in a 2005 review conducted by the US Forest Service regarding Land Management Plans in the National Forests of Southern California that states the "greatest concern for the long-term health of mountain lion populations on the national forests of southern California is loss of landscape connectivity between mountain ranges and large blocks of open space on private land." [14] The review emphasizes that continued development along with new and wider roads degrade habitat linkages and create movement barriers, and "[w]ithout the national forests and linkages between the mountain ranges and other large habitat preserves, there is not much long term potential for mountain lions in southern California."

Ultimately, the persistence of mountain lions in the Central Coast and Southern California requires maintenance and restoration of connectivity between subpopulations and adequate habitat. The extreme isolation, dangerously low genetic diversity, high levels of inbreeding, and high rates of human-caused mortalities (*e.g.*, vehicle strikes, depredation kills, intra-specific strife due to limited space, rodenticide poisoning, etc.) underscore the urgent need for proactive measures to enhance connectivity (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2017; Benson et al. 2019).

Male mountain lion M110 in San Diego County was euthanized by a CDFW warden because he was severely injured and for stated public safety concerns (he was found in a neighborhood close to homes). This occurred days after he was illegally shot by a livestock owner (open wound on right flank). Necropsy results indicated he had two broken legs consistent with a vehicle strike and four different compounds of anticoagulant rodenticides in his blood. Had he not been euthanized, he likely would have died from starvation due to his injuries. Source: Vickers (2014).

[14] Forest Service, U.S. Department of Agriculture, *Final Environmental Impact Statement, Land Management Plans, Angeles National Forest Cleveland National Forest Los Padres National Forest San Bernardino National Forest* (Sept. 2005), available at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5166889.pdf.

Measures to conserve core habitat areas and functional wildlife corridors, like the recently adopted Habitat Connectivity and Wildlife Movement Ordinances in Ventura County,[15] are vital to the preservation of Central Coast and Southern California mountain lion populations, but just protecting land is not enough to ensure their survival. Conserving natural habitats on both sides of freeways and constructing effective crossing infrastructure (*e.g*., culverts, underpasses, vegetated overpasses, and exclusionary fencing) at existing roads and barriers would facilitate movement and gene flow while reducing mortalities due to vehicle strikes (Riley et al. 2014; Vickers et al. 2015; Benson et al. 2019). Promoting wider implementation of predator-proof enclosures for domestic animals would further reduce human-caused mortalities by limiting opportunities for potential conflict and reducing the use of depredation permits (Vickers et al. 2015). In addition, changes in depredation permit policy could further reduce mortalities. For example, CDFW adopted a new depredation permit policy based on a 2017 bulletin for mountain lions in the CC-S and SAM areas, which requires affirmative non-lethal alternatives and improved husbandry before kill permits are issued when mountain lion depredations occur in those areas (CDFW 2017; see *Section 8.1.1 CDFW Departmental Bulletins*). Expanding these policies in conjunction with enforceable implementation and reporting requirements across the state, or at least into the SGSB, EPR, CC-N, and CC-C, population areas, would reduce mortalities from this source. Prohibiting the use of second-generation anticoagulants, rodenticides, and other environmental toxicants in California (*i.e*., with AB 1788, sponsored by Assembly Member Richard Bloom in 2019) would even further reduce human-caused mortalities of mountain lions, as toxicants bioaccumulate up the food chain and can kill mountain lions or weaken their immune systems and make them more susceptible to disease or more vulnerable to conspecifics (Riley et al. 2003; Riley et al. 2007; Serieys et al. 2015). A combination of habitat conservation, implementation of effective road/barrier crossing infrastructure, and outreach and education to property owners and owners of domestic animals combined with depredation permit policy change could save these populations from extinction (Vickers et al. 2015).

6.1 Low Genetic Diversity and Inbreeding Depression

As detailed in *Section 2.2 Taxonomy and Population Genetics* and *Section 5.0 Abundance and Population Trends*, inbreeding is a serious threat to the persistence of the Central Coast and Southern California mountain lion populations. Inbreeding depression, loss of genetic diversity, and accumulation of deleterious mutations can lead to elevated extinction risk due to reduced reproductive fitness and evolutionary potential (*i.e*., the ability to adapt to change) (Spielman et al. 2004; Frankham 2005; Traill et al. 2010). Decades of isolation due to roads and development fragmenting habitat and limiting connectivity has led to low genetic diversity and effective population sizes, high levels of inter-relatedness, and dangerous levels of inbreeding, especially in the CC-S, SAM, SGSB, and CC-N populations (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Gustafson et al. 2017; Gustafson et al. 2018; Benson et al. 2019). Although demographic and environmental stochasticity (*e.g*., a disease outbreak, wildfire, drought or flooding) can increase risk of extinction, especially in small populations, inbreeding has also been shown to be an indicator of extinction risk and may impact how populations are able to respond to stochastic events (Frankham and Ralls 1998). In addition, endangered species

[15] More information regarding the Habitat Connectivity and Wildlife Movement Ordinances available at: https://vcrma.org/habitat-connectivity-and-wildlife-movement-corridors

tend to have lower genetic diversity than non-endangered species, which suggests that inbreeding and low genetic variation may have an important role in a species' risk of extinction (Frankham and Ralls 1998). Thus, genetic factors should be considered when assessing the status of these populations.

The CC-S, SAM, SGSB, and CC-N populations have been found to have low genetic diversity, with the SAM population's genetic variation nearly as low as the endangered Florida panther's (*Puma concolor coryi*) (Ernest et al. 2014; Riley et al. 2014; Gustafson et al. 2017). And, as mentioned previously in *Section 2.2 Taxonomy and Population Genetics*, the CC-S, SGSB, SAM, CC-N, and EPR populations have effective population sizes well below the older and less conservative threshold of 50, while the CC-C population's effective population size is just barely above that threshold at $N_e = 56.6$ (Ernest et al. 2014; Riley et al. 2014; Benson et al. 2016a; Gustafson et al. 2018; Benson et al. 2019). These numbers suggest that inbreeding depression could occur within the short-term (over the duration of five generations) and these populations are at increased risk of extinction.

Without improved connectivity, the SAM and Santa Monica Mountains (within the CC-S) populations are predicted to experience continued genetic erosion and losses in heterozygosity of 28-49% and 40-57%, respectively, within 50 years (Benson et al. 2016a; Benson et al. 2019). This could lead to inbreeding depression, which could cause reduced fitness in a variety of ways. In Florida panthers, inbreeding depression led to reproductive issues (*e.g.*, poor sperm quality, low testosterone levels, poor fecundity and recruitment, failure of testes to descend), increased susceptibility to parasites and disease, and physical issues (*e.g.*, atrial septal defect, a deadly congenital heart defect; kinked tails) (Roelke et al. 1993; Johnson et al. 2010). Suffering from shrinking, fragmented habitats, high mortality rates from hunting, and inbreeding depression, the Florida panther population declined to less than 30 individuals, and genetic restoration via the translocation of eight female mountain lions from Texas (*Puma concolor stanleyana*) was needed to prevent their extinction (Johnson et al. 2010).

The SAM and CC-S populations are severely constrained in fragmented habitats with similar numbers as the Florida panther population prior to genetic rescue (Beier and Barrett 1993; Johnson et al. 2010; Riley et al. 2014; Vickers et al. 2015). Although the fragmented populations appear to be stable, high levels of inbreeding have been documented in the Santa Monica Mountains (Riley et al. 2014) and evidence of inbreeding depression (*i.e.*, low genetic diversity and kinked tails) has been observed in the SAM (Ernest et al. 2014). If these populations remain isolated, they will inevitably have the same fate as the Florida panthers. Researchers predict that with inbreeding depression, the SAM and Santa Monica Mountains populations have a 100% and 99.7% chance of becoming extinct within 50 years, with median time to extinction of 11.7 and 15.1 years, respectively (Benson et al. 2019).

The SGSB population was also found to have low genetic diversity and effective population size (Gustafson et al. 2018), which suggests that the population experienced a prior genetic bottleneck and inbreeding is likely. Although genetic studies on this population are limited, it is clear that continued development in and around the SGSB will further isolate the population and lead to more inbreeding and even lower genetic diversity, which will drive the population faster towards extinction. It is important to note that despite only limited gene flow

between the SGSB population and the Western Sierra Nevada, CC-C, and the EPR (Gustafson et al. 2018), this population represents a critical linkage between mountain lion populations in the northern and southern mountain ranges of California. Restoration and enhancement of connectivity is key for the continued survival of the SGSB population as well as all of the other the Central Coast and Southern California mountain lion populations.

Gustafson et al. (2018) found that the EPR population also exhibits a prior genetic bottleneck. The EPR population was found to be largely disconnected from all the other California populations, with limited gene flow and low connectivity with the SAM and SGSB populations (Gustafson et al. 2018). Movement patterns and genetics indicate potential isolation from other populations (Vickers et al. 2015; Gustafson et al. 2017; Gustafson et al. 2018), and continued development in these areas will likely lead to further isolation, genetic drift, and risk of extinction similar to what is being observed in the CC-S, SAM, and SGSB populations.

Although genetic studies are limited for the CC-N population, it was found to have low genetic diversity and low effective population size (Gustafson et al. 2018), which forewarns of inbreeding depression and increased risk of extinction. CDFW has identified the Santa Cruz Mountains mountain lion population, which occurs within the CC-N area, as vulnerable to decline and extinction due to fragmentation from roads and development as well as lack of protected habitat (Dellinger 2019).

Studies suggest that one immigrant every 1-2 years would reduce extinction risk in the SAM and Santa Monica Mountains populations (Beier and Barrett 1993; Gustafson et al. 2017; Benson et al. 2019). This may apply to the other populations with low genetic diversity and effective population size (Gustafson et al. 2018). Increasing connectivity throughout the Central Coast and Southern California would address issues of inbreeding by facilitating movement between populations, increasing effective population size, and reducing high mortality rates driven by vehicle strikes and depredation. Thus, proactive measures to effectively restore and enhance connectivity are needed to minimize risk of inbreeding depression and extinction in Central Coast and Southern California populations.

6.2 Vehicle Strikes

In California, an estimated 100 mountain lions are killed every year by vehicle strikes (Pollard 2016). In the Central Coast and Southern California, vehicle strikes represent a significant threat to the persistence of mountain lion populations, though Southern California has more documentation regarding this issue. The number of mortalities caused by vehicle strikes has been increasing in Southern California since the 1980s, and vehicle strikes account for a high proportion of deaths in mountain lions in the SAM, CC-S, and EPR (Beier and Barrett 1993; Riley et al. 2014; Vickers et al. 2015:Vickers et al. 2017). From 1981 to 2013 vehicle strikes accounted for 53% (50/94) of mountain lion deaths in the SAM and 30% of mountain lion deaths in the EPR (46/154) (Vickers et al. 2015). Riley reported that 14% (2/14) of collared mountain lion deaths from 2002 to 2012 were due to vehicle strikes, and the NPS reported that 18 mortalities from vehicle strikes occurred between July 2002 and January 2018 in the CC-S (Figure 9). Although the CC-N population is less studied, there is evidence that vehicle strikes are a significant cause of mortalities in this population; at least six mountain lions have been

killed by vehicle strikes on Highway 17 in the Santa Cruz Mountains between 2008 and 2018 (Midpeninsula Regional Open Space 2017; Slade 2018) and news outlets reported at least three vehicle strikes killing mountain lions on the I-280 in San Mateo County between 2014 and 2016 (Wilmers 2014; CBS San Francisco 2015; Kamala 2016). Similarly, in 2018 at least two mountain lions were reported to have been killed by vehicle strikes in San Luis Obispo County in the CC-C (Tanner 2018). Clearly, vehicle strikes are an important cause of mortality for the Central Coast and Southern California mountain lion populations.

Figure 9. Locations of 18 mountain lion vehicle strikes in the Santa Monica Mountains and surrounding areas from July 2002 to January 2018. Source: NPS

High adult mortality rates can have severe consequences, particularly for small populations with female-biased adult sex ratios and low effective population sizes (Beier and Barrett 1993; Benson et al. 2019). Vehicle strikes have been found to affect males and females equally, regardless of age, which can result in relatively high adult male mortalities (Vickers et al. 2015). Low male adult survival increases the risk of extinction, as it could result in occasional extinctions of breeding males and therefore reduced reproductivity (Benson et al. 2019), which has been previously observed in the SAM (Beier and Barrett 1993). In the Santa Monica Mountains, where adult survival is high, vehicle strikes (along with intraspecific strife) make it more difficult for subadults to successfully disperse, which limits breeding opportunities for mountain lions born in the Santa Monica Mountains (Riley et al. 2014; Benson et al. 2019). Freeways and vehicle strikes also limit the ability for immigrants to enter the Santa Monica Mountains and contribute to the population's gene pool (Riley et al. 2014; Benson et al. 2019). These patterns highlight the dire outlook for Central Coast and Southern California mountain lion populations due to lack of connectivity between populations and suitable habitat. The continued construction of roads and development and inaction to enhance connectivity threatens the survival of these struggling populations.

6.3 Depredation and Illegal Kills

Mountain lions killed on depredation permits (and one killed by vehicle strike) in San Diego County in 2015. Source: Vickers et al. (2017).

In 1990 California voters passed The California Wildlife Protection Act (Proposition 117), making the mountain lion a "specially protected species" and outlawing mountain lion sport-hunting in California. However, the law requires CDFW to issue depredation permits that allow people to "take" mountain lions when a mountain lion kills or injures domestic animals such as livestock or pets or damages property. The legal definition of "take" is to "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill" (Cal Fish & Game Code, *§86*), and the vast majority of permits to take in the three decades since the passage of Proposition 117 have authorized killing one or more mountain lions. The number of depredation permits issued and the number of reported kills has varied over time, and on average over 40% of permits result in reported kills. Since 1990 there has been an average of 97 reported depredation kills every year; however, these estimates are likely low due to underreporting and incomplete records (W. Vickers, *pers comm*). Depredation kills (along with vehicle strikes) account for the majority of mountain lion mortalities in the SAM and EPR (Vickers et al. 2015; Vickers et al. 2017). Although less is known about depredation kill impacts in the CC-N and CC-C, there is evidence that suggests depredation kills could be a significant source of mortality in these populations. In the Santa Cruz Mountains in the CC-N, depredation kills are the leading cause of death in collared mountain lions (Wang et al. 2017), and CDFW reported 34 depredation kills between 2010 and 2016 in the CC-N counties of Alameda, Contra Costa, San Mateo, Santa Clara, and Santa Cruz (see Appendix A[16]). Although population dynamics are even less studied in the CC-C, between 2010 and 2016 there were 46 reported depredation kills in the counties of Monterey, San Benito, San Luis Obispo, and Santa Barbara (See Appendix A[*Id.*]).

[16] These data were downloaded from the CDFW website; however, they no longer appear to be available online. These numbers have been shown to be low by a factor of two in some areas, likely due to incomplete reporting, and therefore should be considered absolute minimums (W. Vickers, *pers comm*).

An illegally killed mountain lion in San Mateo County. Photo: Tiffany Yap

Depredation kills result in more deaths in male mountain lions compared to female mountain lions. Statewide, of mountain lions killed for depredation in 2017, 68% were males (CDFW 2018), and from 1981 to 2013, there were 3.4 times more male than female mountain lions killed for depredating in the SAM and EPR (Vickers et al. 2015). The majority of lions reported killed for depredating were of subadult (1-2 years old) and adult mountain lions (>2 years old) (CDFW 2018), many of which were likely dispersers that may have not yet established home ranges. Dispersing lions often come up against roads and development as they search to establish home ranges (Beier 1995, Vickers 2015, Riley 2014). This suggests that even if individuals are able to navigate across roads and freeways without being struck by vehicles, they often come into conflict with humans, which threatens their survival. This was reflected in the EPR, when the only GPS collared immigrant to have crossed I-15 from 2001 to 2013 arrived from the SAM only to be killed on a depredation permit 25 days after his arrival for depredating a sheep (Vickers et al. 2015). Not only do lions killed for depredating diminish the total abundance of these populations, but because males are predominantly killed, the number of animals that are the primary gene dispersers are also greatly reduced, which further inhibits adequate genetic connectivity (Vickers et al. 2017).

Reported depredation kills do not include mountain lions that are illegally poached or killed, many of which likely go undocumented (Beier and Barrett 1993; Vickers et al. 2015). Illegal kills have been observed in the CC-S, SAM, and EPR (Beier and Barrett 1993; Riley et al. 2014; Vickers et al. 2015) as well as in the CC-N (Yap 2018 *pers observation*), and although 80 mountain lions were reported as being killed under depredation permits in 2017, 89 deaths were being investigated (CDFW 2018).

As mentioned in *Section 6.2 Vehicle Strikes*, high levels of mortalities among male breeders or potential male breeders (*i.e*., dispersers) can have severe impacts on small, isolated mountain lion populations with female-biased adult sex ratios and low effective population sizes (Beier and Barrett 1993; Benson et al. 2019). Low survival of breeding males increases extinction risk, as occasional breeding male extinctions can occur and therefore reduce reproductivity throughout the population (Beier and Barrett 1993; Benson et al. 2019). And low survival of subadults and adults may limit both dispersers and immigrants from successfully

breeding and increasing genetic diversity (Vickers et al. 2015; Benson et al. 2019). Thus, depredation and illegal kills in conjunction with lack of connectivity between populations and suitable habitat in the Central Coast and Southern California severely limit the potential for these populations to survive and reproduce. Continued development and lack of connectivity will likely push mountain lions into more conflicts with humans, which could increase depredation and retributory kills and further drive these populations towards extinction.

6.4 Intraspecific Strife

Intraspecific strife: a female mountain lion, P-7, was killed by her father, P-1. Photo: NPS

As detailed in *Section 5 Abundance and Population Trends*, intraspecific strife is the leading cause of mortality in the Santa Monica Mountains (Riley et al. 2014). Although intraspecific strife is a common source of mortality in mountain lion populations, (Beier and Barrett 1993; Logan and Sweanor 2001; Allen 2014), unusually high levels of intraspecific strife have been observed in this population (Riley et al. 2014). About 41% (9/22) of deaths in radio-collared mountain lions being tracked from 2002 to 2018 were from intraspecific strife,[17] with multiple cases of aggressive adult males killing their siblings, offspring (male and female), and previous mates (Riley et al. 2014). While males are likely to have larger home ranges to protect food resources and access to females, killing offspring or potential mates has no apparent evolutionary benefit, as it reduces chances of future reproduction (Riley et al. 2014). In addition, infanticide has been documented in the Santa Monica Mountains (Riley et al. 2014), perhaps to trigger the female to come into estrous. These high levels of intraspecific strife are likely due to limited space in the Santa Monica Mountains caused by dispersal barriers (Riley et al. 2014; Benson et al. 2019). As roads and development further encroach on Central Coast and Southern California mountain lion populations, intraspecific strife could become more common; this was

[17] The NPS provides puma profiles (last updated August-November 2018) of the marked animals (*i.e.*, tagged or radio-collared) they have been studying in the CC-S, which includes those studied in Riley et al. (2014). Some data presented in this section take these data into account. Accessed on 3 April 2019 at: https://www.nps.gov/samo/learn/nature/puma-profiles.htm.

documented in the SAM on two occasions (one GPS-collared, one previously GPS-collared) since the publication of Vickers et al. (2015) (W. Vickers *unpublished data*). Enhanced connectivity between populations and suitable habitat would facilitate dispersal, which would reduce and/or prevent high levels of intraspecific strife (Riley et al. 2014; Benson et al. 2019) and improve the survival and reproduction rates, especially for the most struggling populations.

6.5 Abandonment

Santa Monica Mountains mountain lion kittens P-57 and P-58 were abandoned by their mother, P-42, a first-time mother who left with male P-27 and never returned. Photo: NPS

Abandonment of kittens is fairly common in the Santa Monica Mountains and accounts for about 23% (5/22) of the known causes of death for marked/collared animals.[18] Although this likely occurs in other mountain lion populations, the causes of abandonment are unclear. There are various reasons why females might abandon their cubs. The cubs could be sick, the female may not be able to take care of them, or perhaps the female was initially protecting them from a mature male. Unfortunately, there is a lack of data regarding why and how often cubs get abandoned. Yet this is one of the main causes of death for mountain lions in the Santa Monica Mountains, which likely affects this already-small population.

Mountain lion cubs can also become orphaned if the mother is killed before they have dispersed. If they are too young to fend for themselves, they likely starve to death or are preyed upon by other predators. If the young are more mobile, they may come up against areas where they are more likely to encounter humans as they search for food. This was seen in November 2017, when a mother mountain lion was killed by a vehicle strike in the SAM and two of her cubs were found roaming near human establishments – one in a backyard and the other along a road (Veklerov 2018). Both were too young to survive on their own and were placed in the Oakland Zoo.

[18] Id.

6.6 Poisoning from Rodenticides and Other Environmental Toxicants

The famous mountain lion of Griffith Park, P-22, suffering from notoedric mange, a parasitic skin disease that has been linked with the ingestion of rodenticide poisoning (left) and mountain lion P-34 found dead on a trail due to rodenticide poisoning (right). Photos: NPS

Although mountain lions are not the primary target of environmental toxicants, such as rodenticides and other pesticides and herbicides, secondary poisoning has been documented in many non-target animals, especially predators (e.g., coyotes (Riley et al. 2003), bobcats (Riley et al. 2007; Serieys et al. 2015), San Joaquin kit fox (McMillin et al. 2008), California fishers (Gabriel et al. 2012), raptors (Lima and Salmon 2010), and many more). Data regarding pesticide poisoning in mountain lions are limited; however, there is evidence that these big cats are likely vulnerable to similar negative impacts that other predators experience, including direct death, weakened immune systems, and vulnerability to predators or conspecifics (Riley et al. 2003; Riley et al. 2007; Serieys et al. 2015; Rudd et al. 2019).

While poisoning can sometimes lead to direct death, rodenticide exposure has also been associated with notoedric mange, a parasitic skin disease that has led to high levels of mortalities, population declines, and even local extirpations in Southern California bobcats (Riley et al. 2007; Serieys et al. 2015). Although the link between rodenticide poisoning and mange is not as clear in mountain lions, since 2002 five mountain lions in the CC-S have been found suffering from mange, and researchers suspect that rodenticide poisoning may have played a role (Reyes-Velarde 2019a). In addition, of four dead mountain lions in the Santa Monica Mountains that were found to have rodenticides in their systems, two died from poisoning and two died from intraspecific strife, and it is possible that indirect effects of poisoning may have prevented the mountain lions from escaping conflict or fighting back (Riley et al. 2007). And rodenticide poisoning is suspected to be the cause of death in mountain lion P-47, who was recently found dead in Santa Monica Mountains (Reyes-Velarde 2019b), and CC-N mountain lion 36m, who was found dead in the Santa Cruz Mountains in 2015 (Wilmers 2015).

The Department of Pesticide Regulation (DPR) analyzed data provided by CDFW and found that 92% (59/64) of tested mountain lions from throughout the state had detectable levels of anticoagulant rodenticides, which indicates alarmingly high exposure rates (DPR 2018). This has been found to be true in the CC-S as well, where researchers have found that 94% (17/18) of mountain lions tested had traces of rodenticides in their systems (Reyes-Velarde 2019a).

Rodenticides have been implicated in mountain lion mortalities in the CC-S, and in the SAM anticoagulant rodenticide residues were detected in the livers of 100% of deceased animals tested, with up to five different compounds being detected in some animals (Riley et al. 2007; Riley et al. 2014; W. Vickers, *pers comm*). And a study conducted by CDFW and the Integral Ecology Research Center (IERC) has found that mountain lions are being exposed to dangerously high levels of illegal pesticides, such as carbofuran, being used on illegal marijuana grow sites, which can also bioaccumulate and cause health issues (Rudd et al. 2019). Furthermore, it is possible that herbicide exposure from deer could be detrimental to mountain lions as well. Although poisoning from environmental toxicants may not constitute a large proportion of direct deaths (that we are aware of), it is possible that high exposure levels influence other causes of mortalities. Any additional mortalities in the small, isolated Central Coast and Southern California populations suffering from other anthropogenic pressures could impact the short- and long-term survival of these mountain lions.

6.7 Wildfires

After the Woolsey Fire, the body of mountain lion P-64, known to use culverts to cross the Hwy-101 and SR-118 freeways a total of 41 times, was found dead with severely burned paws. Photos: NPS

Although fire is a natural disturbance in California ecosystems, sprawl development with low/intermediate densities extending into habitats that are prone to fire have led to more frequent wildfires that burn larger areas (Syphard et al. 2007; Syphard et al. 2009). Most wildfires in California are caused by human ignitions, like power lines, arson, improperly disposed cigarette butts, debris burning, fireworks, campfires, or sparks from cars or equipment (Keeley and Fotheringham 2003; Syphard et al. 2007; Syphard et al. 2012; Bistinas et al. 2013; Balch et al. 2017; Radeloff et al. 2018; Syphard et al. 2019). In fact, human-caused fires account for 95-97% of all fires in California's Mediterranean habitats (Syphard et al. 2007, Balch et al. 2017). In addition, climate change is leading to hotter, drier conditions that make fires more likely to burn. At least 29 fires throughout California in the last two years were caused by electric power and distribution lines, and transmission lines are suspected to be the cause of last year's Camp Fire and Woolsey Fire (Atkinson 2018; Chandler 2019).

Increased frequency of wildfires poses a threat to the survival of Central Coast and Southern California mountain lions. Although mountain lions are highly mobile and generally able to move away from wildfires, in severe weather conditions wind-driven fires can spread quickly – they can cover 10,000 hectares in one to two days, as embers are blown ahead of the

fires and towards adjacent fuels (*e.g*., flammable vegetation, structures) (Syphard et al. 2011). If their movement is constrained by roads and development and they are unable to access escape routes, then their chances of surviving wildfires are greatly reduced. Vickers et al. (2015) documented one death of a collared mountain lion in the SAM and one in the EPR due to human-caused wildfires, and the deaths of two collared mountain lions in the CC-S in 2018 have been attributed to the Woolsey Fire.[19] Environmentally stochastic events (*e.g*., wildfires, flooding) could destabilize small mountain lion populations and make them vulnerable to extinction (Benson et al. 2016a; Benson et al. 2019). In addition, increased frequency of fire ignitions can cause shifts in natural fire regimes, which can lead to large-scale landscape changes, such as vegetation-type conversion or habitat fragmentation, which can impact wide-ranging species like the mountain lion (Jennings 2018).

Increasing landscape connectivity (*e.g*., by designing corridors, removing barriers, and preserving habitats that are close to each other) is important for resilience to environmentally stochastic events and climate change adaptation (Heller and Zavaleta 2009). Enhanced connectivity that incorporates corridor redundancy (*i.e*. the availability of alternative pathways for movement) would allow for improved functional connectivity and resilience. Compared to a single pathway, multiple connections between habitat patches increase the probability of movement across landscapes by a wider variety of species, and they provide more habitat for low-mobility species while still allowing for their dispersal (Mcrae et al., 2012; Olson & Burnett, 2008; Pinto & Keitt, 2008). In addition, corridor redundancy provides resilience to uncertainty, impacts of climate change, and extreme events, including wildfires, by providing alternate escape routes or refugia for animals seeking safety (Cushman et al., 2013; Mcrae et al., 2008; Mcrae et al., 2012; Olson & Burnett, 2008; Pinto & Keitt, 2008).

6.8 Climate Change

A strong, international scientific consensus has established that human-caused climate change is causing widespread harms to human society and natural systems, and climate change threats are becoming increasingly dangerous. In a 2018 *Special Report on Global Warming of 1.5°C* from the Intergovernmental Panel on Climate Change (IPCC), the leading international scientific body for the assessment of climate change describes the devastating harms that would occur at 2°C warming, highlighting the necessity of limiting warming to 1.5°C to avoid catastrophic impacts to people and life on Earth (IPCC 2018). In addition to warming, many other aspects of global climate are changing. Thousands of studies conducted by researchers around the world have documented changes in surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor (USGCRP, 2017).

Climate change is increasing stress on species and ecosystems, causing changes in distribution, phenology, physiology, vital rates, genetics, ecosystem structure and processes, and increasing species extinction risk (Warren et al., 2011). A 2016 analysis found that climate-related local extinctions are already widespread and have occurred in hundreds of species, including almost half of the 976 species surveyed (Wiens 2016). A separate study estimated that nearly half of terrestrial non-flying threatened mammals and nearly one-quarter of threatened

[19] Id.

birds may have already been negatively impacted by climate change in at least part of their distribution (Pacifici et al. 2017). A 2016 meta-analysis reported that climate change is already impacting 82% of key ecological processes that form the foundation of healthy ecosystems and on which humans depend for basic needs (Scheffers et al. 2016). Genes are changing, species' physiology and physical features such as body size are changing, species are moving to try to keep pace with suitable climate space, species are shifting their timing of breeding and migration, and entire ecosystems are under stress (Cahill et al., 2012; Chen et al., 2011; Maclean & Wilson, 2011; Parmesan, 2006; Parmesan & Yohe, 2003; Root et al., 2003; Warren et al., 2011).

Improving landscape connectivity is a key factor for climate change resilience and adaptation (Heller and Zavaleta 2009). Without functional connectivity that provides multiple pathways for mountain lion movement, isolated Central Coast and Southern California mountain lion populations and the prey they depend on may not be able to shift their ranges as available resources shift. Enhanced connectivity that provides redundant corridors for safe passage between suitable habitats would improve chances of survival and reproduction in the face of climate change by increasing the probability of movement across landscapes by a wider variety of species and providing alternate escape routes or refugia for animals seeking safety (Mcrae et al. 2008; Pinto and Keitt 2008; Mcrae et al. 2012; Cushman et al. 2013; Olson and Burnett 2013).

7 Degree and Immediacy of Threat

As demonstrated in the previous sections, Central Coast and Southern California mountain lions are at risk of extirpation under current conditions. Roads and development have fractured connectivity, which has led to the separation of at least six isolated, genetically distinct populations in the CC-N, CC-C, CC-S, SAM, SGSB, and EPR (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Benson et al. 2019). Due to extreme isolation and high levels of human-caused mortalities, the SAM and CC-S mountain lions have low genetic diversity, low effective population sizes, and high levels of inbreeding (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Benson et al. 2019). Benson et al. (2019) predicted high losses of heterozygosity in the SAM and Santa Monica Mountains populations, which suggests that inbreeding depression is imminent. If inbreeding depression occurs, the SAM and Santa Monica Mountains/CC-S populations will likely go extinct within 50 years, with median times to extinction of 11.7 years and 15.1 years, respectively (Benson et al. 2019). With similarly low genetic diversity and effective population size, the SGSB and CC-N populations likely have a similar fate. And although the CC-C and EPR populations appear to be slightly healthier with more genetic diversity and a higher effective population size, these populations have effective population sizes that are still well below the most recent recommended threshold to prevent inbreeding depression in the short-term (Frankham et al. 2014; Gustafson et al. 2018); continued development in these areas could propel these populations towards extinction more quickly. Clearly, Central Coast and Southern California mountain lion populations are succumbing to anthropogenic pressures, and without immediate action to restore and enhance connectivity between the populations and suitable habitat, they will be lost, potentially within our lifetimes.

Immediate action is critical for the long-term persistence of Central Coast and Southern California mountain lions and the health of Central Coast and Southern California ecosystems. Connectivity between the populations and suitable habitat must be restored and enhanced to facilitate movement and gene flow while reducing human-caused mortalities. Anthropogenic pressures, especially vehicle strikes and depredation kills, should be minimized to help the recovery of these populations. Although translocation of outbred animals has been shown to be effective to increase genetic diversity (Johnson et al. 2010), this would only be a short-term, unsustainable solution given the current level of isolation of these populations (Ernest et al. 2014; Riley et al. 2014; Vickers et al. 2015; Benson et al. 2016a; Benson et al. 2019). Strategically-placed road/barrier crossing infrastructure that allows for dispersal and gene flow and reduces mortalities would be a more comprehensive, long-term solution to save these populations in perpetuity. And the preservation of intact linkages, especially the Tehachapi and Sierra Pelona Mountains, is essential to maintain statewide genetic connectivity. Immediate regulatory action under the CESA is needed to enhance connectivity among Central Coast and Southern California mountain lion populations and suitable habitat to ensure the conservation of these iconic big cats.

8 Inadequacy of Existing Regulatory Mechanisms

8.1 State Regulatory Mechanisms

Proposition 117

The California Wildlife Protection Act of 1990 (Proposition 117) declared that the mountain lion is a "specially protected mammal under the laws of this state." (Cal. Fish & Game Code § 4800(a).) Proposition 117 acknowledged that mountain lion habitat in the Santa Monica Mountains, Santa Ana Mountains, Santa Susana Mountains, and Simi Hills is disappearing rapidly and that "[s]mall and often isolated wildlife populations are forced to depend upon these shrinking habitat areas within the heavily urbanizing areas of this state." (Cal. Fish & Game Code § 2780(d).) Proposition 117 further found that "[c]orridors of natural habitat must be preserved to maintain the genetic integrity of California's wildlife." (*Id.*)

In order to preserve mountain lion populations in California, Proposition 117 mandated that mountain lions are not to be considered a "game mammal," such that hunting is generally prohibited. (Cal. Fish & Game Code § 3950.1(a).) Subject to certain exceptions, Proposition 117 makes it unlawful to take, injure, possess, transport, import, or sell a mountain lion. (Cal. Fish & Game Code § 4800(b).) Nonetheless, a mountain lion may still be removed or killed if it is "perceived to be an imminent threat to public health or safety" or is perceived by CDFW to be "an imminent threat to the survival of any threatened, endangered, candidate, or fully protected sheep species." (Cal. Fish & Game Code § 4801.) Mountain lions that have not been designated an "imminent threat to public health or safety" may still be removed via nonlethal means. (Cal. Fish & Game Code § 4801.5(a).)

A person whose livestock or other property has been damaged or destroyed by a mountain lion may request a permit to "take" the mountain lion. (Cal. Fish & Game Code § 4802.) CDFW is required to immediately take action to confirm that there has been a

depredation. (Cal. Fish & Game Code § 4803.) If CDFW is satisfied that there has been a depredation, CDFW "shall promptly issue a permit to take the depredating mountain lion." (*Id.*) There is no limit to the number of depredation permits a property owner can request from CDFW. In addition, mountain lions that are encountered while pursuing or inflicting injury on livestock or domestic animals may be taken immediately without the need for a permit. (Cal. Fish & Game Code § 4807.)

While Proposition 117 prohibits all hunting of mountain lions as well as the purposeful killing of mountain lions in most circumstances, it does not contain provisions to ensure that connectivity between core habitats for the Southern California or Central Coast mountain lions will be protected. As discussed above in *Section 6.0 Factors Affecting the Ability to Survive and Reproduce*, the primary threat to Southern California and Central Coast mountain lions is not hunting—it is habitat fragmentation and the lack of crossing infrastructure, which has led to major declines in genetic diversity, high levels of inbreeding, and high levels of human-caused mortalities via vehicle strikes, depredation kills, and intraspecific strife due to limited space and the inability for young mountain lions to disperse.

8.1.1 CDFW Departmental Bulletins

CDFW has issued "Departmental Bulletins" relating to mountain lions. The most recent bulletin was issued in December 2017 and applied specifically to the Santa Monica Mountains and SAM mountain lion populations (the "2017 Bulletin") (CDFW 2017).[20] The 2017 Bulletin acknowledged (1) the lack of genetic diversity in the Santa Monica Mountains and SAM mountain lion populations and (2) that human population growth and anthropogenic barriers are restricting connectivity with other mountain lion populations. In order to reduce unnecessary killings of mountain lions in the Santa Monica Mountains and SAM populations, the 2017 Bulletin provides that any person reporting a depredation (a "reporting party") may be issued a first permit to employ non-lethal measures to deter mountain lions from further depredation, and a second permit to "haze" a depredating mountain lion. In the first instance, the reporting party would institute economically feasible measures designed to reduce the potential for attracting mountain lions such as removing the carcasses of depredated animals, installing or repairing and consistently using enclosures to exclude mountain lions, or employing guardian animals in the immediate vicinity of livestock or other domestic animals. The 2017 Bulletin provides that CDFW would not be required to issue a lethal depredation permit until (1) a third depredation event has occurred, and (2) CDFW has confirmed that the reporting party has already implemented all reasonable preventative measures.

In January of 2018, CDFW adopted the 2017 Bulletin's new depredation permit policy. Although this provides some additional protections and will likely reduce lethal take of mountain lions in the Santa Monica Mountains and the SAM, researchers have documented instances wherein domestic animal owners killed mountain lions in these areas without complying with CDFW instructions under the new policy (W. Vickers, *pers comm*). The 2017 Bulletin does not apply to other vulnerable populations, like the SGSB, EPR, CC-N, and CC-C mountain lions. In

[20] California Department of Fish and Wildlife, *Human/Wildlife Interactions in California: Mountain Lion Depredation, Public Safety, and Animal Welfare – Amendment to Department Bulletin 2013-02* (Dec. 15, 2017), available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=153021.

addition, the new policy is not designed to ensure protection of habitat or connectivity necessary for the continued survival of the Santa Monica Mountains and SAM mountain lion populations and is insufficient to ameliorate the anthropogenic mortalities related to potential extirpation.

8.1.2 California Environmental Quality Act

The California Environmental Quality Act ("CEQA") is California's landmark environmental law and establishes a state policy to prevent the "elimination of fish or wildlife species due to man's activities, ensure that fish and wildlife populations do not drop below self-perpetuating levels, and preserve for future generations representations of all plant and animal communities...." (Cal. Pub. Res. Code § 21001(c)). Towards this end, state and local agencies are required to analyze and disclose the impacts of any discretionary decision or activity. CEQA contains a substantive mandate that agencies should not approve projects as proposed if there are feasible alternatives or mitigation measures which would substantially lessen the significant environmental effects of such projects. (Cal. Pub. Res. Code § 21002.)

CEQA requires a "mandatory finding of significance" if a project may "substantially reduce the number or restrict the range of an endangered, rare or threatened species." (Cal. Code Regs., tit. 14, § 15065(a)(1).) CDFW has interpreted this provision to apply to species of special concern, which are species that are "experiencing, or formerly experienced, serious (noncyclical) population declines or range retractions (not reversed) that, if continued or resumed, could qualify it for State threatened or endangered status."[21] CDFW further provides that species of special concern "should be considered during the environmental review process." (*Id.*; Cal. Code Regs., tit. 14, § 15380.) Thus, a potentially substantial impact on a species of special concern, threatened species, or endangered species could be construed as "per se" significant under CEQA. (*Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 449.) And under CEQA, when an effect is "significant," the lead agency approving the project must make a finding that changes or alterations have been incorporated into the project to avoid or mitigate its significant impacts, or that such changes are within the responsibility of another agency, or that mitigation is infeasible. (Cal. Pub. Res. Code § 21081(a).) These provisions therefore provide some protections to species that are listed as species of special concern, threatened, or endangered.

However, Southern California and Central Coast mountain lions are not listed as a species of special concern or as threatened or endangered, such that a project that has the potential to significantly impact one of these populations would not necessarily qualify as a "significant effect" under a lead agency's interpretation of CEQA. In such case, CEQA's substantive mandate to adopt all feasible alternatives or mitigation measures might not be triggered.

CEQA also requires a "mandatory finding of significance" if a project may "substantially reduce the habitat of a fish or wildlife species; cause a fish or wildlife population to drop below self-sustaining levels; threaten to eliminate a plant or animal community." (Cal. Code Regs., tit. 14, § 15065.) Moreover, CEQA's "Environmental Checklist" in Appendix G of the CEQA

[21] California Department of Fish and Wildlife, *Species of Special Concern* , available at https://www.wildlife.ca.gov/Conservation/SSC.

Guidelines characterizes a project's effects as "significant" if the project would "interfere substantially with the movement of any native [] wildlife species or with established native resident or migratory wildlife corridors...."

While these provisions might theoretically offer some protection for Southern California or Central Coast mountain lions, in practice they have not provided sufficient protection. Under CEQA, lead agencies have discretion to develop their own thresholds of significance. (*East Sacramento Partnerships for a Livable City v. City of Sacramento* (2016) 5 Cal.App.5th 281, 300; Cal. Code Regs., tit. 14, § 15064(d)). This allows local agencies—who are often under pressure from developers to approve projects—to make significance determinations that are inconsistent with independent scientific analysis, including CDFW's analysis. For instance, in December 2017, the City of Temecula approved a 200-acre mixed use project called the Altair Specific Plan that would allow development in the last remaining viable linkage for the SAM mountain lion population between the Santa Ana Mountains and Peninsular Ranges. The City determined that impacts to mountain lions were not significant despite strong disagreement by CDFW, USFWS, and independent mountain lion experts.[22] CDFW warned the City of Temecula that the SAM population has "extremely low genetic diversity which is attributed to low gene flow between the small Santa Ana Mountains population and the larger population in the Peninsular Ranges" and that development is contributing to this genetic decay. (*Id*.) CDFW concluded that "increased human activity associated with the proposed Civic Site at this sensitive location would [] be detrimental to facilitating the movement of mountain lions across Interstate Highway 15 (I-15) to the Peninsular Range." (*Id*.)

Even when a lead agency acknowledges that an effect is "significant," CEQA allows a lead agency to adopt a "statement of overriding considerations" and approve a project if the agency finds that other factors outweigh the environmental costs of the project or that further mitigation is infeasible. (Cal. Code Regs., tit. 14, § 15093(b); Cal. Pub. Res. Code § 21081.) This means that even if a project may have a significant effect on a "wildlife population" like the CC-S, SAM, SGSB, or EPR mountain lions, an agency could interpret CEQA as still allowing approval of the project. CEQA in practice is therefore inadequate to protect the Southern California and Central Coast mountain lions.

Finally, as noted above, the lack of adequate wildlife connectivity and wildlife crossings is the primary factor driving Southern California and Central Coast mountain lions closer to extinction. Yet, agencies have not interpreted CEQA (or the National Environmental Policy Act, discussed further below) as including a clear legal mechanism for mitigation for impacts on wildlife connectivity. For example, in the Final Environmental Impact Report/Final Environmental Impact Statement for the Northwest 138 Corridor Improvement Project (the "Northwest 138 EIR"), Caltrans and the Los Angeles County Metropolitan Transportation Authority wrote: "The proposed project has the potential to directly or indirectly impact wildlife movement throughout the project limits. However, with the inclusion of the proposed avoidance and minimization measures, impact levels area expected to be relatively low. Exact acres of impacts to wildlife corridors are unable to be quantified, and currently there is no real

[22] City of Temecula, *Altair Specific Plan Final Environmental Impact Report* (Oct. 2017), available at https://temeculaca.gov/DocumentCenter/View/4513/Altair-Specific-Plan-Final-Environmental-Impact-Report-FEIR.

mechanism for compensatory mitigation for these types of impacts."[23] The Northwest 138 EIR also contained no analysis of the highway's impacts on mountain lions, given that they are not presently listed as threatened or endangered.

Indeed, CDFW has urged lead agencies to consider wildlife connectivity in CEQA planning documents, without success. For instance, the Los Angeles County General Plan Draft EIR concluded that the buildout of the General Plan "will impact regional wildlife linkages" and have a "significant adverse effect on wildlife movement."[24] The Draft EIR concluded that policies proposed in the General Plan "do not provide for mitigation for loss of wildlife movement opportunities. If development impacts regional wildlife linkages and impedes wildlife movement, connectivity will be lost on a regional scale in these vital landscape corridors and linkages. Thus impacts to wildlife movement remain significant at the General Plan level." (*Id.*) In commenting on the Draft EIR, CDFW specifically objected to this conclusion:

> The Department does not concur with the conclusion in the DPEIR that unavoidable loss of wildlife movement opportunities or nursery sites within or outside of an SEA does not warrant mitigation. Without mitigation, the Project and subsequent projects would result in direct and cumulative loss of biological diversity. Mitigation opportunities for wildlife corridors and nursery sites are best established during large scale planning efforts such as this General Plan. Wildlife corridor areas can be delineated and set aside in the General Plan for current and future conservation efforts. An assessment could be placed on development within the Project area to secure the acquisition of these critical linkages and sites, therefore reducing impacts to wildlife corridors and nursery sites and ensuring biological diversity.[25]

In responding to this comment, Los Angeles County refused to implement CDFW's recommendations, claiming "it cannot be assumed that wildlife corridor areas for future conservation that can be set aside because those properties may not become publicly owned." (*Id.*) Los Angeles County's responses to CDFW's recommendations underscore that lead agencies have not interpreted CEQA to include a clear legal mechanism for mitigation for impacts on wildlife connectivity, even though such connectivity is critical to the survival of Southern California and Central Coast mountain lions.

8.1.3 Significant Natural Areas Program

The Significant Natural Areas Program ("SNAP") requires CDFW to develop and maintain a spatial data system that identifies those areas in the state that are most essential for maintaining habitat connectivity, including wildlife corridors and habitat linkages. (Cal. Fish & Game Code § 1932(b).) SNAP also requires CDFW to consult with other government agencies and stakeholders to identify natural areas deemed to be most significant. (Cal. Fish & Game

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[23] State of California Department of Transportation, *Northwest State Route 138 Corridor Improvement Project Final Environmental Impact Report / Environmental Impact State and Section 4(f) Evaluation* (June 2017), available at https://www.metro.net/projects/nw138/nw138-FEIR-FEIS/.

[24] County of Los Angeles, *Los Angeles County General Plan Update Draft Environmental Impact Report* (June 2014), available at http://planning.lacounty.gov/assets/upl/project/gp_2035_deir.pdf.

[25] County of Los Angeles, *Los Angeles County General Plan Update Final Environmental Impact Report* (March 2015), available at http://planning.lacounty.gov/assets/upl/project/gp_2035_lac-gpu-final-eir-final.pdf.

Code § 1932(f).) SNAP further requires CDFW to seek maintenance and perpetuation of the state's most significant natural areas for present and future generations in the most feasible manner. (Cal. Fish & Game Code § 1932(g).)

However, SNAP does not require or authorize any particular land use action or decision. (Cal. Fish & Game Code § 1932.5.) Likewise, SNAP does not change or prevent the change of use of any area identified pursuant to the program. (Cal. Fish & Game Code § 1933.) It therefore does not *require* any particular natural areas to be conserved. Because of this, it is insufficient to protection wildlife connectivity essential to the survival of Southern California and Central Coast mountain lions.

8.1.4 Natural Community Conservation Planning Act

The Natural Community Conservation Planning Act is a voluntary conservation planning mechanism for proposed development projects within a planning area to avoid or minimize impacts to wildlife. (Cal. Fish & Game Code § 2801(f).) The NCCP Act is designed to promote coordination among agencies and landowners to conserve unfragmented habitat areas and multihabitat management. (Cal. Fish & Game Code § 2801(d).)[26]

There are no Natural Community Conservation Plans ("NCCPs") that cover the Santa Monica Mountains or San Gabriel Mountains. There are a few NCCPs that cover portions of the Santa Ana Mountains and Eastern Peninsular Ranges, some of which also act as "habitat conservation plans" or "HCPs" pursuant to the Federal Endangered Species Act (16 U.S.C. § 1539). These include the County of Orange (Central Coastal) NCCP/HCP, the Orange County Transportation Authority NCCP/HCP, Western Riverside County Multiple Species HCP, San Diego Multiple Habitat Conservation Program, San Diego Multiple Species Conservation Program, and the San Diego North County Multiple Species Conservation Plan. There also is an NCCP that covers the Coachella Valley and portions of the San Bernardino Mountains called the Coachella Valley NCCP/HCP.

Of these NCCPs, only four "cover" portions of the Southern California mountain lion populations: (1) Western Riverside County Multiple Species HCP; (2) San Diego Multiple Habitat Conservation Program; (3) San Diego County Multiple Species Conservation Program; and (4) San Diego North County Multiple Species Conservation Plan.[27] Below is a discussion of each as they relate to mountain lions:

(1) The Western Riverside County Multiple Species HCP acknowledges that the SAM mountain lion population is at high risk of extirpation due to demographical instability unless there is a "movement connection between the Santa Ana Mountains

[26] The NCCP Act also is described on CDFW's website at https://www.wildlife.ca.gov/conservation/planning/NCCP.

[27] California Department of Fish and Wildlife, *Conservation Plans By Species*, available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=108719&inline. Both San Diego Gas & Electric and San Diego County Water Authority are permittees of HCPs/NCCPs covering mountain lions, but these only apply to activities undertaken by these entities.

and the Palomar Mountains."[28] However, mountain lions are considered to be "adequately conserved."[29] As such, the Western Riverside County Multiple Species HCP offers little protection for the SAM mountain lion population. While this HCP does identify linkages designed to ensure connectivity for mountain lions, the Western Riverside County Regional Conservation Authority has failed to enforce the HCP to protect such linkages when permittees such as the City of Temecula approve development that would severely constrict or impair such linkages.

(2) The San Diego Multiple Habitat Conservation Program is an NCCP and HCP that purportedly covers mountain lions, but the program readily concedes that mountain lions (as well as deer) "were not a major consideration in linkage design."[30] In addition, the EIR/EIS states that "[d]ue to the limited availability of habitat in the study area, implementation of the MHCP is not expected to substantially increase or decrease the population viability of the mountain lion."[31] The EIR/EIS likewise concludes there are no major populations or critical locations for the mountain lion within the plan area, and concludes it is "adequately conserved" under the plan. (*Id.*)

(3) The San Diego Multiple Species Conservation Program is an NCCP and HCP that covers 900 square miles in the southwestern portion of the San Diego. The Program lists mountain lions as "conserved" and states that mountain lions "will be covered by the MSCP because 81% of the core areas (105,000± acres) that support its habitat will be conserved."[32] While the Program generally notes that linkage areas were designed to accommodate "large animal movement," the Program does not identify any linkages designed for mountain lions or any specific measures designed to protect them. Likewise, while the Program states that "[s]pecific design criteria for linkages and road crossings/undercrossings are included in subarea plans," not all subarea plans are complete.

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[28] Western Riverside County Regional Conservation Authority, *Western Riverside County MSHCP Species Accounts*, available at http://wrcrca.conserveriverside.com/wrcrca/Permit_Docs/MSHCP_Docs/volume2/vol2-secb_Mammals.pdf.

[29] Western Riverside County Regional Conservation Authority, *Western Riverside County Multiple Species Habitat Conservation Plan*, available at http://wrcrca.conserveriverside.com/wrcrca/Permit_Docs/MSHCP_Docs/volume1/Vol1-sec2.pdf.

[30] San Diego Association of Governments, *San Diego Multiple Habitat Conservation Program Biological Monitoring and Management Plan (Volume III)* (Mar. 2003), available at https://www.sandag.org/programs/environment/habitat_preservation/mhcp_vol3.pdf.

[31] San Diego Association of Governments, *Final Environmental Impact Statement/Environmental Impact Report for Threatened and Endangered Species Due to Urban Growth within the Multiple Habitat Conservation Program Planning Area* (Mar. 2003), available at https://www.sandag.org/programs/environment/habitat_preservation/mhcp_eir_vol1.pdf.

[32] County of San Diego, *Final Multiple Species Conservation Program* (Aug. 1998), available at https://www.sandiegocounty.gov/content/dam/sdc/pds/mscp/docs/SCMSCP/FinalMSCPProgramPlan.pdf.

(4) The San Diego North County Multiple Species Conservation Plan is one of the "subarea" plans anticipated by San Diego Multiple Species Conservation Program. However, it has not been completed and is still "in development."[33]

(5) The Orange County Transportation Authority NCCP/HCP ("OCTA Plan") lists the mountain lion as a covered species for purposes of the federal HCP, but not for purposes of the NCCP permit. The OCTA Plan acknowledges that despite protection from hunting, annual survival for radio-collared lions is "surprisingly low" at 55.8 percent and that vehicle collisions and depredation permits are primary sources of mortality. The OCTA Plan states that targeted investment in habitat protection is "especially urgent to maintain viability of the Santa Ana Mountains populations."[34] The OCTA Plan does contain four "Species Goals" for mountain lions, including (1) acquiring 1,013 acres of suitable habitat; (2) fencing realignment near the Highway 241 toll road; (3) funding of the North Coal Canyon Restoration Project; and (4) a "wildlife crossing policy" requiring pre-construction surveys to ensure existing crossings "maintain or improve functionality" if modified by new freeway projects. However, despite allowing the expansion of two highways in lion habitat (Projects G and J), the OCTA Plan does not require the construction of any specific wildlife crossings. The OCTA Plan nonetheless claims that impacts on the mountain lion will be offset through these "Species Goals."

There are no NCCPs that cover the Central Coast. In addition, there are no NCCPs that cover portions of the Santa Cruz Mountains except the Santa Clara Valley Habitat Plan. However, this Plan does not cover mountain lions.

8.2 Federal Regulatory Mechanisms

8.2.1 National Environmental Policy Act

The National Environmental Policy Act ("NEPA") is the nation's charter for protection of the environment. (40 C.F.R. § 1500.1(a).) NEPA is designed to ensure that environmental information is available to the public *before* decisions are made or actions taken and to help public officials make decisions based on an understanding of the environmental consequences. (40 C.F.R. § 1500.1(b)-(c).) Federal agencies must prepare an environmental impact statement ("EIS") if it is known that an action will significantly affect the environment, or an environmental assessment ("EA") if the extent of effects are unknown. (42 U.S.C§ 4332; 40 C.F.R. §§ 1502.3 & 1508.9.) NEPA further requires federal agencies to analyze reasonable alternatives to the proposed project. (40 C.F.R. § 1502.14(a)-(c).) NEPA requires the federal agency to consider the degree of adverse effect on a species or its critical habitat designated pursuant to the Federal Endangered Species Act. (*Conservation Cong. v. United States Forest Serv*. (E.D.Cal. 2017) 235 F.Supp.3d 1189, 1207.)

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[33] County of San Diego, *Multiple Species Conservation Program*, available at https://www.sandiegocounty.gov/pds/mscp/.

[34] Orange County Transportation Authority, *Natural Community Conservation Plan/Habitat Conservation Plan* (Nov. 2016), available at https://www.octa.net/pdf/NCCP%20HCP%20FINAL.pdf.

However, agencies have not interpreted NEPA as requiring analysis of impacts to populations that are not currently listed as threatened or endangered, such as the Southern California or Central Coast mountain lions. For instance, Caltrans prepared an Initial Study with Proposed Mitigated Negative Declaration/Environmental Assessment for the State Route 118 Widening Project (the "State Route 118 EA") in October 2017 pursuant to NEPA and CEQA. The State Route 118 EA contains no analysis of whether adding more traffic lanes to State Route 118 will impact mountain lions or degrade wildlife connectivity even though multiple mountain lions have died recently attempting to cross State Route 118.[35]

NEPA also is insufficient to protect Southern California and Central Coast mountain lions because courts have interpreted NEPA as primarily a "procedural" statute. While NEPA does require federal agencies to consider detailed information regarding a project's environmental effects, "NEPA itself does not mandate particular results." (*Winter v. NRDC, Inc.* (2008) 555 U.S. 7, 23.)

8.3 Regional and Local Plans and Policies

8.3.1 Santa Monica Mountains National Recreation Area General Management Plan

The Santa Monica Mountains National Recreation Area General Management Plan ("GMP") was prepared pursuant to NEPA and provides a framework for the management of the Santa Monica Mountains National Recreation Area ("SMMNRA"), which is administered by the National Park Service, California State Parks, and the Santa Monica Mountains Conservancy. The GMP recognizes that the Santa Monica Mountains mountain lion population's ability to survive in the face of large-scale habitat fragmentation and destruction is uncertain.[36] (GMP at 154.) The GMP states that "it is likely that their persistence [] would depend upon their capability of dispersing to and from other habitat areas beyond the Santa Monica Mountains." (GMP at 154; see also GMP at 157.) The GMP identifies the "greatest threat" to natural resource preservation in the SMMNRA as "loss of habitat connectivity from increased development and urban encroachment." (*Id*. at 157.) The GMP concedes that "the situation is especially serious for mountain lions" and lists mountain lions as a "park species of concern." (*Id*. at 157 & 161.) The GMP agrees that improvements to facilitate wildlife movement across freeways or through developments may be necessary, but does not propose or require any specific actions to improve wildlife movement across freeways or through development.

The preferred alternative in the GMP provides for enhancing connectivity of undisturbed habitats in the SMMNRA by creating large expanses of open space. (*Id*. at 292.) In addition, the Las Virgenes Canyon and Liberty Canyon areas are included within the SMMNRA boundary to help provide wildlife connectivity for mountain lions and other large species. (*Id*. at 293.) Even though the GMP recognizes the threats facing the Santa Monica Mountains mountain lion

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[35] National Parks Traveler, *Another Mountain Lion Killed Near Santa Monica Mountains National Recreation Area* (Jan. 27, 2017), available at https://www.nationalparkstraveler.org/2017/01/another-mountain-lion-killed-near-santa-monica-mountains-national-recreation-area.

[36] National Park Service, U.S. Department of Interior, *Santa Monica Mountains National Recreation Area General Management Plan Environmental Impact Statement* (July 2002), available at https://www.nps.gov/samo/learn/management/loader.cfm?csModule=security/getfile&PageID=383979.

population and takes steps to protect this population, the GMP does not apply to lands outside of the SMMNRA and thus is insufficient to address the regional connectivity issues facing the population. Nor does the GMP apply to roads and highways under Caltrans' jurisdiction.

8.3.2 Ventura County Wildlife Connectivity Ordinance

The Ventura County Board of Supervisors adopted an ordinance on March 12, 2019 (the "Connectivity Ordinance") to help facilitate wildlife connectivity and minimize habitat fragmentation for mountain lions, mule deer, California gnatcatchers, bobcats, least bell's vireos, California red-legged frogs, and other species. The Connectivity Ordinance establishes overlay zones called "habitat connectivity and wildlife corridors" ("HCWCs") and "critical wildlife passage areas" ("CWPAs") in which development standards and permitting requirements apply. Development standards include 200-foot setbacks from surface water features such as streams and wetlands, limits on certain wildlife impermeable fencing, encouraging compact siting of development, and prohibiting non-commercial planting of invasive plants. Two of the linkages targeted in the Connectivity Ordinance are the Santa Monica Mountains – Sierra Madre Mountains connection and the Sierra Madre Mountains – Castaic Connection, which connect wildlife habitat in the Santa Monica Mountains, Santa Susana Mountains, Simi Hills, and Los Padres National Forest.

While the Connectivity Ordinance should help allow wildlife to move more easily through private lands between core habitat areas, it would do little to ensure connectivity across major roads and highways because Ventura County does not have jurisdiction over these areas. The ordinance would, however, establish 200-foot setbacks from the exit and entry points of 25 existing road crossings in order to facilitate wildlife movement through the crossings. Caltrans and its road maintenance and improvement activities are not regulated by the Connectivity Ordinance. The Connectivity Ordinance is therefore a step in the right direction but insufficient on its own to address the threats facing the CC-S mountain lion population.

8.3.3 Los Angeles County Significant Ecological Areas Program

Los Angeles County is currently in the process of updating the Significant Ecological Areas ("SEAs") Ordinance. The draft ordinance is intended to protect biodiversity in SEAs from incompatible development and ensure that projects reduce habitat fragmentation and edge effects by providing technical review of impacts and requiring mitigation.[37] Like the Ventura County ordinance, the SEAs designations can lead to compact development and allow wildlife to more easily move across private lands between core habitat areas. However, the SEA ordinance is not specifically designed to protect mountain lions and would not regulate Caltrans and its road maintenance and expansion activities.

[37] Los Angeles County Department of Regional Planning, *Significant Ecological Areas Ordinance Update, Public Hearing Draft* (Feb. 14, 2019), available at http://planning.lacounty.gov/site/sea/wp-content/uploads/2019/02/EX-C-SEA-Ordinance-Public-hearing-Draft-2-14-2019.pdf

8.4 Future Development Will Further Threaten the Survival of Southern California Mountain Lions

Continued development in Southern California is expected to further impair connectivity between core habitat areas, leading to further decreases in genetic diversity for Southern California mountain lions. In the environmental review for Southern California national forest land management plans, the U.S. Forest Service found that impaired connectivity poses a serious threat to Southern California mountain lions: the "greatest concern for the long-term health of mountain lion populations on the national forests of southern California is loss of landscape connectivity between mountain ranges and large blocks of open space on private land."[38] The review warned that private land development in Southern California is "steadily reducing the habitat linkages that wildlife species need to connect large blocks of national forest land with other public and private natural spaces and habitat reserves." The review observed that the "widening of the existing highway system and new highways" are a threat to mountain lions because they create barriers to movement. The review concluded that "[w]ithout the national forests and linkages between the mountain ranges and other large habitat preserves*, there is not much long term potential for mountain lions in southern California.*" The review noted that maintenance and restoration of corridors between large wildlands is essential to conserving mountain lions in Southern California

As anticipated by the U.S. Forest Service's environmental review, private land development is currently being approved on linkage areas without sufficient mitigation for Southern California mountain lions or wildlife connectivity. For instance, the 1,000-acre Northlake Specific Plan ("Northlake") was approved by the Los Angeles County Board of Supervisors on April 2, 2019. The Santa Monica Mountains Conservancy ("SMMC") formally objected to the Board's approval of Northlake, noting that the development would degrade a known wildlife linkage between the Angeles National Forest and Los Padres National Forest.[39] CDFW raised similar concerns about the development because it would impair a linkage that is "highly suitable for regional wildlife movement and connectivity" for mountain lions and other species.[40] The Board of Supervisors approved Northlake notwithstanding the objections and concerns of SMMC and CDFW.

Likewise, the Los Angeles County Board of Supervisors approved the 12,000-acre Centennial Specific Plan ("Centennial") on April 30, 2019, despite SMMC warning the Board that Centennial "would sever the most optimal five-mile-wide habitat linkage across Highway 138 between I-5 and State Route 14."[41]

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[38] Forest Service, U.S. Department of Agriculture, *Final Environmental Impact Statement, Land Management Plans, Angeles National Forest Cleveland National Forest Los Padres National Forest San Bernardino National Forest* (Sept. 2005), available at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5166889.pdf.

[39] Santa Monica Mountains Conservancy, *Draft Supplemental Environmental Impact Report Comments on Northlake Specific Plan Project,* May 22, 2017.

[40] California Department of Fish and Wildlife, *Draft Supplemental Environmental Impact Report Comments on Northlake Specific Plan*, June 12, 2017.

[41] Santa Monica Mountains Conservancy, *Centennial Project Draft Environmental Impact Report Comments County Project No. 02-232*, July 17, 2017.

In the SAM, key linkage and habitat areas remain unprotected and subject to potential or actual development. The Altair Specific Plan discussed in *Section 8 Inadequacy of Existing Regulatory Mechanisms* exemplifies this trend. Other lands in the Santa Ana-Palomar Mountain linkage have been subject to development proposals such as the Temecula Creek Inn (Vickers 2015). The Orange County Board of Supervisors also approved a 6,000-acre development in the Santa Ana Mountains in the "center of puma habitat" (Vickers 2015).[42]

Development in wildlands and linkages will intensify as Southern California's population increases. The Southern California Association of Governments ("SCAG") Program EIR estimates that between 2016 and 2040 the Southern California region will grow by 3.8 million residents and 1.5 million households.[43] The SCAG Program EIR concludes that transportation projects within the SCAG region such as "mixed flow lane projects" and "grade separation projects" may result in significant impacts on wildlife movement, including direct habitat removal and fragmentation that would disrupt corridor functionality. The SCAG Program EIR also acknowledges that "an increase in wildlife-roadway interactions as a result of the development of new transportation projects may increase wildlife injury and fatalities."

The SCAG Program EIR recognizes that "[b]arriers to wildlife movement exist throughout the SCAG region, including large areas of urban development and multilane freeways that cut off regional movement corridors for large migratory species such as mountain lions (*Puma concolor*)." SCAG Program EIR further notes that "wildlife crossings serve to alleviate these barriers and facilitate wildlife movement through the region" and references the planned Liberty Canyon Crossing. However, the Program EIR does not identify any other planned crossings or identify funding for the Liberty Canyon Crossing.

The SCAG Program EIR also confirms that only portions of the lands in the Santa Monica Mountains, SAM, SGSB, and EPR are designated as "open space and recreation" or "undevelopable and protected." Indeed, much of these lands are designated for single family residential or mixed residential. At this time, there are also "vast areas" in Southern California that are undeveloped but are not designated as open space or are otherwise protected, according to SCAG. In addition, agricultural lands are rapidly being converted to urban development throughout Southern California with an estimated 230,000 acres converted between 1996 and 2004 and up to 700,000 acres may be converted by 2030. In short, SCAG recognizes that wildlife connectivity will become even more impaired in the Southern California region due to anticipated growth, but SCAG does not offer any solutions to address the effects of this impaired connectivity on Southern California mountain lions.

Other studies confirm that much of the remaining mountain lion habitat in Southern California is on unprotected lands and at risk of development. According to Burdett et al. (2010), almost half of suitable mountain lion habitat in Southern California (since 1970) is on private lands, of which 35% will be developed by 2030, and other currently contiguous habitat will

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[42] See also Chris Boucly, "New community coming to South County," *The Orange County Register* (Mar. 24, 2012), available at https://www.ocregister.com/2012/03/24/new-community-coming-to-south-county/

[43] Southern California Association of Governments, *Draft Program Environmental Impact Report* (Dec. 2015), available at http://scagrtpscs.net/Documents/2016/peir/draft/2016dPEIR_Complete.pdf.

become fragmented. Hunter et al. (2003) similarly found that 30% of high suitability mountain lion habitat and 76% of medium suitability mountain lion habitat in Southern California is not protected from development. In addition, Zeller et al. (2017) found that only 35% of resource-use patches and 47% of corridors identified in their study area, which encompassed much of the SAM and EPR, were fully protected. Given the extreme isolation, low genetic diversity, and high adult mortality rates from vehicle strikes and depredation kills, increased efforts to protect the species and their habitat are warranted.

Within Riverside County, which covers a significant portion of the Santa Ana Mountains, population growth is expected to be especially high; the Riverside County General Plan predicts that the County's population and housing stock will increase to 3.6 million people and 1.3 million dwelling units by 2035, which constitutes a 65 percent increase.[44] Within San Bernardino County, which encompasses portions of the San Bernardino and San Gabriel Mountains, more than 630,000 people will be added to the County along with 230,000 homes.[45] As urban development overtakes mountain lion habitat and linkage areas throughout the region, conflict with mountain lions, and consequent killing of lions under depredation permits will likely increase. Similarly, use of anticoagulant rodenticides and other environmental toxicants in these areas will likely increase, leading to increased illness and fatalities to "non-target organisms" such as Southern California mountain lions.

Caltrans and local transportation agencies are expected to continue building and expanding roads and highways in Southern California to accommodate actual and anticipated vehicles and development. Caltrans' 2018 State Transportation Improvement Program ("STIP") lists many large-scale road and highway projects planned for Southern California.[46] These include converting SR-71 to a four- and six-lane freeway as well as adding more lanes to the I-15 Freeway adjacent to the SAM,[47] which already acts as a nearly impenetrable barrier to the SAM and EPR mountain lion populations. As noted in *Section 8 Inadequacy of Existing Regulatory Mechanisms*, Caltrans has certified an EIR/EIS to convert the existing two-lane SR-138 into a four or six-lane highway, which will create major barrier between the Tehachapi Mountains and Angeles National Forest. Caltrans also intends to widen SR-118, which will further impair connectivity between the Santa Monica Mountains and Santa Susana Mountains to the detriment of the Santa Monica Mountains mountain lions. There are numerous other road and highway projects planned for Southern California in the next few years.[48] These projects will be funded in part by SB 1, which will raise approximately $52 billion over 10 years.

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[44] County of Riverside, *Riverside County General Plan Environmental Impact Report No. 521* (March 2014), available at https://planning.rctlma.org/Portals/14/genplan/general_plan_2014/EnvironmentalImpactReport/03-0_ProjectDescription_2014-04-07.pdf.

[45] San Bernardino County, *Countywide Plan Growth Forecast*, available at http://countywideplan.com/wp-content/uploads/2018/08/CWP_OH_GrowthForecast_FINAL_20180809.pdf.

[46] California Department of Transportation, *2018 Report on STIP Balances County and Interregional Shares* (Aug. 1, 2018), available at http://www.catc.ca.gov/programs/stip/2018-stip/2018_ORANGE_BOOK.pdf.

[47] Riverside County Transportation Commission, *I-15 Express Lanes Project Southern Extension*, https://www.rctc.org/i15-express-southern-extension/

[48] Kurt Snibbe, "Here are the major highway improvement projects happening in Southern California through 2023," *Orange County Register* (Jan. 23, 2018), https://www.ocregister.com/2018/01/23/here-are-maps-and-a-list-of-the-major-highway-improvement-projects-in-southern-california/; Jeong Park, "2019 will be a busy year for big road construction projects in Orange County," *Orange County Register* (Dec. 31, 2018),

Along with this expansion in roads and highways will come an increase in automobile use: SCAG predicts that the number of vehicle miles travelled ("VMT") in the region is expected to increase 13.3 percent by 2040 (from 448 million VMT per day to 504 million VMT per day). This significant increase in automobile use will further impair connectivity and lead to more collisions between automobiles and lions.

8.5 Future Development Will Further Threaten the Survival of Central Coast Mountain Lions

Future development and highway expansion in the San Francisco Bay Area and Central Coast is anticipated to further fragment habitat for Central Coast mountain lion populations and will increase threats to their survival.

The Association of Bay Area Governments' Plan Bay Area projects that the population of the San Francisco Bay Area is expected to increase from 7.2 million to 9.3 million by 2040—a 30 percent increase.[49] This includes a 26 percent increase in San Mateo County and a 36 percent increase in Santa Clara County, both of which encompass significant portions of the Santa Cruz Mountains. The Plan Bay Area also envisions a 25 percent increase in housing units in San Mateo County, and a 31 percent increase in Santa Clara County.

The Greenbelt Alliance's "At Risk" Report ("Greenbelt Report") estimates that 22,700 acres in San Mateo County are at medium or high risk for development, significant portions of which are in the Santa Cruz Mountains.[50] The Greenbelt Report shows that only 113,000 acres of the Santa Cruz Mountains are permanently protected and warns that San Mateo County has planned to develop housing in remote areas on the eastern slope of the Santa Cruz Mountains. The Greenbelt Report estimates that Santa Clara County has 54,100 acres at high or medium risk of development, significant portions of which are in the Santa Cruz Mountains and eastern foothills. The Greenbelt Report further shows that while large swaths of the eastern Santa Cruz Mountains are currently at "low risk" for development, only fragmented portions enjoy permanent protection.

Similarly, the EIR for the Plan Bay Area 2040 notes that land use growth footprints overlap with approximately 1,040 acres of "Essential Connectivity Areas" or "ECAs."[51] The EIR claims these growth footprints are in already urbanized corridors that are degraded so that their function as linkages is limited. The EIR acknowledges that development projects may directly encroach on wildlife corridors, but does not provide any plan to address the effects of

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https://www.ocregister.com/2018/12/31/2019-will-be-a-busy-year-for-big-road-construction-projects-in-orange-county/.

[49] Metropolitan Transportation Commission and Association of Bay Area Governments, *Bay Area Plan*: *A Strategy for A Sustainable Region* (July 18, 2013), available at http://files.mtc.ca.gov/pdf/Plan_Bay_Area_FINAL/Plan_Bay_Area.pdf.

[50] Greenbelt Alliance, *At Risk 2017* (May 2017), available at https://www.greenbelt.org/at-risk-2017/.

[51] Metropolitan Transportation Commission and Association of Bay Area Governments, *Draft Environmental Impact Report for Plan Bay Area 2040* (April 2017), available at http://2040.planbayarea.org/cdn/farfuture/JHbwWZgw24OSpVBL0b8cJ5_2KHOdckVexpxYp5McOkI/1499352691/sites/default/files/2017-07/PBA%202040%20DEIR_0_1.pdf.

such encroachment. In addition, Caltrans has a number of highway improvement projects planned in Santa Clara and San Mateo counties.[52]

There also is development pressure on the Pajaro Hills linkage, which is important to the Central Coast North mountain lion population and connects the Santa Cruz Mountains and Gabilan Range.[53] The Land Trust of Santa Cruz County notes that while a few large ranches cover most of the Pajaro Hills, many of the properties are parcelized, creating the potential for development which would fragment the landscape. Only 8 percent of the Pajaro Hills is permanently protected.

Growth is expected to increase in the Monterey Bay Area, leading to further fragmentation of natural habitats by urban or exurban development. The Association of Monterey Bay Area Governments predicts that the population in the Monterey Bay Area will rise from 755,403 in 2015 to 883,300 in 2040.[54] The Land Trust of Santa Cruz County notes that while high rates of conversion of forests, rangeland and farmland has largely been prevented in Santa Cruz County, exurban development, roads and mining are fragmenting wildlife habitat. Vineyard conversion adjacent to Zayante, Beer Creek, and Summit roads is causing habitat fragmentation in one of the largest intact habitat patches connecting Santa Cruz and Santa Clara counties. The Land Trust of Santa Cruz County estimates that only 44 percent of the large patches of intact habitat are protected. The Conservation Lands Network likewise confirms that much of the Santa Cruz Mountains do not currently qualify as protected areas.[55]

In San Luis Obispo County, the population is expected to increase by 41,650 between 2015 and 2045.[56] The sparsely populated North Coast region of San Luis Obispo County is currently characterized by ranchlands, rural development, and open space. However, the San Luis Obispo Council of Governments ("SLOCOG") predicts more population growth in this region as compared to other regions. SLOCOG also predicts significant increases in traffic volumes on Highway 101 throughout San Luis Obispo County. The US 101 Corridor Mobility Master Plan also contains various proposals to expand the Interstate 101 freeway in San Luis Obispo County, including adding more lanes to the freeway.[57] There are also proposals to widen portions of State Route 46, the western portions of which bisect mountain lion habitat. The Caltrans State Route 46 Corridor System Management Plan concedes that widening segments 2 and 3 of State Route 46 "could present additional barriers to animal movements by further

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[52] Caltrans District 4, *Projects By County*, available at http://www.dot.ca.gov/d4/projects_list.htm.
[53] Land Trust of Santa Cruz County, *A Conservation Blueprint* (May 2011), available at https://landtrustsantacruz.org/blueprint/conservation-blueprint_low-res_110522.pdf.
[54] Association of Monterey Bay Area Governments, *2040 Metropolitan Transportation Plan/Sustainable Communities Strategy* (June 2018), available at http://ambag.org/programs/met_transp_plann/documents/Final_2040_MTP_SCS/AMBAG_MTP-SCS_Final_EntireDocument.pdf.
[55] Conservation Lands Network, *1.0 Progress Report* (2014), available at https://www.bayarealands.org/wp-content/uploads/2017/07/CLN-1.0-Progress-Report.pdf.
[56] San Luis Obispo Council of Governments, *2019 Regional Transportation Plan Public Review Draft* (Feb. 2019), available at https://www.dropbox.com/s/6pysudp1g36n4a5/__Public%20Rev%20draft.pdf?dl=0 .
[57] San Luis Obispo County of Governments, *US 101Corridor Mobility Master Plan* (Sept. 2014), available at http://www.dot.ca.gov/hq/tpp/offices/ocp/5_SLOCOG%20101_executive_summary_draft_9%2019%2014.pdf.

dividing large, contiguous wildlife habitat areas."[58] There are numerous other road and highway expansion projects planned for Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties.[59] The expansion of existing roads and highways along with increased numbers of automobiles will further impair connectivity in the Central Coast region.

9 CESA Listing for Southern California and Central Coast Mountain Lions Would Supplement Proposition 117's Protections.

9.1 CESA Listing is Consistent with Proposition 117.

CESA protections for Southern California and Central Coast mountain lions are consistent with and supplemental to those established by Proposition 117. Both CESA and Proposition 117 include "take prohibitions"—CESA makes it unlawful for any person or agency to import, export, take, possess, or purchase a listed species. (Cal. Fish & Game Code § 2080.) By the same token, Proposition 117 makes it unlawful to take, injure, possess, transport, import, or sell a mountain lion. (Cal. Fish & Game Code § 4800(b).)

Both CESA and Proposition 117's take prohibitions are subject to certain exceptions. Under CESA, CDFW may authorize that a person, agency, or institution take a listed species "for scientific, educational, or management purposes." (Cal. Fish & Game Code § 2081(a).) CESA defines scientific resources management activities to include "research, census, law enforcement, habitat acquisition, restoration and maintenance, propagation, live trapping, and, transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, [] regulated taking." (*San Bernardino Valley Audubon Society v. City of Moreno Valley* (1996) 44 Cal.App.4th 593, 604, quoting Cal. Fish & Game Code § 2061.) The regulations implementing CESA also allow for the take of a listed species for management or law enforcement purposes: "Department wildlife management activities. The possession or take of endangered, threatened, or candidate species by employees and agents of the Department for scientific, educational and management purposes, and for law enforcement purposes, is not prohibited." (Cal. Code Regs., tit. 14, § 783.1(c).) As discussed above in *Section 8 Inadequacy of Existing Regulatory Mechanisms*, Proposition 117 also contains exceptions which allow for the take of mountain lions in certain circumstances. These exceptions are sufficiently similar that in most cases take of mountain lions properly authorized by Proposition 117 could be consistent with CESA's exceptions for wildlife management activities or law enforcement purposes. (Cal. Code Regs., tit. 14, § 783.1(c).)

9.2 CESA Listing Would Further the Goals of Proposition 117.

CESA listing would further Proposition 117's goals of protecting and restoring wildlife habitat as human populations increase. (Cal. Fish & Game Code § 2780(a).) CESA listing would also help preserve "corridors of natural habitat [] to maintain the genetic integrity" of mountain lions in the Santa Monica Mountains, Santa Ana Mountains, Santa Susana Mountains, Simi Hills, and Coast Range. (Cal. Fish & Game Code § 2780(a).)

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[58] Caltrans, *State Route 46 Corridor System Management Plan* (June 2009), available at http://www.dot.ca.gov/hq/tpp/corridor-mobility/CSMPs/d5_CSMPs/SR%2046/SR-46%20CSMPo100.pdf.
[59] Caltrans District 5, *Projects By County*, available at http://www.dot.ca.gov/d5/.

Likewise, CESA requires that "reasonable and prudent alternatives" that will not jeopardize the existence of a listed species be developed in coordination with the project proponent and state lead agency consistent with conserving the listed species and maintaining the project purpose to the greatest extent feasible. (Cal. Fish & Game Code § 2053(b).) In the event that such alternatives are infeasible, individual projects may still be approved if appropriate mitigation measures are implemented. (Cal. Fish & Game Code § 2054.) CESA envisions these mandates will be incorporated into the CEQA process. (Cal. Fish & Game Code §§ 2064-2065; Cal. Code Regs., tit. 14, §§ 783.3 & 783.5.)

Consistent with Proposition 117, CESA further provides that it is the policy of the state to conserve and protect listed species and their habitat, including through acquiring lands for habitat. (Cal. Fish & Game Code § 2052.) Towards this end, CESA directs state agencies to utilize their authority to conserve listed species. (Cal. Fish & Game Code § 2055.) If the Southern California and Central Coast mountain lions were listed under CESA, this mandate would apply to, for example, Caltrans, which currently lacks a clear mandate to conserve these lions or habitat connectivity necessary for their continued survival.

CESA authorizes CDFW to develop and implement "nonregulatory recovery plans" for listed species with priority given to species that are or may be "significantly affected by anticipated land use changes, climate change, or changes in aquatic conditions." (Cal. Fish & Game Code §§ 2079.1(a) & (b).) Given the strong evidence that land use changes will significantly affect (and have already significantly affected) Southern California and Central Coast mountain lions, CDFW could develop and implement a recovery plan for these lions pursuant to this provision.

In sum, CESA listing would build upon the protections in Proposition 117 by establishing an affirmative duty to ensure the survival and recovery of the Southern California and Central Coast mountain lions by, *inter alia*, (1) prohibiting the approval of projects that could jeopardize their continued existence or result in destruction of essential habitat (Cal. Fish & Game Code § 2053(a)); (2) requiring state agencies such as Caltrans to utilize their authority to conserve listed species (Cal. Fish & Game Code § 2055); and (3) requiring appropriate mitigation measures be implemented for projects that could destroy mountain lion habitat or impair connectivity (Cal. Fish & Game Code § 2054).

To the extent there is any tension between the provisions in Proposition 117 and CESA, Proposition 117 is to be "liberally construed to further its purposes." (Prop. 117 § 9.) Because Proposition 117 and CESA both have similar purposes, Proposition 117 should be construed to be consistent with CESA.

10 Recommended Management and Recovery Actions

Recommendations for the management and recovery of Southern California and Central Coast mountain lion populations are as follows:

1. Design and build crossing infrastructure in strategic locations to improve wildlife connectivity and permeability at existing roads and highways. Crossing infrastructure should include but is not limited to overcrossings, underpasses, culverts, and exclusionary fencing that guides animals to safer crossing areas. The following crossing locations have been identified by mountain lion experts and should be prioritized for the implementation of crossing infrastructure: 1) I-15 Freeway at Temecula Creek Bridge to enhance the Palomar Linkage and connect the Santa Ana and Eastern Peninsular Mountain Ranges (Gustafson et al. 2017; Zeller et al. 2017; Ernest et al. 2014; Riley et al. 2018); 2) I-15 Freeway at "Site 5" as described in Riley et al. (2018); 3) Hwy-101 at West Liberty Canyon. (Riley et al. 2018.)

2. Improve or add large culverts to existing freeways in areas suitable for mountain lion crossing. (Vickers 2015).

3. Dedicate sufficient Wildlife Conservation Board, Habitat Conservation Fund and other state funding sources towards acquiring key mountain lion habitat and for establishment of highway crossing infrastructure.

4. Ensure that suitable habitat exists (through preservation or restoration/enhancement) on both sides of crossing structures and culverts (South Coast Wildlands 2008). Restrict human activity near crossing structures and relocate foot trails away from these structures (South Coast Wildlands 2008).

5. Fully protect mountain lion habitat, including resource-use patches and corridors (Zeller et al. 2017; Vickers et al. 2015). Prohibit large-scale development in primary travel corridors and habitat linkages, such as in and around the last remaining linkage for statewide genetic connectivity in the Tehachapi and Sierra Pelona Mountains (Gustafson et al. 2018) and in corridor areas between the SAM and EPR (Gustafson et al. 2017).

6. Require analysis of region-wide wildlife connectivity in all new development proposals (Gustafson et al. 2018).

7. Reduce depredation conflicts that precipitate mountain lion deaths (Vickers et al. 2015). Develop and implement outreach and education activities to promote use of predator-proof enclosures for domestic animals. (Vickers et al. 2015.) Expand CDFW's new three-step depredation permit policy in the CC-S and SAM areas to include all mountain lions across the state, or at a minimum, within the SGSB, EPR, CC-N, and CC-C population areas. Enhance the policy with enforceable implementation of non-lethal protective measures and reporting requirements.

8. Prohibit the use of second-generation anticoagulant rodenticides ("SGARs"), such as brodifacoum, bromadiolone, difenacoum, and difethialone in Southern California and Central Coast mountain lions' core habitat areas and linkages. Limit the use of other pesticides and herbicides that may have negative effects on mountain lion populations in Southern California and the Central Coast.

9. Identify "priority areas" for establishing wildlife passage features for the Southern California and Central Coast mountain lions using the best available science, including data collected by various agencies, academic institutions, and organizations, including but not limited to the National Park Service, the Karen C. Drayer Wildlife Health Center at UC Davis, the Road Ecology Center at UC Davis, and the Santa Cruz Puma Project at UC Santa Cruz.

10. Require Caltrans to analyze how projects in the State Highway Operation Protection Program and State Transportation Improvement Program can be designed to facilitate wildlife connectivity through wildlife passage features such as culverts, undercrossings, overcrossings, bridges, directional fencing, scuppers, barrier breaks, roadside animal detection systems, etc. Require Caltrans to collect and analyze roadkill data to identify hotspots where mountain lions are killed. Require Caltrans to implement wildlife passage features to the greatest extent feasible and as expeditiously as possible.

11 References

Allen, M., Elbroch, L. M., Casady, D. S., & Wittmer, H. U. (2014). Seasonal variation in the feeding ecology of pumas (Puma concolor) in northern California. *Canadian Journal of Zoology*, *92*(5), 397–403.

Allen, M. L. (2014). *The ecology and behaviour of pumas (Puma concolor) in Northern California, USA*. (Doctoral dissertation, Victoria University of Wellington).

Allen, M. L., Wittmer, H. U., & Wilmers, C. C. (2014). Puma communication behaviours: understanding functional use and variation among sex and age classes. *Behaviour, 151*(6),9 819-840.

Anderson , Jr ., C. R., & Lindzey, F. G. (2003). Estimating Cougar Predation Rates from GPS Location Clusters Author (s): *The Journal of Wildlife Management*, *67*(2), 307–316.

Atkinson, W. (2018, December 3). The Link Between Power Lines and Wildfires. *Electrical Contractor Magazine*.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Nagy, R. C., Fusco, E. J., & Mahood, A. L. (2017). Human-started wildfires expand the fire niche across the United States. *Proceedings of the National Academy of Sciences*, *114*(11), 2946–2951.

Ballou, J. D., Foose, T. J., Lacey, R. C., & Seal, U. S. (1989). Florida panther (*Felis concolor*) coryi population viability analysis and recommendations. *Captive Breeding Specialist Group, Species Survival Commission, IUCN,* Apple Valley, MN.

Barry, J. M., Elbroch, L. M., Aiello-Lammens, M. E., Sarno, R. J., Seelye, L., Kusler, A., ... & Grigione, M. M. (2019). Pumas as ecosystem engineers: ungulate carcasses support beetle assemblages in the Greater Yellowstone Ecosystem. *Oecologia*, *189*(3), 577-586.

Beier, Paul. (1993). Determining minimum habitat areas and habitat corridors for cougars. *Cosnervation Biology*, *7*(1), 94–108.

Beier, Paul. (1995). Dispersal of Juvenile Cougars in Fragmented Habitat. *The Journal of Wildlife Management*, *59*(2), 228–237.

Beier, P., & Barrett, R. H. (1993). The cougar in the Santa Ana Mountain Range, California. Final report. Orange County Cooperative Mountain Lion Study, Department of Forestry and Resource Management. *University of California, Berkeley, USA*.

Beier, P., Choate, D., & Barrett, R. H. (1995). Movement patterns of mountain lions during different behaviors. *Journal of Mammalogy*, *76*(4), 1056–1070.

Beier, P., Riley, S.P.D., and Sauvajot, R.M. (2010). Mountain Lions (*Puma concolor*). In *Urban Carnivores: Ecology, Conflict, and Conservation*, S.D. Gehrt, S.P.D. Riley, and B. Cypher, eds. (Baltimore: Johns Hopkins University Press), pp. 141–155.

Benson, J. F., Mahoney, P. J., Sikich, J. A., Serieys, L. E. K., Pollinger, J. P., Ernest, H. B., & Riley, S. P. D. (2016). Interactions between demography, genetics, and landscape connectivity increase extinction probability for a small population of large carnivores in a major metropolitan area. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1837), 20160957.

Benson, J. F., Mahoney, P. J., Vickers, T. W., Sikich, J. A., Beier, P., Riley, S. P. D., … Boyce, W. M. (2019). Extinction vortex dynamics of top predators isolated by urbanization. *Ecological Applications*, e01868.

Benson, J. F., Sikich, J. A., & Riley, S. P. D. (2016). Individual and population level resource selection patterns of mountain lions preying on mule deer along an urban-wildland gradient. *PLoS ONE*, *11*(7), 1–16.

Bistinas, I., Oom, D., Sá, A. C. L., Harrison, S. P., Prentice, I. C., & Pereira, J. M. C. (2013). Relationships between human population density and burned area at continental and global scales. *PLoS ONE*, *8*(12), 1–12.

Burdett, C. L., Crooks, K. R., Theobald, D. M., Wilson, K. R., Boydston, E. E., Lyren, L. M., ... & Boyce, W. M. (2010). Interfacing models of wildlife habitat and human development to predict the future distribution of puma habitat. *Ecosphere*, *1*(1), 1-21.

Cahill, A. E., Aiello-Lammens, M. E., Fisher-Reid, M. C., Hua, X., Karanewsky, C. J., Ryu, H. Y., … Wiens, J. J. (2012). How does climate change cause extinction? *Proceedings of the Royal Society B: Biological Sciences*, *280*(1750), 20121890. https://doi.org/10.1098/rspb.2012.1890

Caragiulo, A., Dias-Freedman, I., Clark, J. A., Rabinowitz, S., & Amato, G. (2013). Mitochondrial DNA sequence variation and phylogeography of Neotropic pumas (Puma concolor). *Mitochondrial DNA*, *25*(4), 304–312.

CBS San Francisco. (2015, January 2). Car Strikes, Kills Mountain Lion On I-280 In San Bruno (WARNING : Contains Graphic Images). *CBS San Francisco*.

California Department of Fish and Wildlife (CDFW). (2017, December 15)

California Department of Fish and Wildlife (CDFW). (2018). *Report to the Fish and Game Commission Regarding Findings of Necropsies on Mountain Lions Taken Under Depredation Permits in 2017*.

Chandler, J. (2019, February 8). Edison now facing at least seven lawsuits over Woolsey Fire. *Curbed Los Angeles*.

Chen, I.-C., Hill, J. K., Ohlemüller, R., Roy, D. B., & Thomas, C. D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science*, *333*, 1024–1026.

Cooley, H. S., Robinson, H. S., Wielgus, R. B., & Lambert, C. S. (2008). Cougar prey selection in a white-tailed deer and mule deer community. *Journal of Wildlife Management*, *72*(1), 99–106.

Côté, S. D., Rooney, T. P., Tremblay, J. P., Dussault, C., & Waller, D. M. (2004). Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution, and Systemtatics*, *35*, 113-147.

Culver, M., Johnson, W. E., Pecon-Slattery, J., & O'Brien, S. J. (2000). Genomic Ancestry of the American Puma. *The American Genetic Association*, *91*, 186–197.

Currier, M. J. (1983). Felis concolor. *Mammalian Species*, (200), 1–7.

Cushman, S. A., McRae, B., Adriaensen, F., Beier, P., Shirley, M., & Zeller, K. (2013). Biological corridors and connectivity. In D. W. Macdonald & K. J. Willis (Eds.), *Key Topics in Conservation Biology 2* (First Edit, pp. 384–403). John Wiley & Sons, Ltd.

Dellinger, J. (2019). *Relationship between habitat and genetics in a wide-ranging large carnivore*. Temecula, CA.

Department of Pesticide Regulation. (2018). *An Investigation of Anticoagulant Rodenticide Data Submitted to the Department of Pesticide Regulation*.

Dickson, B. G., & Beier, P. (2002). Home-range and habitat selection by adult cougars in Southern California. *The Journal of Wildlife Management*, *66*(4), 1235–1245.

Dickson, B. G., & Beier, P. (2006). Quantifying the influence of topographic position on cougar (Puma concolor) movement in southern California , USA. *Journal of Zoology*, *271*(3), 270–277.

Dickson, B. G., Jennes, J. S., & Beier, P. (2005). Influence of Vegetation, Topography, and Roads on Cougar Movement in Southern California. *Journal of Wildlife Management*,

69(1), 264–276. https://doi.org/10.2193/0022-541X(2005)069<0264:IOVTAR>2.0.CO;2
Elbroch, L. M., O'Malley, C., Peziol, M., & Quigley, H. B. (2017). Vertebrate diversity benefiting from carrion provided by pumas and other subordinate, apex felids. *Biological conservation*, *215*, 123-131.
Elbroch, L. M., & Quigley, H. (2019). Age-specific foraging strategies among pumas, and its implications for aiding ungulate populations through carnivore control. *Conservation Science and Practice*, *1*(4), e23.
Ernest, H. B., Boyce, W. M., Bleich, V. C., May, B., Stiver, S. J., & Torres, S. G. (2003). Genetic structure of mountain lion (*Puma concolor*) populations in California. *Conservation Genetics*, (4), 353–366.
Ernest, H. B., Vickers, T. W., Morrison, S. A., Buchalski, M. R., & Boyce, W. M. (2014). Fractured genetic connectivity threatens a Southern California puma (Puma concolor) population. *PLoS ONE*, *9*(10).
Frankham, R. R. (1995). Effective population size/adult population size ratios in wildlife: a review. *Genetics Research*, *66*, 95–107. https://doi.org/10.1017/S0016672308009695
Frankham, R., & Ralls, K. (1998). Inbreeding leads to extinction. *Nature*, *392*(2), 441–442.
Frankham, R. (2005). Genetics and extinction. *Biological Conservation*, *126*, 131–140.
Frankham, R., Bradshaw, C. J. A., & Brook, B. W. (2014). Genetics in conservation management: Revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. *Biological Conservation*, *170*, 56–63.
Gabriel, M. W., Woods, L. W., Poppenga, R., Sweitzer, R. A., Thompson, C., Matthews, S. M., … Clifford, D. L. (2012). Anticoagulant rodenticides on our public and community lands : spatial distribution of exposure and poisoning of a rare forest carnivore. *PLoS ONE*, *7*(7).
Gilbert, S. L., Sivy, K. J., Pozzanghera, C. B., DuBour, A., Overduijn, K., Smith, M. M., ... & Prugh, L. R. (2017). Socioeconomic Benefits of Large Carnivore Recolonization Through Reduced Wildlife-Vehicle Collisions. *Conservation Letters*, *10*(4), 431-439.
Gray, M., Wilmers, C. C., Reed, S. E., & Merenlender, A. M. (2016). Landscape feature-based permeability models relate to puma occurrence. *Landscape and Urban Planning*, *147*, 50–58.
Grigione, M. M., Beier, P., Hopkins, R. A., Neal, D., Padley, W. D., Schonewald, C. M., & Johnson, M. L. (2002). Ecological and allometric determinants of home-range size for mountain lions (Puma concolor). *Animal Conservation*, *5*, 317–324.
Gustafson, K. D., Gagne, R. B., Vickers, T. W., Riley, S. P. D., Wilmers, C. C., Bleich, V. C., … Ernest, H. B. (2018). Genetic source–sink dynamics among naturally structured and anthropogenically fragmented puma populations. *Conservation Genetics*, *20*(2), 215–227.
Gustafson, K. D., Vickers, T. W., Boyce, W. M., & Ernest, H. B. (2017). A single migrant enhances the genetic diversity of an inbred puma population. *Royal Society Open Science*, *4*(5).
Hansen, K. (1992). *Cougar: the American lion*. Northland Pub.
Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, *142*(1), 14–32.
Hornocker, M. G. (1970). *An analysis of mountain lion predation upon mule deer and elk*. (Doctoral dissertation, University of British Columbia).
Hunter, R. D., Fisher, R. N., & Crooks., K. R. (2003). Landscape-level connectivity in coastal southern California, USA, as assessed through carnivore habitat suitability. *Natural Areas Journal*, *23:302-314*.

Intergovernmental Panel on Climate Change (IPCC). (2018). *Global Warming of 1.5° C: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Intergovernmental Panel on Climate Change. Available at: http://www.ipcc.ch/report/sr15/

Iriarte, J. A., Franklin, W. L., Johnson, W. E., & Redford, K. H. (1990). Biogeographic variation of food habits and body size of the America puma. *Oecologia*, *85*, 185–190.

Jamieson, I. G., & Allendorf, F. W. (2012). How does the 50/500 rule apply to MVPs? *Trends in Ecology and Evolution*, *27*(10), 578–584.

Jennings, M. (2018). *Effects of Wildfire on Wildlife and Connectivity*.

Johnson, W. E., Onorato, D. P., Roelke, M. E., Land, E. D., Cunningham, M., Belden, R. C., … O'Brien, S. J. (2010). Genetic restoration of the Florida panther. *Science*, *329*, 1641–1645.

Kamala. (2016, July 15). Dead puma found on Hwy 280. *Everything South City*.

Keeley, J. E., & Fotheringham, C. J. (2003). Impact of Past Present and Future Fire Regimes on North American Mediterranean Shrublands. In *Fire and climatic change in temperate ecosystems of the Western Americas* (pp. 218–262).

Kertson, B. N., Spencer, R. D., Marzluff, J. M., Hepinstall-Cymerman, J., & Grue, C. E. (2011). Cougar space use and movements in the wildland – urban landscape of western Washington. *Ecological Applications*, *21*(8), 2866–2881.

Kitchener, A. (1991). *The natural history of the wild cats*. Comstock Pub. Associates.

Kitchener, A. C., Breitenmoser-Würsten, C., Eizirik, E., Gentry, A., Werdelin, L., Wiltin, A., … Tobe, S. (2017). *A revised taxonomy of the Felidae. The final report of the Cat Classification Task Force of the IUCN/ SSC Cat Specialist Group.* Cat News.

Knopff, K. H., Knopff, A. A., Kortello, A., & Boyce, M. S. (2010). Cougar kill rate and prey composition in a multiprey system. *Journal of Wildlife Management*, *74*(7), 1435–1447.

Kucera, T. E. (1998). Yuma mountain lion, Felis concolor browni. In *Terrestrial Mammal Species of Special Concern in California* (pp. 135–138).

Laundré, J., & Clark, T. W. (2003). Managing puma hunting in the western United States: Through a metapopulation approach. *Animal Conservation*, *6*, 159–170.

Lima, L. L., & Salmon, T. P. (2010). Assessing some potential environmental impacts from agricultural anticoagulant uses. *Proceedings of the Vertebrate Pest Conference*, *24*(24), 199–203.

Logan, K.A., & Sweanor, L.L. (2001). Desert Puma: Evolutionary Ecology and Conservation of an Enduring Carnivore (Washington: Island Press).

Logan, K. A., & Sweanor, L.L. (2010). Behavior and social organization of a solitary carnivore. In i*Cougar: Ecology and Conservation* (pp. 105-117).

Mace, G. M., & Lande, R. (1991). Assessing extinction threats: Toward a reevaluation of IUCN threatened species categories. *Conservation Biology*, *5*(2), 148–157.

Maclean, I. M. D., & Wilson, R. J. (2011). Recent ecological responses to climate change support predictions of high extinction risk. *Proceedings of the National Academy of Sciences*, *108*(30), 12337–12342.

Maehr, D. S. ., Belden, R. C. ., Land, E. D., & Wilkins, L. (1990). Food habits of panthers in southwest Florida. *The Journal of Wildlife Management*, *54*(3), 420–423.

Mansfield, T. M., & Weaver, R. A. (1989). The status of mountain lions in California. *Transactions of the Western Section of the Wildlife Society*, *25*, 72-76.

McMillin, S. C., Hosea, R. C., Finlayson, Brian, F., Cypher, B. L., & Mekebri, A. (2008). Anticoagulant rodenticide exposure in an urban population of the San Joaquin kit fox. *Proceedings of the Vertebrate Pest Conference*, *23*(23), 163–165.

Mcrae, B. H., Dickson, B. G., Keitt, T. H., & Shah, V. B. (2008). Using circuit theory to model connectivity in ecology , evolution , and conservation. *Ecology*, *89*(10), 2712–2724.

Mcrae, B. H., Hall, S. A., Beier, P., & Theobald, D. M. (2012). Where to restore ecological connectivity? Detecting barriers and quantifying restoration benefits. *PLoS ONE*, *7*(12), e52604.

Midpeninsula Regional Open Space. (2017). *Highway 17 Wildlife Passage and Bay Area Ridge Trail Crossing Lexington Study Area*.

Nielsen, C., Thompson, D., Kelly, M., & Lopez-Gonzalez, C. A. (2015). Puma concolor (errata version published in 2016). *The IUCN Red List of Threatened Species*, 2015-4.

Olson, D. H., & Burnett, K. M. (2013). Geometry of forest landscape connectivity: pathways for persistence. *In: Anderson, PD; Ronnenberg, KL, eds. Density management in the 21st century: West Side Story. Gen. Tech. Rep. PNW-GTR-880. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station: 220–238.*, *880*, 220-238.

Pacifici, M., Visconti, P., Butchart, S. H. M., Watson, J. E. M., Cassola, F. M., & Rondinini, C. (2017). Species' traits influenced their response to recent climate change. *Nature Climate Change*, *7*(3), 205–208. https://doi.org/10.1038/nclimate3223

Parmesan, C. (2006). Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology, Evolution, and Systematics*, *37*, 637–669.

Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change ipacts across natural systems. *Nature*, *421*(2), 37–42. https://doi.org/10.1038/nature01286

Pierce, B. M., & Bleich, V. C. (2003). Mountain Lion Puma concolor. In G. A. Feldhamer, B. C. Thompson, & J. A. Chapman (Eds.), *Wild Mammals of North America Biology, Management, and Economics* (2nd ed., pp. 744–757). Baltimore, Maryland: The Johns Hopkins University Press.

Pinto, N., & Keitt, T. H. (2008). Beyond the least-cost path: Evaluating corridor redundancy using a graph- theoretic approach. *Landscape Ecology*, *24*(2), 253–266.

Pollard, L. (2016, December 27). 100+ Calif. Mountain Lions a Year Killed by Motor Vehicles. *Public News Service*.

Radeloff, V. C., Helmers, D. P., Kramer, H. A., Mockrin, M. H., Alexandre, P. M., Bar-Massada, A., … Stewart, S. I. (2018). Rapid growth of the US wildland-urban interface raises wildfire risk. *Proceedings of the National Academy of Sciences*, *115*(13), 3314–3319.

Reed, D. H., Grady, J. J. O., Brook, B. W., Ballou, J. D., Frankham, R., & Analysis, P. V. (2003). Estimates of minimum viable population sizes for vertebrates and factors influencing those. *Biological Conservation*, *113*, 23–34.

Reyes-Velarde, A. (2019a, March 7). Fifth mountain lion diagnosed with mange , possibly linked to rat poison. *LA Times*.

Reyes-Velarde, A. (2019b, April 30). Mountain lion dies of rat poison in Santa Monica Mountains. *LA Times*.

Riley, S. P. D., Bromley, C., Poppengia, R. H., Uzal, F. A., Whited, L., & Sauvajot, R. M. (2007). Anticoagulant Exposure and Notoedric Mange in Bobcats and Mountain Lions in Urban Southern California. *The Journal of Wildlife Management*, *71*(6), 1874–1884.

Riley, S. P. D., Sauvajot, R. M., Fuller, T. K., York, E. C., Kamradt, D. A., Bromley, C., & Wayne, R. K. (2003). Effects of Urbanization and Habitat Fragmentation on Bobcats and

Coyotes in Southern California. *Conservation Biology*, *17*(2), 566–576.
Riley, S. P. D., Serieys, L. E. K., Pollinger, J. P., Sikich, J. A., Dalbeck, L., Wayne, R. K., & Ernest, H. B. (2014). Individual behaviors dominate the dynamics of an urban mountain lion population isolated by roads. *Current Biology*, *24*(17), 1989–1994.
Riley, S. P. D., Smith, T., & Vickers, T.W. (2018). Assessment of Wildlife Crossing Sites for the Interstate 15 and Highway 101 Freeways in Southern California.
Ripple, W. J., & Beschta, R. L. (2006). Linking a cougar decline , trophic cascade , and catastrophic regime shift in Zion National Park. *Biological Conservation*, *133*, 397–408.
Ripple, W. J., & Beschta, R. L. (2008). Trophic cascades involving cougar, mule deer, and black oaks in Yosemite National Park. *Biological Conservation*, *141*, 1249–1256.
Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., … Wirsing, A. J. (2014). Status and ecological effects of the world 's largest carnivores. *Science*, *343*(6167), 1241484.
Roelke, M. E., Martenson, J. S., & O'Brien, S. J. (1993). The consequences of demographic genetic depletion in the endangered reduction and Florida panther. *Current Biology*, *3*(6), 340–350.
Root, T. L., Price, J. T., Hall, K. R., Schneider, S. H., Resenzweig, C., & Pounds, J. A. (2003). Fingerprints of global warming on wild animals and plants. *Nature*, *421*, 57–60.
Rosas-Rosas, O. C., Valdez, R., Bender, L. C., & Daniel, D. (2003). Food habits of pumas in northwestern. *Wildlife Society Bulletin*, *31*(2), 528–535.
Rudd, J. L., McMillin, S. C., Kenyon Jr., M. W., Poppenga, R. H., Clifford, D. L. (2019). Anticoagulant rodenticide exposure in California mountain lions (*Puma concolor*). Presented at the Western Section of The Wildlife Society Conference, Yosemite, CA.
Ruth, T. K. & Elbroch, M. (2014). The carcass chronicles: carnivory, nutrient flow, and biodiversity. *Wild Felid Monitor*, 13-17.
Santa Cruz Puma Project. (2015, May 19). The Journeys of Young Pumas, and Welcome to Puma 56M. *Santa Cruz Puma Project Blog*.
Scheffers, B. R., De Meester, L., Bridge, T. C. L., Hoffmann, A. A., Pandolfi, J. M., Corlett, R. T., … Watson, J. E. M. (2016). The broad footprint of climate change from genes to biomes to people. *Science*, *354*(6313).
Seidensticker, J. C., Hornocker, M. G., Wiles, W. V, & Messick, J. P. (1973). Mountain lion social organization in the Idaho primitive area. *Wildlife Monographs*, *35*, 3–60.
Serieys, L. E. K., Armenta, T. C., Moriarty, J. G., Boydston, E. E., Lyren, L. M., Poppenga, R. H., … Riley, S. P. D. (2015). Anticoagulant rodenticides in urban bobcats: exposure , risk factors and potential effects based on a 16-year study. *Ecotoxicology*.
Shilling, F. M., Denney, C., Waetjen, D., Harrold, K., Farman, P., & Perez, P. (2018). *Impact of Wildlife-Vehicle Conflict on California Drivers and Animals*.
Shilling, F. M., Waetjen, D. P., & Harrold, K. (2017). *Impact of Wildlife-Vehicle Conflict on California Drivers and Animals*.
Slade, S. (2018). Another Mountain Lion Killed on 17. *Land Trust of Santa Cruz County.*
Smith, J. A., Suraci, J. P., Clinchy, M., Crawford, A., Roberts, D., Zanette, L. Y., & Wilmers, C. C. (2017). Fear of the human 'super predator' reduces feeding time in large carnivores. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1857), 20170433.
Smith, J. A., Wang, Y., & Wilmers, C. C. (2015). Top carnivores increase their kill rates on prey as a response to human-induced fear. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1802).

Soule, M., Gilpin, M., Conway, W., & Foose, T. (1986). The Millenium Ark : How Long a Voyage , How Many Staterooms , How Many Passengers ? *Zoo Biology*, *5*(2), 101–113.

South Coast Wildlands. (2008). South coast missing linkages: a wildland network for the south coast ecoregion. *South Coast Wildlands, Fair Oaks, CA*.

Spielman, D., Brook, B. W., & Frankham, R. (2004). Most species are not driven to extinction before genetic factors impact them. *Proceedings of the National Academy of Sciences*, *101*(42), 15261–15264.

Spong, G., Johansson, M., & Bjorklund, M. (2000). High genetic variation in leopards indicates large and long-term stable effective population size. *Molecular Ecology*, *9*, 1773–1782.

State Farm Insurance Company. (2016). Deer Collision 2015-2016.

State Farm Insurance Company. (2018). Deer Collision 2017-2018.

Syphard, A. D., Keeley, J. E., & Brennan, T. J. (2011). Comparing the role of fuel breaks across southern California national forests. *Forest Ecology and Management*, *261*(11), 2038–2048.

Syphard, A. D., Keeley, J. E., Massada, A. B., Brennan, T. J., & Radeloff, V. C. (2012). Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLoS ONE*, *7*(3), e33954.

Syphard, A. D., Radeloff, V. C., Hawbaker, T. J., & Stewart, S. I. (2009). Conservation threats due to human-caused increases in fire frequency in mediterranean-climate ecosystems. *Conservation Biology*, *23*(3), 758–769.

Syphard, A. D., Radeloff, V. C., Keeley, J. E., Hawbaker, T. J., Clayton, M. K., Stewart, S. I., … Hammer, R. B. (2007). Human influence on California fire regimes. *Ecological Society of America*, *17*(5), 1388–1402.

Syphard, A. D., Rustigian-romsos, H., Mann, M., Conlisk, E., Moritz, M. A., & Ackerly, D. (2019). The relative influence of climate and housing development on current and projected future fire patterns and structure loss across three California landscapes. *Global Environmental Change*, *56*, 41–55.

Tanner, K. (2018, May 15). Mountain lion killed near Cambria after being hit by a car. *San Luis Obispo Tribune*.

Telford, S. R. (2017). Deer reduction is a cornerstone of integrated deer tick management. *Journal of Integrated Pest Management*, *8*(1).

Traill, L. W., Brook, B. W., Frankham, R. R., & Bradshaw, C. J. A. (2010). Pragmatic population viability targets in a rapidly changing world. *Biological Conservation*, *143*, 28–34.

U.S. Global Change Research Program (USGCRP). (2017). *Climate Science Special Report Fourth National Climate Assessment*. Washington, D.C.

Lander, Wyoming.

US Fish and Wildlife Service. (2008). *Florida Panther Recovery Plan*. Atlanta, Georgia.

Van Dyke, F. G., Brocke, R. H., Shaw, H. G., Ackerman, B. B., Hemker, T. P., & Lindzey, F. G. (1986). Reactions of mountain lions to logging and human activity. *The Journal of Wildlife Management*, *50*(1), 95–102.

Vaughan, M. (2018, July 8). How many mountain lions are in California? We don't know. *San Luis Obispo Tribune*.

Veklerov, K. (2018 Jan 7). Orphaned mountain lion cubs at Oakland Zoo part of trend in California. San Francisco Chronicle.

Vickers, T. W. (2014). Re: SANDAG contract UCD 12-00606 – Mountain Lion Connectivity Study. Final Report.

Vickers, T. W., Sanchez, J. N., Johnson, C. K., Morrison, S. A., Botta, R., Smith, T., … Boyce, W. M. (2015). Survival and mortality of pumas (Puma concolor) in a fragmented, urbanizing landscape. *PLoS ONE*, *10*(7), 1–18.

Vickers, T. W., Zeller, K., Ernest, H., Gustafson, K., & Boyce, W. (2017). Mountain Lion (*Puma concolor*) Connectivity in the North San Diego County Multi-Species Conservation Plan Area, and Assessment of Mountain Lion Habitat Use and Connectivity in Northern San Diego and Southern Riverside and Orange Counties, with Special Focus on Prioritization of North San Diego County MSCP Lands for Conservation, and Identification of Critical Highway Barriers and Solutions. A joint report to the San Diego County Association of Governments and California Department of Wildlife.

Wang, Y., Allen, M. L., & Wilmers, C. C. (2015). Mesopredator spatial and temporal responses to large predators and human development in the Santa Cruz Mountains of California. *Biological Conservation*, *190*, 23–33.

Wang, Y., Smith, J. A., & Wilmers, C. C. (2017). Residential development alters behavior, movement, and energetics in a top carnivore. *PLoS ONE*, 1–17.

Warren, R., Price, J., Fischlin, A., de la Nava Santos, S., & Midgley, G. (2011). Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise. *Climatic Change*, *106*(2), 141–177.

Wiens, J. J. (2016). Climate-related local extinctions are already widespread among plant and animal species. *PLoS Biology*, *14*(12), 1–18. https://doi.org/10.1371/journal.pbio.2001104

Wilmers, C. C. (2014, October 10). Mountain view puma (46m) killed on Highway 280. *Santa Cruz Puma Project Blog*.

Wilmers, C.C. (2015, May 2). RIP 36m – Genomics godfather to all pumas! *Santa Cruz Puma Project Blog.*

Wilmers, C. C., Wang, Y., Nickel, B., Houghtaling, P., Shakeri, Y., Allen, M. L., … Williams, T. (2013). Scale dependent behavioral responses to human development by a large predator, the puma. *PLoS ONE*, *8*(4).

Young, S.P., & Goldman, E.A. (1946). Puma, mysterious American cat.

Zeller, K. A., Vickers, T. W., Ernest, H. B., & Boyce, W. M. (2017). Multi-level, multi-scale resource selection functions and resistance surfaces for conservation planning: Pumas as a case study. *PLoS ONE*, *12*(6), 1–20.

State of the Global Climate 2023

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WMO-No. 1347

WMO-No. 1347

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Chair, Publications Board
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7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Email: publications@wmo.int

ISBN 978-92-63-11347-4

Cover illustration: A melting glacier with chunks of ice breaking apart. The background captures the consequences of global warming on ice formations. Generative AI. Par Regina. N° de fichier: 640624130

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We need your feedback

This year, the WMO team has launched a process to gather feedback on the State of the Climate reports and areas for improvement. Once you have finished reading the publication, we ask that you kindly give us your feedback by responding to this short survey. Your input is highly appreciated.

Key messages

2023 was the warmest year on record at 1.45 ± 0.12 °C above the pre-industrial average.

Concentrations of the three main greenhouse gases – carbon dioxide, methane and nitrous oxide – reached record-high observed levels in 2022. Real-time data show that levels continued to increase in 2023.

Ocean heat content reached its highest level in the 65-year observational record.

Global mean sea level reached a record high. The rate of sea-level rise in the past 10 years (2014–2023) has more than doubled since the first decade of the satellite record (1993–2002).

Antarctic sea-ice extent reached an absolute record low in February. The annual maximum extent was about 1 million km^2 below the previous record low maximum.

Preliminary data from the global set of reference glaciers for the hydrological year 2022–2023 show they experienced the largest loss of ice on record (1950–2023), driven by extremely negative mass balance in both western North America and Europe.

Glaciers in Switzerland have lost about 10% of their remaining volume in the past two years.

Extreme weather continued to lead to severe socioeconomic impacts. Extreme heat a□ected many parts of the world. Wildfires in Canada, Europe and Hawaii (United States of America) led to loss of life, the destruction of homes and large-scale air pollution. Flooding associated with extreme rainfall from Mediterranean Cyclone *Daniel* a□ected Greece, Bulgaria, Türkiye and Libya, with particularly heavy loss of life in Libya.

Food security, population displacement and impacts on vulnerable populations continued to be of mounting concern in 2023, with weather and climate hazards exacerbating the situation in many parts of the world.

Foreword

The climate crisis is the defining challenge that humanity faces.

The *WMO State of the Global Climate 2023* report confirms that the year 2023 broke every single climate indicator.

It was by far the warmest year on record. The global average temperature in 2023 was 1.45 ± 0.12 °C above the 1850–1900 average. Never have we been so close – albeit on a temporary basis – to the 1.5° C lower limit of the Paris Agreement on climate change.

Concentrations of greenhouse gases continued to rise. Ocean heat content and sea level reached record observed highs, and the rate of increase is accelerating. Antarctic sea-ice extent hit record observed lows. Key glaciers su□ered record losses.

Heatwaves, floods, droughts, wildfires and intense tropical cyclones wreaked havoc on every continent and caused huge socioeconomic losses. There were particularly devastating consequences for vulnerable populations, who su□ered disproportionate impacts.

Extreme climate conditions exacerbated humanitarian crises, with millions experiencing acute food insecurity and hundreds of thousands displaced from their homes.

WMO is committed to increasing collaboration with the international community to confront the enormity of this challenge.

WMO and its Members are expanding life-saving early warning services to achieve the ground-breaking Early Warnings for All initiative. A new Global Greenhouse Gas Watch (GGGW) seeks to provide scientifically based information for climate change mitigation. The transition to renewable energy must be supported by tailor-made weather and climate services.

To succeed, it is imperative to leverage e□orts across the entire value chain – from improving climate data and monitoring to strengthening prediction and projections and building capacity. We must make climate information more accessible and actionable to serve society.

I hope this report will raise awareness of the vital need to scale up the urgency and ambition of climate action.

I take this opportunity to congratulate and thank the experts and lead authors who compiled this report. I extend my gratitude to all the contributors, particularly to WMO Member National Meteorological and Hydrological Services (NMHSs) and Regional Climate Centres (RCCs) and United Nations agencies.

(Prof. Celeste Saulo)
Secretary-General

Global climate indicators

Global climate indicators provide an overview of changes in the climate system.[1] The set of interlinked physical indicators presented here connect the changing composition of the atmosphere with changes in energy in the climate system and the response of land, ocean and ice.

Global climate indicators are based on a wide range of datasets that comprise data from multiple observing systems, including satellites and in situ networks (for details on the datasets used in the present publication, see Data set and methods).

Changes to the physical climate, measured in the present publication by key indicators, can have cascading impacts on national development and progress towards the United Nations Sustainable Development Goals (SDGs).[2] For example, changes in the acidity or temperature of the ocean can a□ect marine life, in turn potentially a□ecting coastal communities that may depend on the local catch for their livelihood or food security. Nevertheless, climate science has a critical role to play in facilitating sustainable development. As demonstrated by the United in Science 2023 report, weather-, climate- and water-related sciences support the achievement of many of the SDGs.[3] Recognizing the interconnections between climate and development can therefore lead to synergistic action – an increasing necessity as the world strays further from achieving both the SDGs and the Paris Agreement goals.[4]

BASELINES

Baselines are periods of time, usually spanning three decades or more, that are used as a fixed benchmark with which current conditions can be compared. For scientific, policy and practical reasons, several di□erent baselines are used in the present publication, and these are specified in the text and figures. Where possible, the most recent WMO climatological standard normal, 1991–2020, is used for consistent reporting.

For some indicators, however, it is not possible to use the standard normal owing to a lack of measurements during the early part of the period. There are also two specific exceptions. First, for the global mean temperature time series – and only for the global mean series – a reference period of 1850–1900 is used. This is the baseline used by Working Group I in its contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6 WG I) as a reference period for pre-industrial conditions and is relevant for understanding progress in the context of the Paris Agreement. Secondly, greenhouse gas concentrations can be estimated much further back in time using gas bubbles trapped in ice cores. Therefore, the year 1750 is used in the present publication to represent pre-industrial greenhouse gas concentrations.

GREENHOUSE GASES

Concentrations of the three main greenhouse gases – carbon dioxide, methane and nitrous oxide – reached record-high observed levels in 2022, the latest year for which consolidated global values are available (1984–2022). Real-time data from specific locations show that levels of the three main greenhouse gases continued to increase in 2023.

Atmospheric concentrations of greenhouse gases reflect a balance among emissions from human activities, natural sources and sinks. Increasing levels of greenhouse gases in the atmosphere owing to human activities have been the major driver of climate change since the Industrial Revolution. Global average mole fractions of greenhouse gases – referred to in the present publication for simplicity as the "concentration" in the atmosphere – are calculated from in situ observations made at multiple sites through the Global Atmosphere Watch (GAW) Programme of WMO, and partner networks.

In 2022 – the latest year for which consolidated global figures are available – atmospheric levels of greenhouse gases reached new observed highs (see Figure 1), with globally averaged concentrations of carbon dioxide (CO_2) at 417.9 ± 0.2 parts per million (ppm), methane (CH_4) at 1 923 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 335.8 ± 0.1 ppb, respectively 150%, 264% and 124% of pre-industrial (1750) levels. The rate of increase in CH_4 was the second highest on record, after 2021, and the rate of increase in N_2O was the highest on record. The rate of increase in CO_2 at 2.2 ppm was slightly below the 10-year average of 2.46 ppm yr^{-1}. CO_2 growth rate is typically lower in years that start with La Niña, as 2022 did, and higher in years that start with El Niño, as 2016 did.[5] Real-time data from specific locations, including Mauna Loa[6] (Hawaii, United States of America) and Kennaook/Cape Grim[7] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2023.

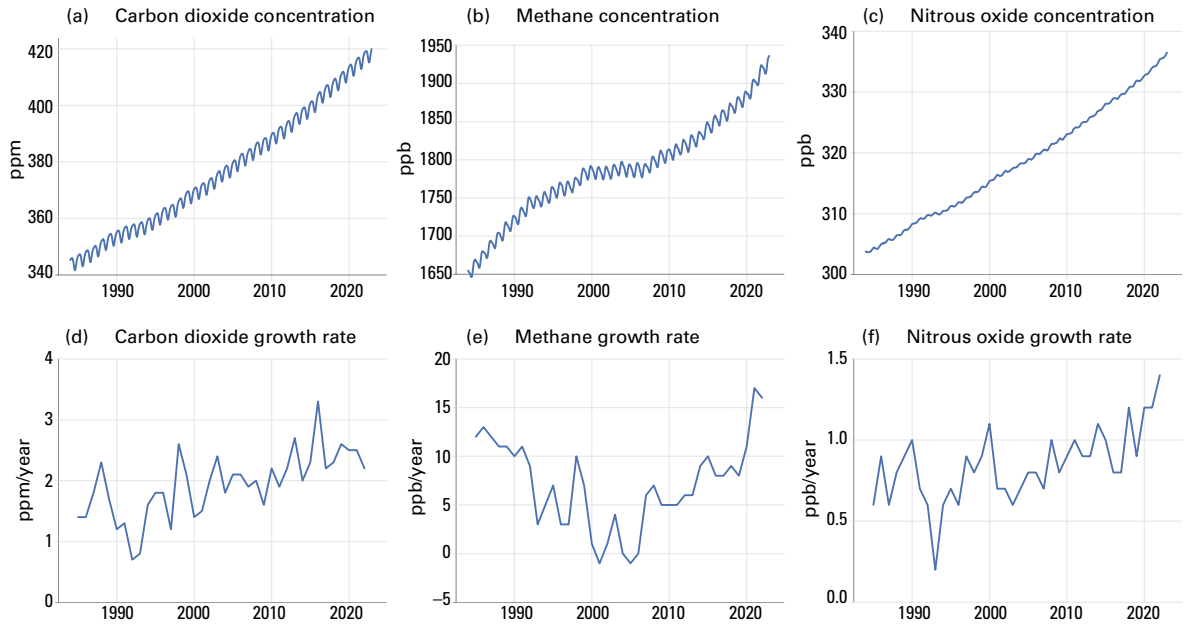


Figure 1. Top row: Monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2022, of (a) CO_2 in ppm, (b) CH_4 in ppb and (c) N_2O in ppb. Bottom row: Growth rates representing increases in successive annual means of mole fractions for (d) CO_2 in ppm per year, (e) CH_4 in ppb per year and (f) N_2O in ppb per year.

Source: World Data Centre for Greenhouse Gases (WDCGG)

TEMPERATURE

The global mean near-surface temperature in 2023 was 1.45 ± 0.12 °C above the 1850–1900 average. 2023 was the warmest year in the 174-year observational record, clearly surpassing the previous joint warmest years, 2016 at 1.29 ± 0.12 °C above the 1850–1900 average and 2020 at 1.27 ± 0.13 °C.

The past nine years, 2015–2023, were the nine warmest years on record.

Record monthly global near-surface temperatures have been observed for the ocean – from April through December – and, starting slightly later, the land – from July through November.

The 10-year average 2014–2023 global temperature was 1.20 ± 0.12 °C above the 1850–1900 average, making it the warmest 10-year period on record.

Global mean near-surface temperature in 2023 was 1.45 ± 0.12 °C above the 1850–1900 average[8] (see Figure 2). The analysis is based on a synthesis of six global temperature datasets (see Data set and methods). 2023 was the warmest year in the 174-year instrumental record in each of the six datasets. The past nine years – from 2015 to 2023 – were the nine warmest years on record. The two previous warmest years were 2016, with an anomaly of 1.29 ± 0.12 °C, and 2020, with an anomaly of 1.27 ± 0.13 °C.

Globally, every month from June to December was record warm for the respective month. September 2023 was particularly noteworthy, surpassing the previous global record for September by a wide margin (0.46 °C–0.54 °C) in all datasets. The second-highest margin by which a September record was broken in the past 60 years (the period covered by all datasets) was substantially smaller, at 0.03 °C–0.17 °C in 1983. July is typically the warmest month of the year globally, and thus July 2023 became the warmest month on record.

The long-term increase in global temperature is due to increased concentrations of greenhouse gases in the atmosphere. The shift from La Niña, which lasted from mid-2020 to early 2023, to fully developed El Niño conditions by September 2023 (see Short-term climate drivers)

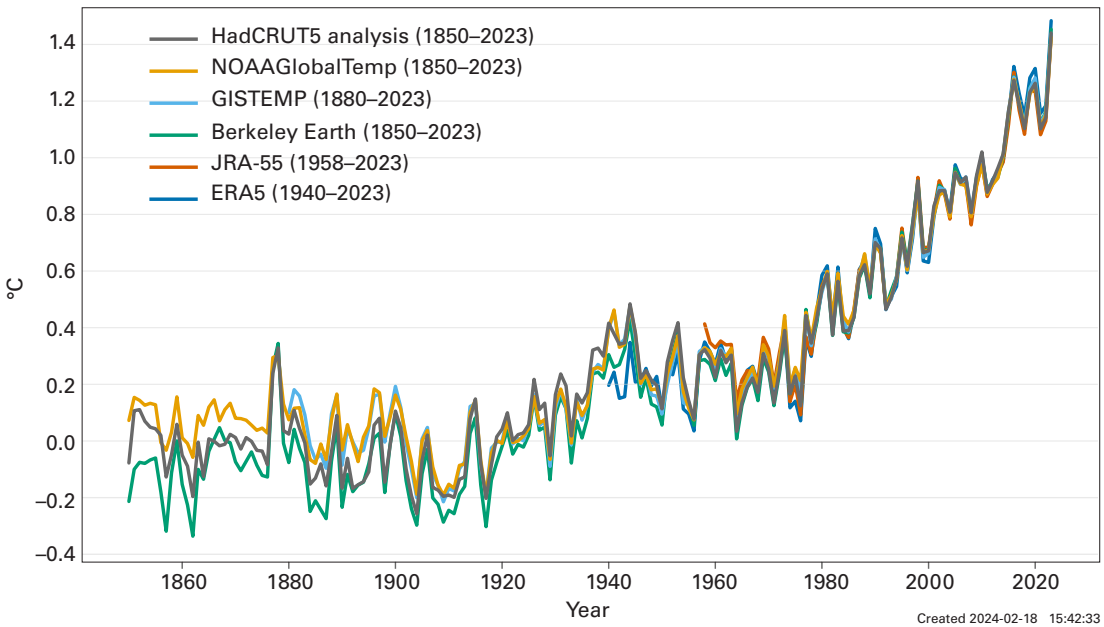


Figure 2. Annual global mean temperature anomalies (relative to 1850–1900)

Source: Data are from the six datasets indicated in the legend. See Data set and methods for details.

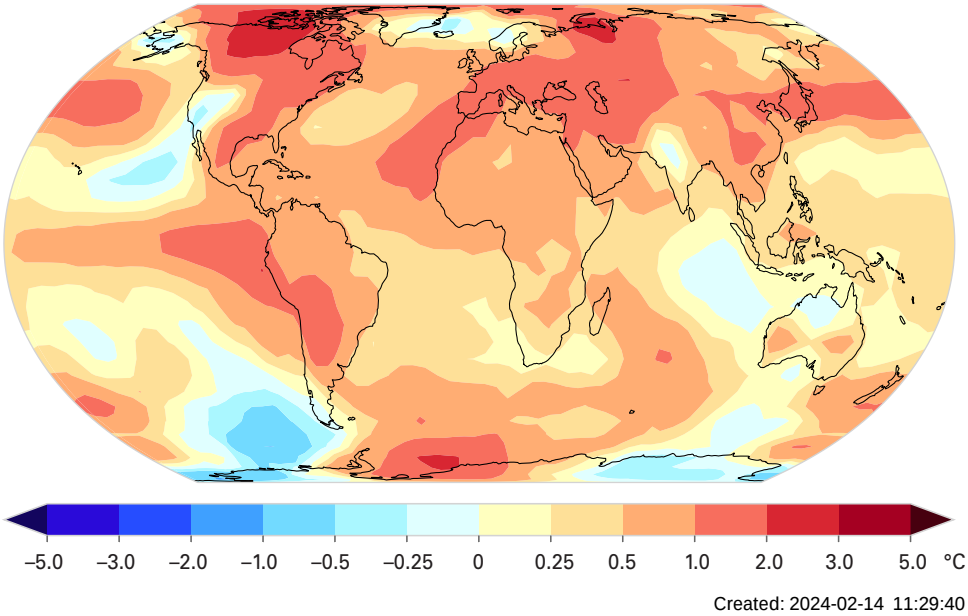


Figure 3. Mean near-surface temperature anomalies (difference from the 1991–2020 average) for 2023.

Source: Data are the median of the six datasets indicated in the legend. See Data set and methods for more details

likely explains some of the rise in temperature from 2022 to 2023. However, some areas of unusual warming, such as the North-East Atlantic (see Figure 3) do not correspond to typical patterns of warming or cooling associated with El Niño. Other factors, which are still being investigated, may also have contributed to the exceptional warming from 2022 to 2023, which is unlikely to be due to internal variability alone.[9]

The average global temperature over the past 10 years, from 2014 to 2023, was 1.20 ± 0.12 °C above the 1850–1900 average, making the past 10 years the warmest among all 10-year periods on record in all six datasets.

Between late spring in the northern hemisphere and the end of 2023, global average sea-surface temperatures (SSTs) were also at a record observed high. The records for July, August and September were each broken by a large margin (between 0.21 °C and 0.27 °C). Exceptional warmth relative to the 1991–2020 baseline was recorded in the eastern North Atlantic, the Gulf of Mexico and the Caribbean, the North Pacific extending eastward from the Sea of Japan, the Arabian Sea and large areas of the Southern Ocean (see Figure 3; see also Marine heatwaves and cold spells).

Observed global land temperature anomalies reached record levels in July and August, somewhat later than for SSTs, but the September average was also a record by a large margin of 0.53 °C–0.71 °C. The second-widest margin by which a record has been broken in the past 60 years was 0.22 °C–0.27 °C in September 2002. In 2023, most land areas were warmer than the 1991–2020 average (see Figure 3). Unusual warmth was reported across large areas of northern Canada, the southern United States of America, Mexico and Central America, as well as large areas of South America. Large areas from Central Asia to western Europe, including parts of North Africa and the Arabian Peninsula, were also unusually warm, as were South-East Asia and Japan.

OCEAN

Increasing human emissions of carbon dioxide (CO_2) and other greenhouse gases cause a positive radiative imbalance at the top of the atmosphere. This imbalance leads to the accumulation of energy in the Earth system in the form of heat, which is driving global warming.[10,11] The ocean, which covers about 70% of the Earth's surface, absorbs heat and CO_2, which can act to slow the rate of warming in the atmosphere. However, the heat absorbed by the ocean leads to ocean warming, which, together with the melting of ice on land, raises sea levels, while the absorption of CO_2 leads to ocean acidification. Warming waters, sea-level rise and ocean acidification all have significant e□ects on the ocean, as well as on the plants and animals that live in it and the people who rely upon it for their livelihoods.

OCEAN HEAT CONTENT

In 2023, ocean heat content reached its highest level in the 65-year observational record.

About 90% of the energy that has accumulated in the Earth system since 1971 is stored in the ocean. As energy has accumulated in the ocean, it has warmed, and global ocean heat content has increased (see Figure 4).

According to a consolidated analysis based on several individual datasets, the upper 2 000 m of the ocean continued to warm in 2023.[12] IIt is expected that warming will continue – a change that is irreversible on centennial to millennial timescales.[13,14] Ocean heat content in 2023 was the highest on record, exceeding the 2022 value by 13 ± 9 ZJ (see Figure 4)[15] cconsistent with estimates published in early 2024.[16]

All datasets agree that ocean warming rates show a particularly strong increase in the past two decades. The rate of ocean warming for the 0–2 000 m layer was 0.7 ± 0.1 W m^{-2} from 1971 to 2023 on average, but 1.0 ± 0.1 W m^{-2} from 2005 to 2023 (the period covered by the Argo programme). The steady increase in ocean warming rates[17,18] is seen consistently in direct estimates from in situ observations, indirect estimates from remote sensing and direct estimates of the net flux at the top of the atmosphere as measured by satellites.[19] Di□erent drivers of this change are discussed in literature, including a change in anthropogenic climate forcing[20] and natural variability.[21] Deep-ocean global warming below 2 000 m depth is estimated to be 0.07 ± 0.03 W m^{-2} from 1992 to 2022.[22]

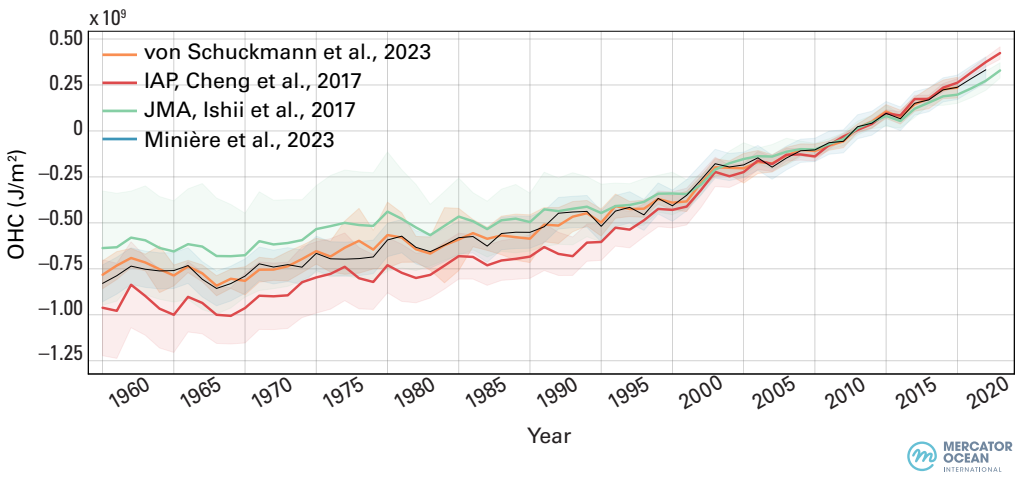


Figure 4. Global ocean heat content anomalies relative to the 2005–2021 average for the 0–2 000 m depth layer 1960–2023 (orange). Ensemble mean time series and ensemble standard deviation (2-standard deviations, shaded) updated from Schuckmann et al., 2023 (red); Cheng et al., 2017 (green); Minière et al., 2023 (light blue); and Ishii et al., 2017 (dark blue).

Source: Mercator Ocean international.

Although ocean heat content has increased strongly through the entire water column, the rate of warming has not been the same everywhere.[23] The strongest warming in the upper 2 000 m occurred in the Southern Ocean (60° S–35° S), North Atlantic (20° N–50° N) and South Atlantic (60° S–0° S) (see Figure 5). The Southern Ocean domain is the largest reservoir of heat, accounting for about 32% of the global ocean heat content increase in the upper 2 000 m since 1958.[24] The Atlantic Ocean accounts for approximately 31% of the global 0–2 000 m ocean heat content increase, and the Pacific Ocean for about 26%.

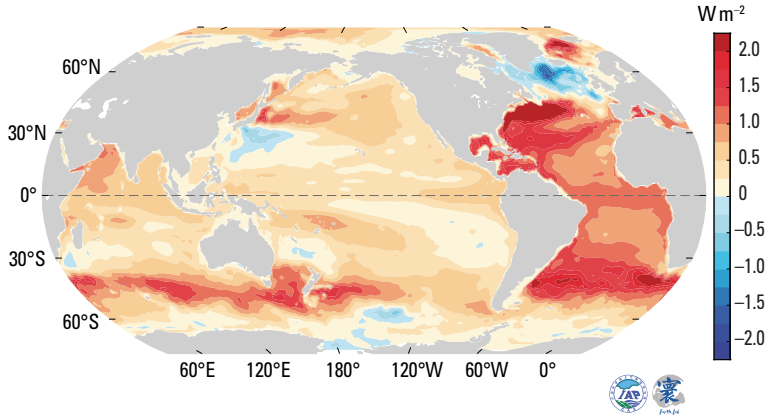


Figure 5. Observed upper 2000 m OHC trend from 1958 to 2023.

Source: Data updated from Cheng et al.[25]

Some relatively small regions are cooling, including the subpolar North Atlantic Ocean, extending from near the surface to a depth of over 800 m (also the only area to show centennial cooling at the surface). The contrasting pattern of cooling (50° N–70° N) and warming (20° N–50° N) in the North Atlantic has been associated with a slowing of the Atlantic Meridional Overturning Circulation and local interactions between the air and sea.[26] Other cooling regions include the North-West Pacific, the South-West Pacific and the South-West Indian Ocean.

SEA LEVEL

In 2023, global mean sea level reached a record high in the satellite record (from 1993 to present), reflecting continued ocean warming as well as the melting of glaciers and ice sheets

The rate of global mean sea-level rise in the past 10 years (2014–2023) is more than twice the rate of sea-level rise in the first decade of the satellite record (1993–2002).

Global mean sea level (GMSL) continued to rise in 2023 (see Figure 6). The La Niña conditions between mid-2020 and early 2023 had only a small apparent e□ect on GMSL, unlike the 2011 La Niña, which led to a temporary decrease in GMSL of several millimetres. The rapid rise observed in 2023 is likely due in part to El Niño. The long-term rate of sea-level rise has more than doubled since the start of the satellite record, increasing from 2.13 mm yr^{-1} between 1993 and 2002 to 4.77 mm yr^{-1} between 2014 and 2023.

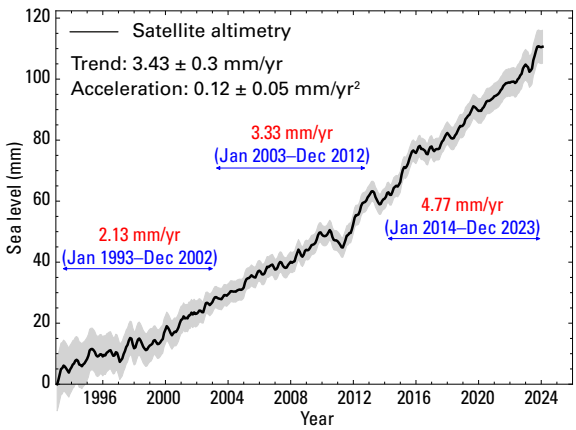


Figure 6. GMSL evolution between January 1993 and December 2023 based on satellite altimetry. The black line is the best estimate, and the grey shaded area indicates uncertainty. Red and blue annotations indicate the average rate of sea-level rise during three decades of the record as indicated.

Source: AVISO altimetry

From January to March 2023, sea levels (see Figure 7) were higher than the long-term average (1993–2012) in the western tropical Pacific. This is characteristic of warm seawater in the region associated with El Niño–Southern Oscillation (ENSO)-neutral conditions. Sea levels in the North Atlantic and eastern tropical Pacific were lower than the long-term average. Warming of the surface waters in the eastern tropical Pacific during

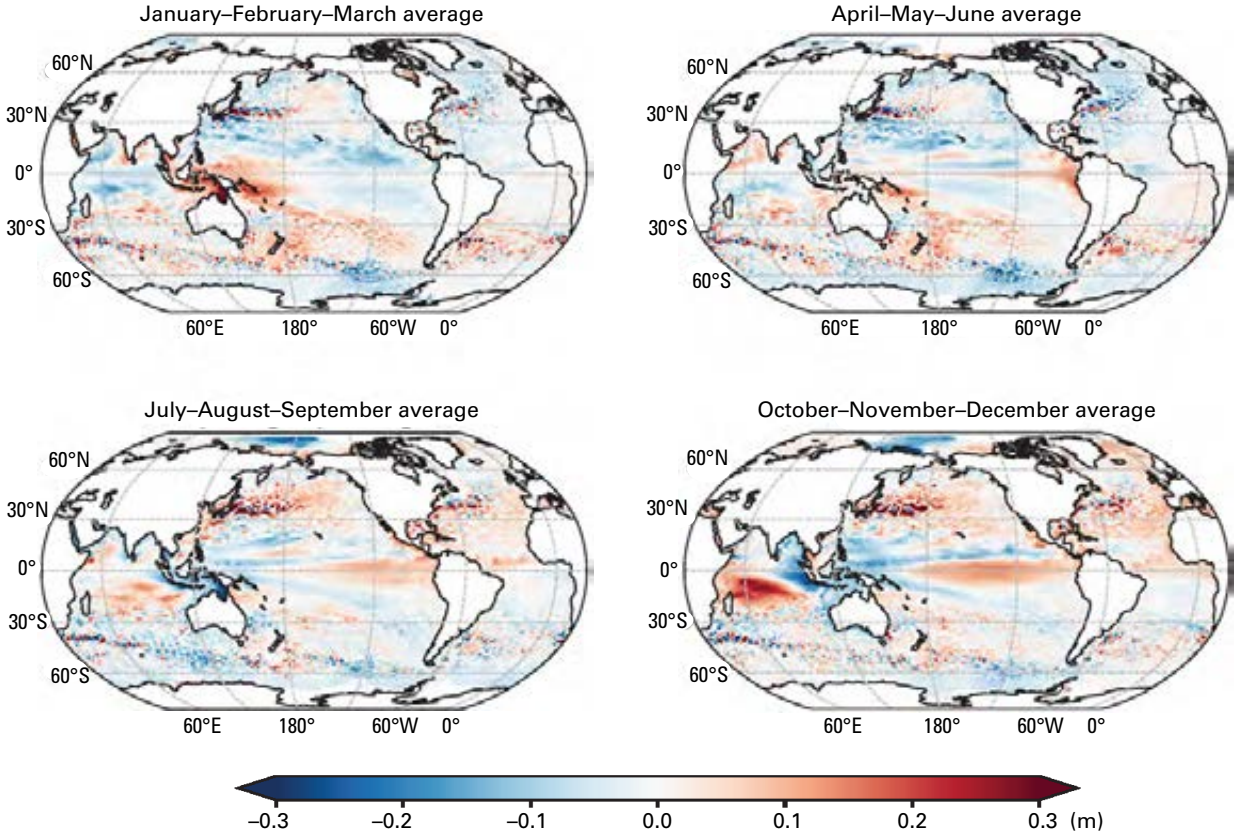


Figure 7. Three-month averages of altimetry-based sea-level anomalies (relative to the 1993–2012 average, which is the product climatology) for (top left) January–March 2023, (top right) April–June 2023, (bottom left) July–September 2023 and (bottom right) October–December 2023

Source: Data downloaded from the Copernicus Marine Service

the early stages of the 2023 El Niño (see Short-term climate drivers) led to an increase in sea levels relative to the long-term mean in the most eastern part of the tropical Pacific between April and June. Between July and September, the El Niño signature was clearly visible, with above-average sea levels from the mid-tropical Pacific to the coasts of Central and South America. Above-average sea levels were also observed in the tropical and North-East Atlantic, associated with the anomalous warming in these areas during the northern hemisphere summer. From October to the end of the year, the El Niño pattern continued to develop. The shift to the positive phase of the Indian Ocean Dipole (IOD) led to higher-than-average sea levels in the western Indian Ocean and lower-than-average sea levels in the East (see Short-term climate drivers).

MARINE HEATWAVES AND COLD SPELLS

As with heatwaves and cold spells on land, marine heatwaves and cold spells are prolonged periods of extreme high or low temperatures in the seas and ocean that can have a range of consequences for marine life and dependent communities.[27] Marine heatwaves have become more frequent, intense and longer lasting since the late twentieth century, while marine cold spells have been decreasing by those same measures. Satellite retrievals of sea-surface temperature (SST) are used to monitor marine heatwaves and cold spells globally, categorized in the present publication as "moderate", "strong", "severe", "extreme" or "ice" (for definitions, see Data set and methods).

El Niño events tend to cause widespread marine heatwaves in the eastern tropical Pacific. While this region did experience strong marine heatwaves in 2023 until late October (see Figure 8a), and moderate marine heatwaves for the rest of 2023, the overall areal coverage was smaller than in previous El Niño events.

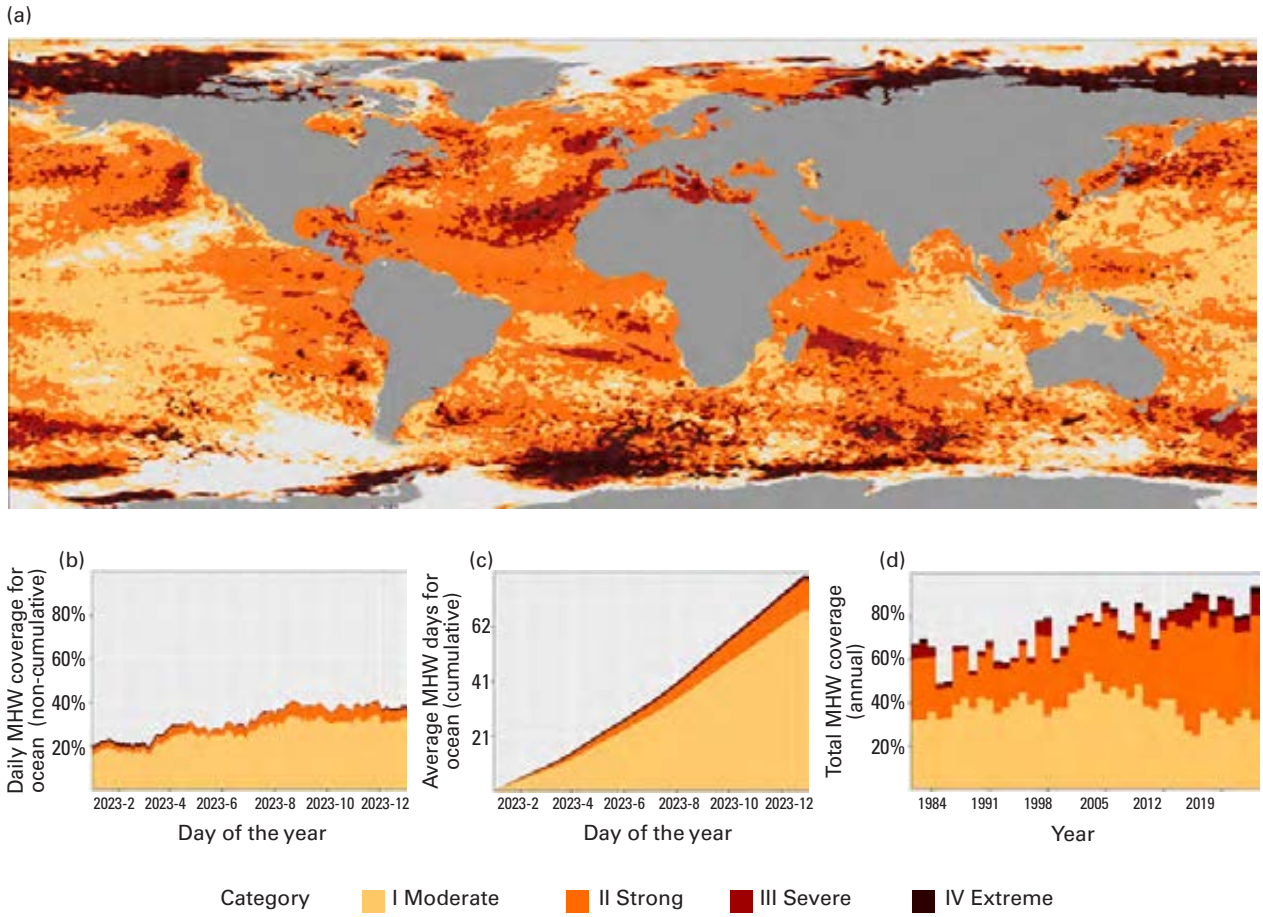


Figure 8. (a) Global map showing the highest marine heatwave category (for definitions, see Data set and methods) experienced at each pixel over 2023 (reference period 1982–2011). Light grey indicates that no marine heatwave occurred in a pixel over the entire year; (b) Stacked bar plot showing the percentage of the surface of the ocean experiencing a marine heatwave on any given day of the year; (c) Stacked bar plot showing the cumulative number of marine heatwave days averaged over the surface of the ocean, calculated by dividing the cumulative sum of marine heatwave days per pixel weighted by the surface area of those pixels); and (d) Stacked bar plot showing the total percentage of the surface of the ocean that experienced a marine heatwave from 1982 to present. Data are from the National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation Sea-Surface Temperature (OISST).

Source: Robert Schlegel

Of note in 2023 were the persistent and widespread marine heatwaves in the North Atlantic, which began in the northern hemisphere spring, peaked in extent in September and persisted through the end of the year. While areal coverage diminished in December, intensity increased. The end of 2023 saw a broad band of severe and extreme marine heatwaves across the North Atlantic, with temperature anomalies in the open ocean of +3 °C.

The Mediterranean Sea was also unusually warm relative to the baseline period and experienced near-complete coverage of strong and severe marine heatwaves for the twelfth consecutive year. In the southern hemisphere, the waters surrounding New Zealand remained 1 °C–2 °C above the long-term average from January to September (~270 days).

At the end of 2023, most of the global ocean from roughly 20° N to 20° S of the equator had been in a marine heatwave state since early November. In contrast, there were almost no occurrences of marine cold spells within 60° N or 60° S of the equator in 2023 (see Figure 9a).

The global ocean experienced an average daily marine heatwave coverage of 32% (see Figure 8b), well above the previous record of 23% in 2016. In contrast, the average daily coverage of marine cold spells (see Figure 9b) was only 4%, far below 2022 (7%).

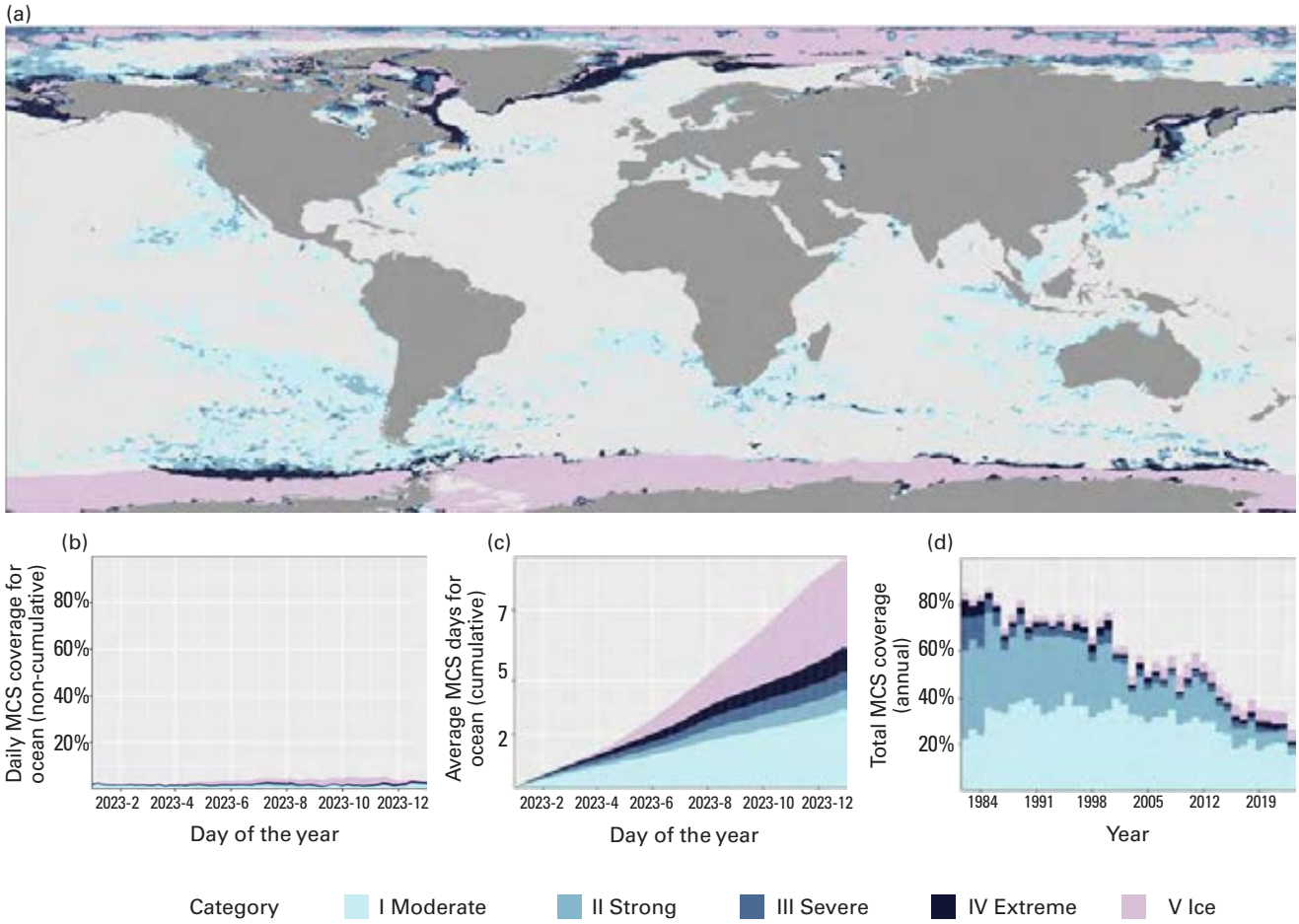


Figure 9. As for Figure 8 but showing marine cold spells rather than heatwaves. Data are from the NOAA OISST.

Source: Robert Schlegel.

OCEAN ACIDIFICATION

The ocean absorbs about one quarter of the annual emissions of anthropogenic carbon dioxide (CO_2) released into the atmosphere.[28,29] CO_2 reacts with seawater and alters the carbonate chemistry, resulting in a decrease in pH referred to as "ocean acidification" (see Figure 10). Ocean acidification a□ects organisms and ecosystem services, including food security, by reducing biodiversity, degrading habitats and endangering fisheries and aquaculture.[30] The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6) concluded that "[t]here is very high confidence that present-day surface pH values are unprecedented for at least 26 000 years and current rates of pH change are unprecedented since at least that time".[31]

Although global e□orts, many supported by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), and led by the Global Ocean Acidification Observing Network (GOA-ON) and the United Nations Ocean Decade-endorsed Ocean Acidification Research for Sustainability (OARS) Programme, have resulted in an increase in the number of ocean acidification observations, many regions remain under sampled. Data collected for Sustainable Development Goal (SDG) Indicator 14.3.1 (Average marine acidity (pH) measured at agreed suite of representative sampling stations) show that current coverage is inadequate (see Figure 11), with time series not long enough to determine trends and gaps in observations in all areas. Global trends illustrating the decrease in global ocean surface pH (see Figure 10) show the large-scale e□ects of CO_2 emissions. However, the rate of change in ocean acidification, and its pattern and scale, show great regional and temporal variability, and understanding these variations requires high-resolution, long-term observation at scales relevant to the a□ected communities.

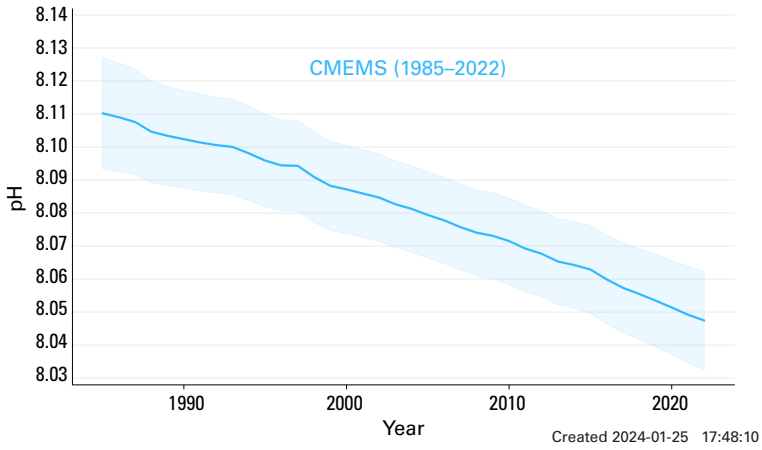


Figure 10. Global annual mean ocean surface pH (purple) covering the period 1985–2022. The shaded area indicates the estimated uncertainty in the values.

Source: Data from the Copernicus Marine Environment Monitoring Service.

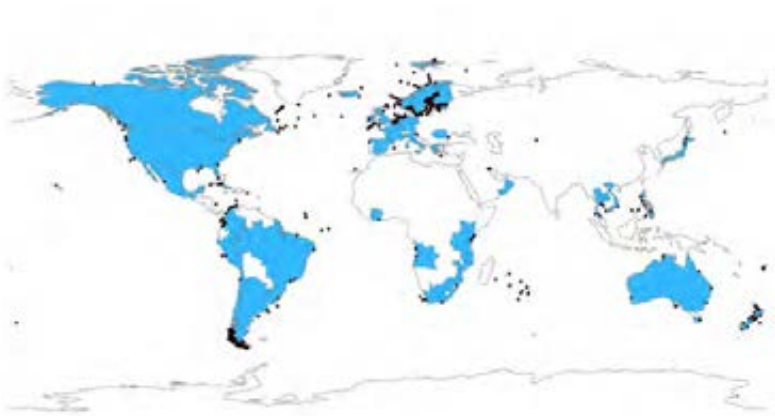


Figure 11. Map illustrating surface ocean carbonate chemistry measurement locations received for SDG Indicator 14.3.1 (Average marine acidity (pH) measured at agreed suite of representative sampling stations) ocean acidification reporting by IOC/UNESCO. Countries highlighted in light blue reported data in accordance with the SDG Indicator 14.3.1 methodology. Black dots show the location of sampling stations from which data were collected.

Source: IOC/UNESCO

CRYOSPHERE

The cryosphere comprises the frozen parts of Earth, namely glaciers and ice sheets, sea ice, snow and permafrost. The inhospitable and often remote environments in which ice forms mean that it has sometimes been challenging to undertake long-term measurements of the cryosphere. At the same time, the profound changes seen in the cryosphere clearly illustrate the global scale of climate change.

SEA-ICE

Arctic sea-ice extent remained well below normal in 2023, with the annual maximum and annual minimum extents being respectively the fifth and sixth lowest in the 45-year satellite record.

Antarctic sea-ice extent reached an absolute record low for the satellite era (from 1979 to present) in February. Sea-ice extent was at a record low for the time of year from June until early November, and the annual maximum in September was about 1 million km² below the previous record low maximum.

Arctic sea-ice extent reached its annual maximum of 14.62 million km² on 6 March, the fifth lowest in the satellite record.[32] The annual minimum Arctic sea-ice extent was reached on 19 September (see Figure 12, left),[33] with a minimum extent of 4.23 million km², well below the long-term average (1991–2020) of ~5.5 million km². This was the sixth lowest minimum Arctic sea-ice extent in the satellite record (1979–2023), not as extreme as 2012 or 2020 but only slightly higher than 2007, 2016 and 2019, and continuing the long-term trend of reduced late-summer and early-autumn Arctic ice cover. Major negative anomalies were observed in the Beaufort, Chukchi and East Siberian Seas (see Figure 12, right). The year ended with extents close to the long-term average, but still the ninth lowest in the satellite record.[34]

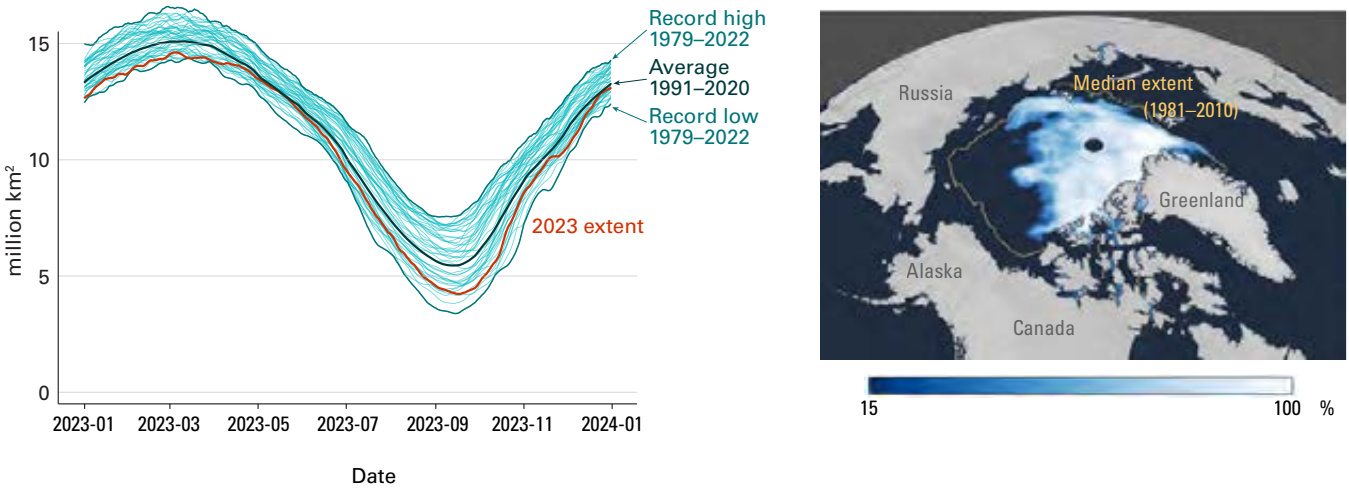


Figure 12. (left) Daily Arctic sea-ice extent from January through December, showing 2023 (red line) against the climate normal (1991–2020, dark blue), and the record highest and lowest extents for each day (mid-blue). Individual years are shown in light blue. (right) Sea-ice concentration on 19 September 2023, at the annual minimum Arctic sea-ice extent. The yellow line indicates the median ice edge for the 1981–2010 period.[35]

Source: Data and map from the National Snow and Ice Data Center (NSIDC).

Antarctic sea-ice extent had declined to 1.79 million km² on 21 February 2023 (see Figure 13, left), an all-time minimum for the satellite era (from 1979 to present) and slightly less than the previous record low, which was set in 2022.[36] Sea-ice extent remained below the average as the growth season commenced, reaching a record low for the time of year in May. Slow growth continued with exceptional record low extents between July and the annual maximum, likely in association with the warming of the Southern Ocean.[37] The maximum Antarctic sea-ice extent for 2023 (see Figure 13, right) was 16.96 million km² on 10 September, roughly 1.5 million km² below the 1991–2020 average and 1 million km² below the previous record low maximum set in 1986.[38] Record low sea-ice extents for the time of year continued until early November, but a slower-than-average rate of decline in December brought sea-ice extents closer to the long-term mean by the end of the year.[39]

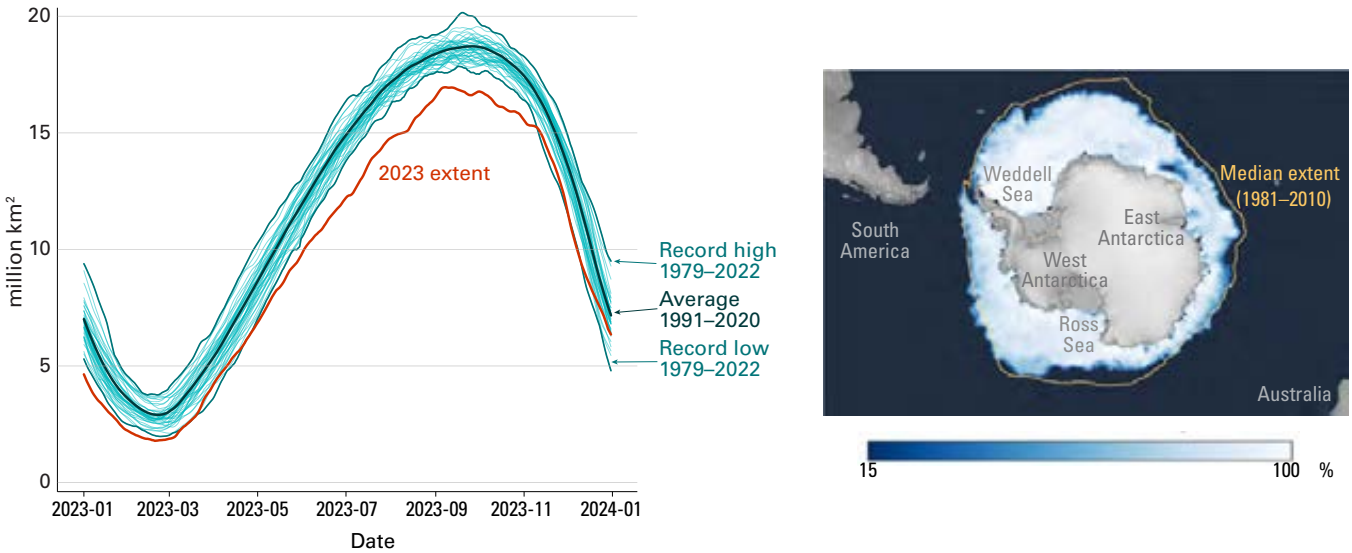


Figure 13. (left) Daily Antarctic sea-ice extent from January through December, showing 2023 (red line) conditions against the 1991–2020 climate normal (dark blue), and the record highest and lowest extents for each day (mid-blue). Individual years are shown in light blue. (right) Sea-ice concentration on 10 September 2023, at the 2023 annual maximum extent. The yellow line shows the median ice edge for the 1981–2010 climatology period.[40]

Source: Data and map from NSIDC.

ICE SHEETS

It was the warmest summer on record at Summit Station, 3.4 °C warmer than the 1991–2020 average and 1.0 °C warmer than the previous record.

An ice sheet[41] is an expanse of ice originating on land that covers an area of more than 50 000 km². There are two principal ice sheets in the present-day climate system, one in Greenland and one in Antarctica.[42] The total mass balance of an ice sheet is the sum of three components: surface mass balance, marine mass balance and basal mass balance. Surface mass balance is the di□erence between snow accumulation and meltwater runo□ from the ice sheet. Marine mass balance is the mass loss at the edge of the ice sheet from the calving of icebergs and the melting of ice that is in contact with the ocean. Basal mass balance consists of melting at the ice sheet bed owing to geothermal heat and friction as the ice slides over the ground beneath. A negative mass balance indicates loss of ice mass; a positive mass balance indicates gain.

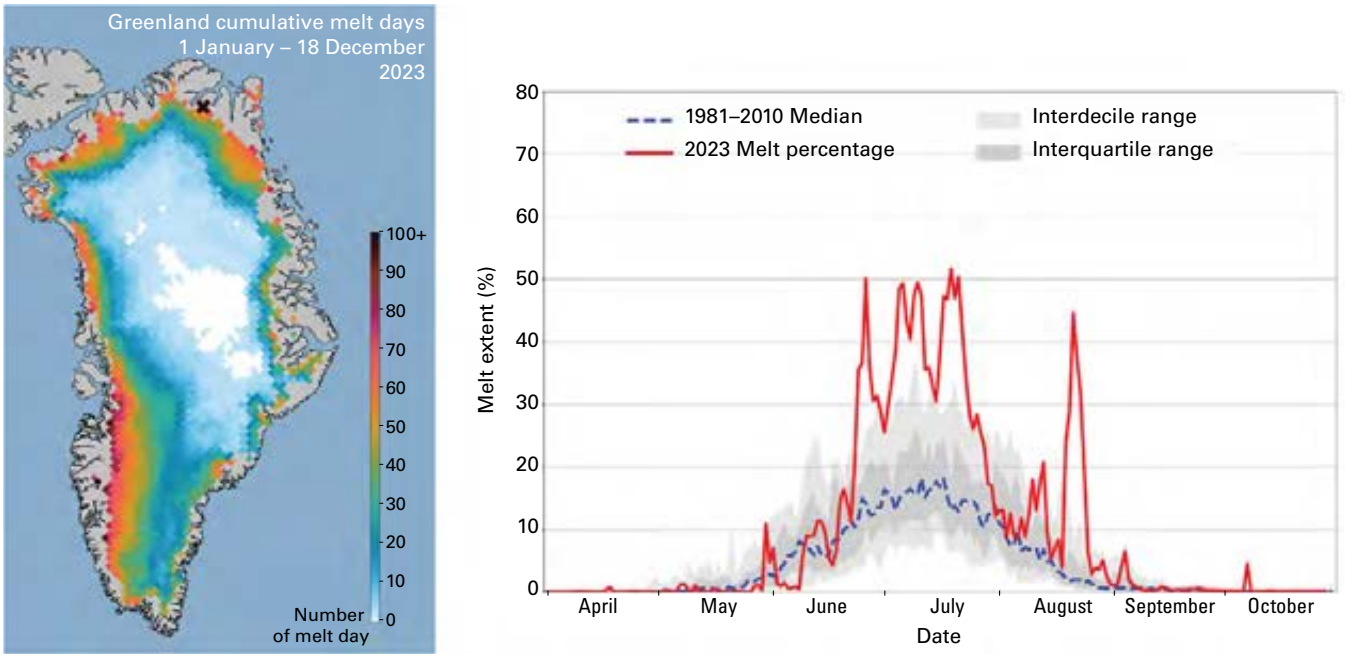


Figure 14. Greenland ice sheet melt conditions through 2023: (left) Cumulative melt days for Greenland in 2023. White areas indicate no melting occurred. (right) Percentage of the ice sheet experiencing melting conditions each day.

Source: Images and analysis courtesy of Thomas Mote, University of Georgia, and the National Snow and Ice Data Center (NSIDC).

Based on estimates from an ensemble of regional climate models, the Greenland ice sheet continued to lose mass in the hydrological year 2022/2023 (from 1 September 2022 to 31 August 2023).[43] Annual snow accumulation over Greenland still exceeds surface melt in most years, giving a positive surface mass balance. For 2022–2023 this was estimated at +317 Gt, below the long-term average but well above the extreme melt years of 2011–2012 and 2018–2019. Combined with the basal mass balance (−27 Gt) and the marine mass balance (−504 Gt), the estimated 2022–2023 ice sheet total mass balance was about −217 Gt.

The summer 2023 melt season was relatively intense, punctuated by major heatwaves in July and August.[44] Satellite melt extent data indicate that the ice sheet had the third highest cumulative melt-day area[45] on record (1978–2023), after the extreme melt season of 2012 and 2010 (see Figure 14). It was the warmest summer on record (1987–present) at Summit Station,[46] 3.4 °C warmer than the 1991–2020 average and 1.0 °C warmer than the previous record.[47] Summit Station experienced melting conditions for the fifth year on record (2012, 2019, 2021, 2022 and 2023); ice core records indicate that significant melting conditions last happened in the late nineteenth century.[48]

The Ice Sheet Mass Balance Inter-comparison Exercise has documented the acceleration in combined mass loss from the Greenland and Antarctic ice sheets over the period of the satellite record, 1992–2020.[49] The average total mass balance of the Greenland and Antarctic ice sheets over this period were −169 Gt yr^{-1} and −92 Gt yr^{-1},[50] respectively, and −261 Gt yr^{-1} combined. Combining the two ice sheets, the seven highest melt years on record have all occurred since 2010, and average rates of mass loss increased from 105 Gt yr^{-1} between 1992 and 1996 to 372 Gt yr^{-1} between 2016 and 2020. This is equivalent to ~1 mm yr^{-1} of global sea-level rise attributable to the polar ice sheets in the latter period.

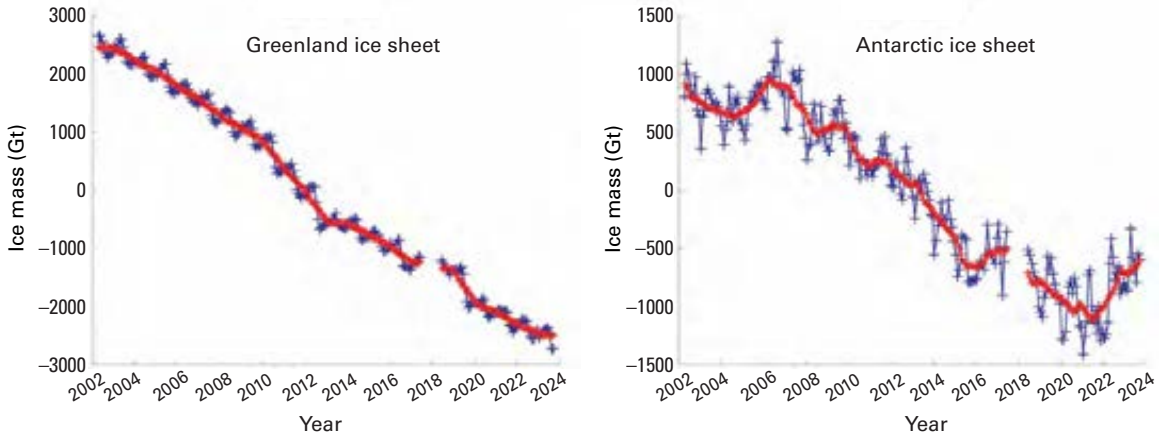


Figure 15. Gravitational mass balance data from the GRACE satellite mission for the Greenland and Antarctic ice sheets, from April 2002 through September 2023.

Source: Data and analysis courtesy of Isabella Velicogna.

Data and modelled estimates of mass balance from 2023 are consistent with these recent rates of mass loss in Greenland, but the Antarctic ice sheet gained mass owing to higher-than-normal snow accumulation in the past year and a half (see Figure 15). Gravitational mass balance data from the Gravity Recovery and Climate Experiment (GRACE) satellite mission for the hydrological year 2022/2023 give an estimated mass change of −196 Gt for Greenland, close to the long-term rate of mass loss from the ice sheet. The Antarctic ice sheet gained 122 Gt over this same period.

GLACIERS

Preliminary data indicate the annual mass balance of a global set of reference glaciers for the hydrological year 2022/2023 was –1.2 m of water equivalent. This is nominally the largest loss of ice on record (1950–2023), driven by extremely negative mass balance in both western North America and Europe.

Glaciers in western North America and the European Alps experienced an extreme melt season. In Switzerland, glaciers have lost about 10% of their remaining volume in the past two years.

Glaciers are formed from snow that has compacted to form ice, which then deforms and flows downhill. Glaciers comprise two zones: an accumulation zone, where accumulation of mass from snowfall exceeds ice loss, and an ablation zone, where ice loss (ablation) from melting and other mechanisms exceeds accumulation. Where glaciers end in a lake or the ocean, ice loss can occur through melting where the ice meets the water, and via calving, when chunks of the glacier break o□.

Glacier mass balance – the amount of mass gained or lost by the glacier – is commonly expressed as the annual thickness change averaged over the glacier area, in turn expressed in metres of water equivalent (m w.e.).[51] Melt rates are strongly a□ected by glacier albedo, the fraction of sunlight that is reflected by the glacier surface. Exposed glacier ice is darker and therefore has a lower albedo than the seasonal snowpack; it is also sensitive to darkening from mineral dust, black carbon, algal activity and fallout from forest fires. Reduced snow cover, long melt seasons and wildfire activity all serve to concentrate darker material on the glacier surface, decreasing its albedo and thereby increasing melt.

Preliminary data from a set of reference glaciers monitored by the World Glacier Monitoring Service (WGMS) indicate a global annual mass balance for the hydrological year 2022/2023 of –1.2 m w.e., which is slightly more negative than 2021/2022 for the set of about 60 WGMS reference glaciers. Based on the available glacier data, this is nominally a record low mass balance (1950–2023, see Figure 16). Record loss was driven by extremely negative mass balance in both western North America and Europe, and 7 out of the 10 most negative mass-balance years have occurred since 2010.

The annual mass loss for Swiss glaciers in 2022–2023 was the second largest on record (from 1950 to present, see Figure 17) at 4.4% of the remaining ice volume. Together with the record mass loss in 2021–2022 of 5.9%, Swiss glaciers have lost about 10% of their remaining volume in just two years. This has been driven by low snowpacks and warm summers each year, with potential cumulative impacts from glacier darkening associated with longer-than-normal periods of exposed glacier ice and loss of high-elevation firn.[53]

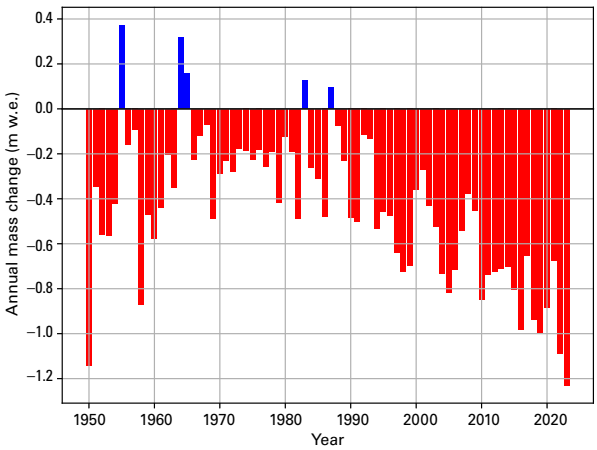


Figure 16. Annual mass balance of reference glaciers with more than 30 years of ongoing glaciological measurements. Annual mass change values are given on the y-axis in the unit meter water equivalent (m w.e.) which corresponds to tonnes per square meter (1 000 kg·m^{-2}).

Source: WGMS (2023, updated and earlier reports[52])

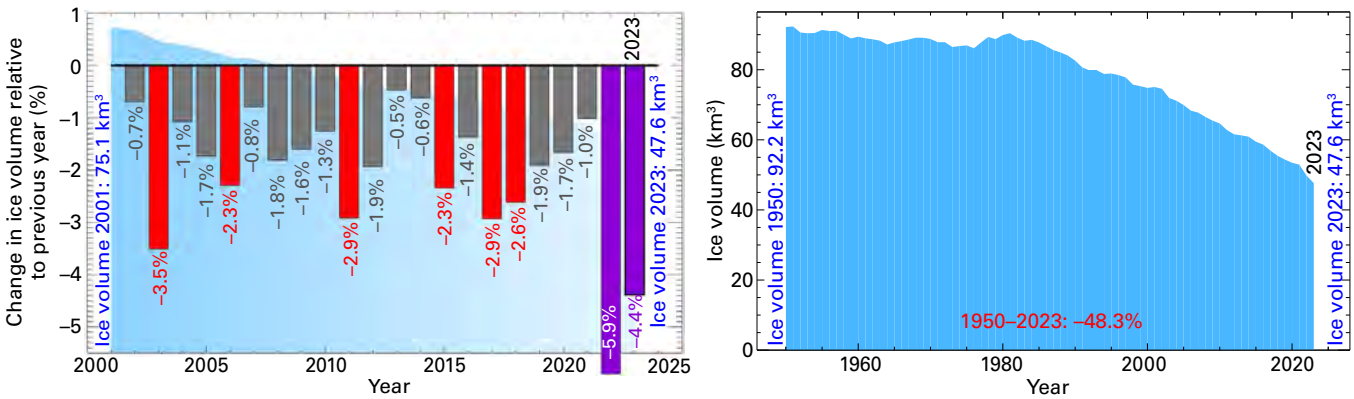
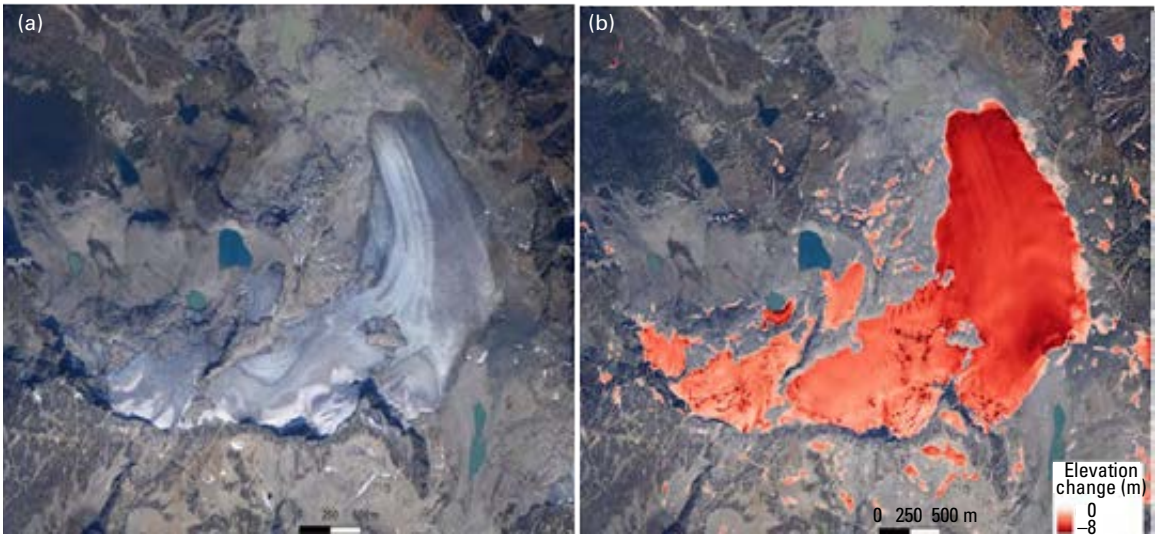


Figure 17. (left) Total annual loss of Swiss glaciers related to current ice volume. The vertical bars indicate the percentage change in ice volume relative to the previous year. Red and purple bars are the eight largest relative mass losses on record. The purple bars are the relative mass losses for 2022 and 2023. The blue shaded area in the background represents overall ice volume as also shown in the right-hand graph. (right) Overall ice volume for Swiss glaciers 1950–2023.

Source: Matthias Huss, based on Glacier Monitoring Switzerland, 2022: *Swiss Glacier Mass Balance (Release 2023)*, https://doi.org/10.18750/massbalance.2022.r2022.



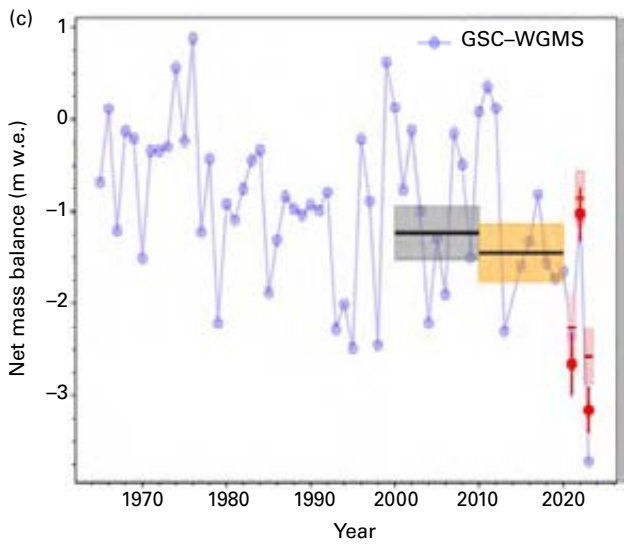


Figure 18. (a) Place Glacier in the southern Coast Mountains, British Columbia, Canada, 16 August 2023, indicating the dearth of seasonal snow and the dark firn and ice surfaces. (b) Elevation change from 18 October 2022 to 16 September 2023 obtained from repeat airborne LiDAR surveys. (c) Long-term mass balance record from Place Glacier showing in situ measurements (blue circles) and repeat LiDAR surveys using current ice extent (red circles) and glacier outlines (pink rectangles) used by Hugonnet et al., 2021. The grey and orange rectangles denote geodetic mass change estimates for the periods 2000–2009 and 2010–2019, respectively, from Hugonnet et al., 2021.

Source: Brian Menounos, University of Northern British Colombia and the Hakai Institute Airborne Coastal Observatory.

Western North America experienced record (from 1965 to present) glacier mass loss in 2023, with glacier-averaged annual thinning of more than 3.5 m at LiDAR-monitored[54] glacier sites in the Canadian Rockies and southern Coast Mountains. Based on regional LiDAR surveys, North American glaciers lost mass at rates that were five times higher than rates measured for the period 2000–2019.[55] Adjusting the LiDAR altimetry data for snow and ice density, estimates of mass balance at two sites with long-term measurements, Place (see Figure 18) and Haig Glaciers, are, respectively, 3.1 ± 0.5 m w.e. and –3.8 ± 0.6 m w.e. In situ mass balance measurements from these two sites give estimates of –3.7 m w.e. and –4.1 m w.e., respectively; far below the long-term mean and more than 1 m w.e. below the previous record minima.

The large negative mass balances are due to a below-average winter snowpack followed by an intense spring heatwave that led to early exposure of bare ice across most glaciers and icefields in south-west Canada. Seasonal snow was mostly gone in midsummer on most glaciers, exposing darker firn or ice over an extended melt season (see Figure 17). Above-average summer temperatures and record wildfire activity in western Canada[56] (see Extreme weather and climate events) contributed to the extreme melt, with particulate deposition

from the wildfires further darkening the glacier surfaces. High rates of cumulative melting over the past several years may also be a factor, as impurities are increasingly concentrated on the glacier surfaces and the firn zone has been lost on many mountain glaciers. These factors are becoming persistent, and glaciers in western North America lost an estimated 9% of their 2020 volume over the period 2020–2023.

SNOW COVER

Seasonal snow cover in the northern hemisphere has been experiencing a long-term decline in the late spring and summer. Northern hemisphere snow-cover extent for May was the eighth lowest on record (1967–2023). North American snow-cover extent for May 2023 was the lowest on record (1967–2023).

Seasonal snow cover in the northern hemisphere has been experiencing a long-term decline in the late spring and summer, which continued in 2023. Northern hemisphere snow-cover extent from January through April 2023 was close to the long-term average (1991–2020), but the spring heatwave in North-western North America drove widespread snowmelt. North American snow-cover extent for May 2023 was the lowest on record (1967–2023) at 7.47 million km^2, about 1.57 million km^2 (17%) below the long-term average, while overall northern hemisphere snow-cover extent was 16.74 million km^2, the eighth lowest since 1967 and 1.47 million km^2 below the long-term average (see Figure 19).

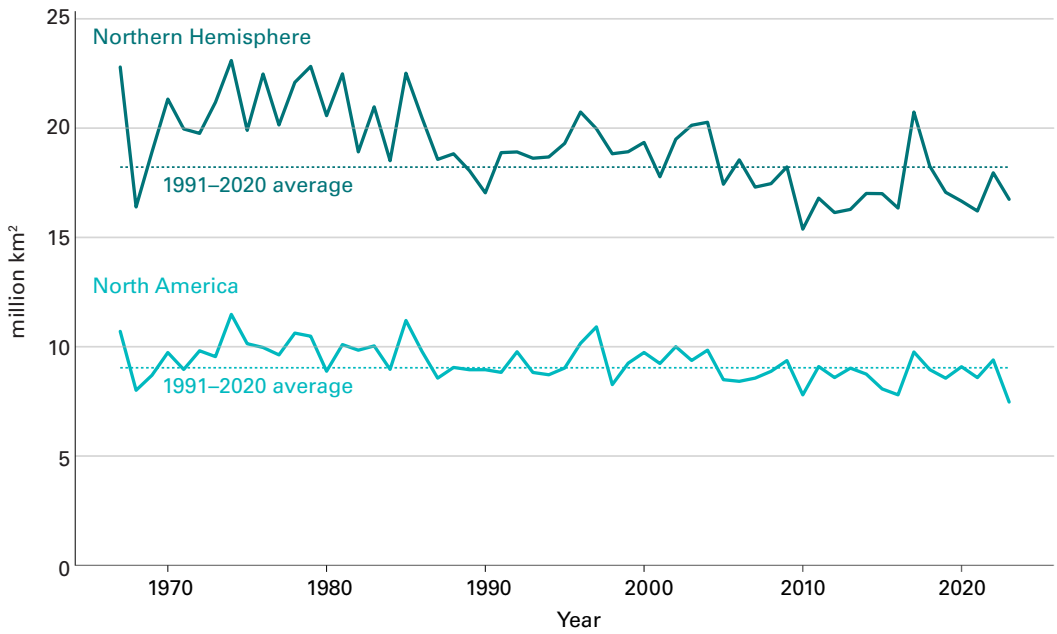


Figure 19. May snow-cover extent for the northern hemisphere (dark blue) and North America (light blue), 1967–2023. The 1991–2020 average for each region is shown as a horizontal dotted line.

Source: Data from the Rutgers University Global Snow Lab[57].

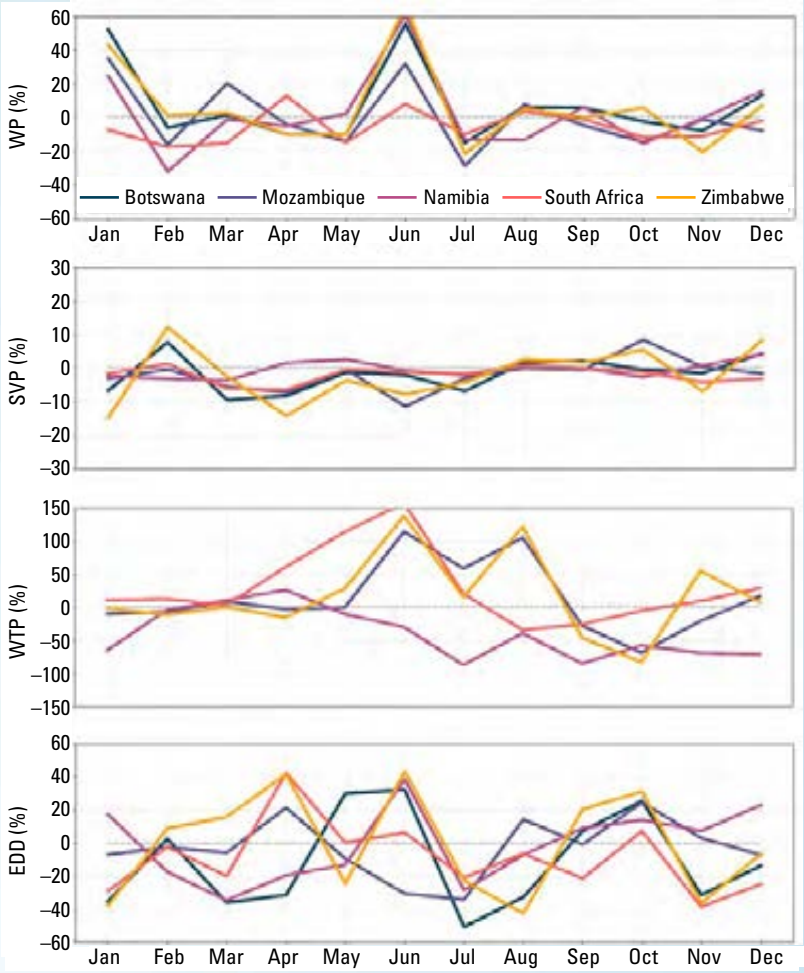
Climate Monitoring and Renewable Energy

Hamid Bastani and Roberta Boscolo

Renewable energy generation, primarily driven by the dynamic forces of solar radiation, wind and the water cycle, has surged to the forefront of climate action for its potential to achieve decarbonization targets. Worldwide, a substantial energy transition is already under way. In 2023, renewable capacity additions increased by almost 50% compared with 2022, for a total of 510 GW.[58] Such growth marks the highest rate observed in the past two decades and, as the International Energy Agency (IEA) indicates, demonstrates the potential to achieve the clean energy goal set at the twenty-eighth United Nations Climate Change Conference (COP 28) to triple renewable energy capacity globally to reach 11 000 GW by 2030.[59]

In the era of this massive and fast transition to renewables, understanding the critical nexus between climate variability and renewable energy is pivotal. A comprehensive knowledge of how the climate is going to modulate the availability of and demand for renewable energy is essential for optimizing the operation and planning of, and investments in, energy resources. The recent joint publication of WMO and the International Renewable Energy Agency (IRENA), *2022 Year in Review: Climate driven Global Renewable Energy Potential Resources and Energy Demand*, underscores the inherent links between renewable energy resources and weather and climate conditions. The publication emphasizes the potential for developing countries – especially in Africa, where energy access remains a key priority – to develop clean energy systems and urges better accounting for climate variability for the improved operation, management and planning of energy resources.

The importance of accounting for climate variability can be seen in Figure 21, which shows monthly energy supply and demand anomalies in Botswana, Mozambique, Namibia, South Africa and Zimbabwe in 2022 relative to the average of the 1991–2020 reference period. The anomalies are measured by four defined energy indicators, which are capacity factors[60] for wind power, solar photovoltaic power, weighted total precipitation as a proxy indicator for hydropower and energy degree days as a proxy indicator for energy demand.



To illustrate how the plots can be interpreted, consider October, when demand in all five countries is between 5% and 30% higher than average, while a large portion of potential generation is lower than average (except for small increases in solar photovoltaic power in Mozambique and Zimbabwe, and wind power in Zimbabwe). In this situation, balancing power would require careful planning, for instance to ensure there were enough water in hydropower dams from the previous rainy season (typically ending in May) ahead of the next rainy season (typically starting in October–November).

For more detailed information about the indicators and additional insights as to other regions and global results, refer to the publication.[61]

Figure 20. Monthly percentage anomalies of four energy indicators for wind power (WP), solar photovoltaic (SPV) power, weighted total precipitation (WTP) (hydropower proxy indicator) and energy degree days (EDD) (energy demand proxy indicator) for 2022 relative to corresponding months in the 1991–2020 reference period for five countries in southern Africa as indicated in the legend. Note that Botswana does not have hydropower plants, and therefore no indicator has been computed. Also note that the y-axis varies depending on the range of the indicator.

Source: WMO–IRENA

STRATOSPHERIC OZONE AND OZONE-DEPLETING GASES

Following the success of the Montreal Protocol, the use of halons and chlorofluorocarbons (CFCs) has been reported as discontinued, but their levels in the atmosphere continue to be monitored.[62] Owing to the long lifetimes of CFCs, these compounds will remain in the atmosphere for many decades and, even if there were no new emissions, there would still be more than enough chlorine and bromine present to cause the complete destruction of the ozone in Antarctica from August to December. As a result, the formation of the Antarctic ozone hole continues to be an annual spring event, with year-to-year variation in its size and depth governed to a large degree by meteorological conditions. The "hole" is not, strictly speaking, a hole; it is an area where the total column ozone in the stratosphere falls below 220 Dobson units.[63]

In 2023, the development of the ozone hole had an unusually early start, becoming the sixth largest in the satellite era. It expanded to 26 million km2 on 21 September (see Figure 20), comparable with the two previous years (2021 and 2022) and close to the maxima observed in earlier years, such as 28.2 million km2 in 2015 and 29.6 million km2 in 2006, according to analyses from the National Aeronautics and Space Administration (NASA)[64] and the Copernicus Atmosphere Monitoring Service (CAMS)[65]. NASA reported a minimum ozone of 99 Dobson units on 3 October 2023. Despite the area of the ozone hole decreasing in a typical manner through early October, it increased again towards the end of the month and remained at or above approximately 15 million km^2 until the first week of December. Although the ozone hole was unusually long-lived in 2023, its longevity was similar to that of the ozone holes of the past three years.

The unusual persistence of the ozone holes of the past three years was due to below-average stratospheric temperatures and a strong polar vortex lasting until December. Several potential drivers for the observed stronger polar vortex have been identified, including water vapour injected into the stratosphere by the eruption of Hunga Tonga–Hunga Ha'apai, wind patterns in the southern hemisphere and climate change.

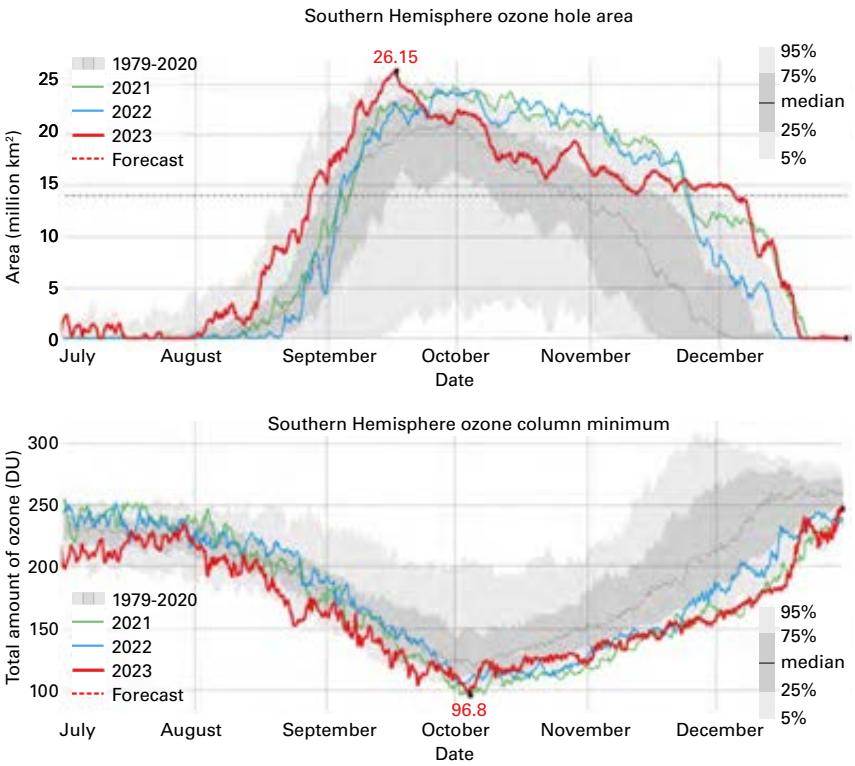


Figure 21. Area (millions of km2) and minimum ozone where the total ozone column is less than 220 Dobson units; 2023 is shown in red. The three most recent years are shown for comparison, as indicated by the legend. The smooth, thick grey line is the 1979–2020 average.

Source: Copernicus Atmosphere Monitoring Service (CAMS)

SHORT-TERM CLIMATE DRIVERS

A prolonged period of La Niña from mid-2020 to early 2023 gave way to El Niño conditions, which were well established by September 2023, contributing to the observed rise in global mean sea-surface temperatures during 2023.

There are many di□erent natural phenomena, often referred to as climate patterns or climate modes, that a□ect weather and climate at timescales ranging from days to several months or even years. In 2023, the El Niño–Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the North Atlantic Oscillation (NAO), highlighted here, contributed to major weather and climate events across large areas of the world.

ENSO – EL NIÑO SOUTHERN OSCILLATION

ENSO is one of the most important climate drivers of year-to-year variability in weather patterns worldwide. It is linked to hazards such as heavy rains, floods, droughts, heatwaves and cold spells. El Niño, characterized by higher-than-average sea-surface temperatures (SSTs) in the eastern tropical Pacific and a weakening of the trade winds, typically has a warming influence on global temperatures. La Niña, which is characterized by below-average SSTs in the central and eastern tropical Pacific and a strengthening of the trade winds, has the opposite e□ect.

A multi-year La Niña event began in mid-2020 and ended in early 2023. Subsequently, SSTs in the eastern tropical Pacific increased, crossing typical El Niño thresholds (0.5 °C in Figure 22 (see below)) by June. However, the atmosphere was slower to respond, and it was not until early September that El Niño conditions were well established in both the atmosphere and ocean. By the end of the year, a strong El Niño had developed, with the Oceanic Niño Index reaching 2.0 °C for the November–January period, the highest value since the 2015/2016 El Niño.

El Niño has an influence on regional rainfall patterns. Precipitation anomalies were typical of El Niño in some regions, including drier-than-usual conditions in maritime South-East Asia and from southern Mexico to northern South America, and wetter-than-normal conditions in parts of Chile (see Figure 23 below).

Decreased monsoon rainfall in South-East Asia is associated with El Niño. The onset of the monsoon over Kerala, India, occurred on 8 June, seven days later than normal. By the end of September, India had received 94% of its typical monsoon rainfall.[66] Higher-than-normal rainfall totals, however, were observed along the lower course of the Indus River and in central India.

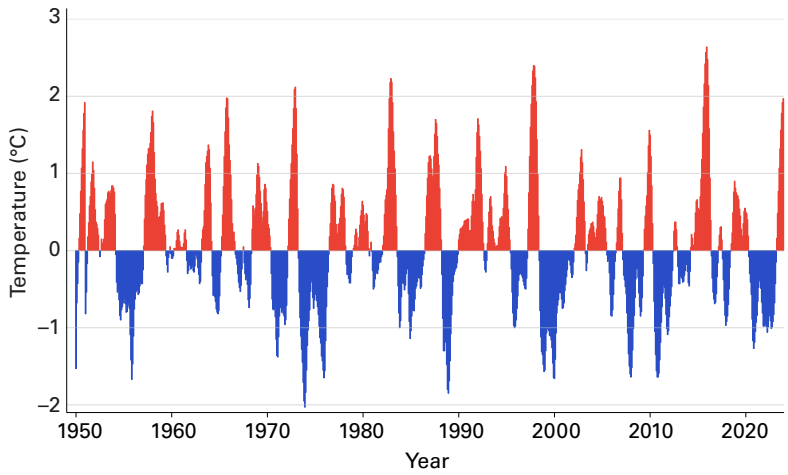


Figure 22. Time series of NOAA's Oceanic Niño index from January 1950 to December 2023 showing the presence of cooler-then-average conditions (blue) and warmer-than-average conditions (red) during 3-month average time periods. Anomalies are with respect to the 1991–2020 average sea-surface temperature.

Source: NOAA NCEP

In Australia, La Niña is associated with wetter-than-normal conditions, and El Niño with drier-than-normal conditions. In January, rainfall for the country was 35% above normal as La Niña drew gradually towards an end, but in August it was 50% below normal with a strengthening El Niño. The dryness was also accompanied by the highest July-to-September national mean temperatures in the country's 114-year record. September was the driest on record in Australia, and August–October was the driest three-month period in the 124-year observational record. However, somewhat atypically for an El Niño event, November and December were wetter than average in much of eastern Australia.

As average global temperature anomalies increased during the transition from La Niña to El Niño, many regions also experienced heatwaves, including parts of China, Europe, Mexico, North Africa and the Middle East, Siberia, South America and the United States of America. A United Nations Environment Programme (UNEP) Frontiers report[67] hhighlighted that variability associated with El Niño has implications for biomass and fire weather,[68] which increases the risk of large and intense wildfires in some places. Please refer to Extreme weather and climate events for more details on extreme events.

INDIAN OCEAN DIPOLE

The positive phase of the IOD is characterized by below-average SSTs (and sea level) in the eastern Indian Ocean and above-average SSTs (and sea level) in the west. The negative phase has the opposite pattern. The resulting change in the gradient of SST across the ocean basin a□ects the weather of the surrounding continents, primarily in equatorial regions and the southern hemisphere. Positive IOD events are often, but not always, associated with El Niño, and negative events with La Niña.

In conjunction with the emergence of El Niño, the first positive IOD since 2019 developed in early austral spring and peaked during October 2023. The positive IOD helped to intensify the anomalously dry and warm conditions over parts of Australia during this time. Conversely, rainfall totals in the Horn of Africa during the October–December rainy season were much higher than normal, leading to flooding in Ethiopia, Kenya and Somalia; this follows the prolonged drought in the region from 2020 to early 2023, when La Niña conditions and a neutral to negative IOD were largely present.

NORTH ATLANTIC OSCILLATION

Average sea-level pressure in the North Atlantic is characterized by an area of lower pressure close to Iceland, known as the Icelandic low, and an area of higher pressure centred over the Azores, known as the Azores high. The NAO is based on the sea-level pressure di□erence between the Icelandic low and the Azores high. It is mainly associated with driving weather conditions in the North Atlantic basin, Europe and the Mediterranean. The positive phase is characterized by below-normal pressure over the North Atlantic and high latitudes, and above-normal pressure over the central Atlantic, the eastern United States and western Europe. The negative phase has the opposite pattern. As the phases are determined by pressure changes in the atmosphere, they can fluctuate more rapidly, from days to weeks, compared with other climate drivers such as ENSO, which are driven by slower changes in ocean temperature and fluctuate from months to years.

High pressure associated with the negative NAO in late June and July 2023 contributed to a heatwave that caused significant snowmelt and ice melt across southern Greenland. Several widespread melting events occurred during this period. Ireland reported its warmest June on record (124 years), as did the long-running Uccle station in Belgium (191 years). In eastern Canada, many locations reported record warmth for July.

PRECIPITATION

Accumulated precipitation totals in 2023 were above the long-term average (see Figure 23) in East and Central Asia and parts of northern Asia; the western Indian summer monsoon region; parts of the Maritime Continent; northern New Zealand; parts of West, Central, southern and East Africa; western, Central and South-East Europe; southern Scandinavia; the western Middle East; North-West, South-West and South-East North America; the Greater Antilles; and parts of South-East South America.

Regions with a marked rainfall deficit included South-East South America, the Amazon basin and much of Central America; southern Canada; the western Mediterranean region and South-West Europe; parts of North-West, Central and southern Africa; parts of Central Asia; the eastern Indian monsoon region; parts of South-East Asia and the Maritime Continent; south-west and coastal north Australia; and many of the Pacific Islands.

The onset of the West African monsoon was around normal. The Greater Horn of Africa region, which had been experiencing long-term drought, su□ered substantial flooding in 2023, particularly later in the year as heavy rains associated with El Niño and the positive IOD became established (see Extreme weather and climate events).

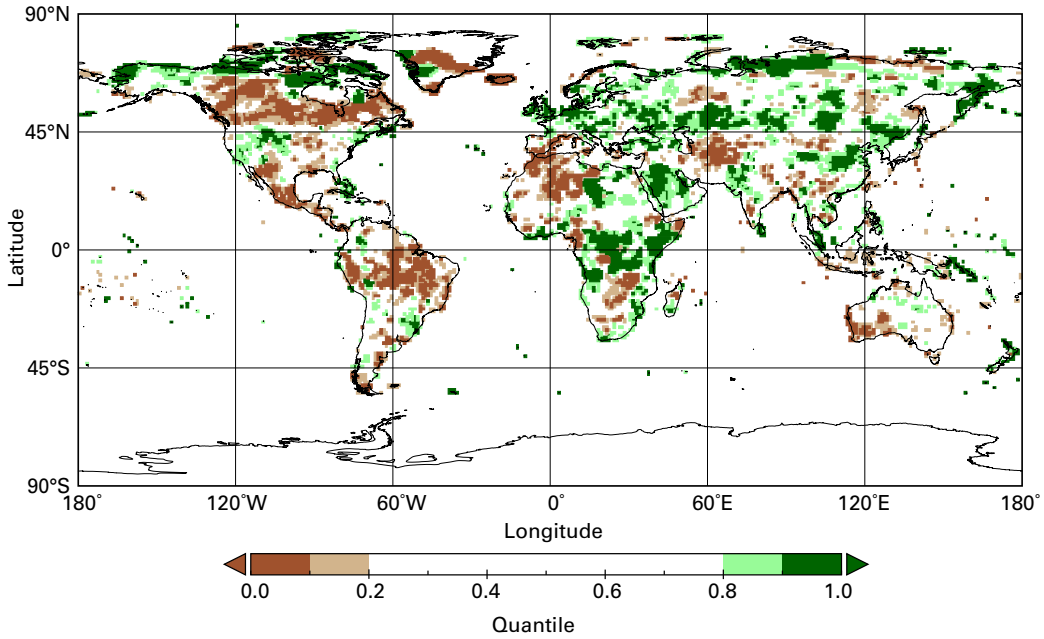


Figure 23. T Total precipitation in 2023, expressed as a quantile of the 1991–2020 reference period, for areas that would have been in the driest 20% (brown) and wettest 20% (green) of years during the reference period, with darker shades of brown and green indicating the driest and wettest 10%, respectively.

Source: Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst (DWD), Germany. For more details, see Data set and methods

Extreme weather and climate events

Extreme weather continues to lead to severe socioeconomic impacts.

Extreme heat affected many parts of the world.

Wildfires in Canada, Europe and Hawaii (United States of America) led to loss of life, the destruction of homes and large-scale air pollution.

Flooding associated with extreme rainfall from Mediterranean Cyclone *Daniel* affected Greece, Bulgaria, Türkiye and Libya, with particularly heavy loss of life in Libyaa.

Extreme weather and climate events had major impacts on all inhabited continents in 2023. These included major floods (some of them associated with tropical cyclones), extreme heat and droughts, and associated wildfires, which presented challenges to water and food security as well as to human welfare.[69,70] Some of the most significant events are described below, with a broader range of events described in the online supplement.

One of the most significant single weather-related events in terms of loss of life was the Mediterranean cyclone (or "medicane"), referred to locally as Storm *Daniel*, in September. In its initial stages, the storm produced extreme rainfall in southern Bulgaria, Greece and parts of Türkiye, while at the same time another storm system produced significant flash flooding in Spain, with adverse e□ects on cereal production.[71] The heaviest falls were in the Thessaly region of Greece, to the north of Athens, where Zagora, Pelion, received 760 mm on 5 September and a five-day total of 1 096 mm from 4 to 8 September, while in Bulgaria 329 mm fell in 16 hours at Kosti on 4–5 September. The storm then remained slow-moving in the eastern Mediterranean for several days before its major rainbands impacted north-eastern Libya on 10 and 11 September. Extreme rainfalls a□ected the coast and nearby mountains, with 414 mm falling in 24 hours at Al-Bayda on 10–11 September. The intense rainfalls resulted in extreme flooding in the region. The most extreme impacts were in the city of Derna (about 50 km east of Al-Bayda), where much of the central city was destroyed by flooding that was exacerbated by the failure of two dams. At least 4 700 confirmed deaths in Libya have been attributed to the flooding,[72] with 8 000 people still missing (as at 15 December). There were 19 additional deaths in Bulgaria and Greece.[73]

Tropical Cyclone *Freddy* in February and March was one of the world's longest-lived tropical cyclones. It formed on 6 February o□ the western coast of Australia and, after earlier landfalls in Madagascar and Mozambique, made its final landfall in Mozambique on 11 March before moving inland as a remnant low. The major impacts of *Freddy* came because of flooding during the final landfall, both in Malawi and Mozambique, as extremely heavy rain fell (up to 672 mm during the storm in Mozambique). Parts of Malawi and Mozambique had not yet recovered from storms in 2022. Malawi was especially hard hit, with at least 679 deaths reported and over 659 000 internal displacements,[74] and there were a further 165 deaths in Mozambique.[75] Casualties were also reported in Madagascar and Zimbabwe, and at sea near Mauritius.

Tropical Cyclone *Mocha*, in May, was one of the most intense cyclones ever observed in the Bay of Bengal, reaching peak 10-minute sustained winds of 115 kt. It formed on 11 May and made landfall near the Bangladesh–Myanmar border on 14 May. Cyclone Mocha triggered 1.7 million displacements across the subregion, from Sri Lanka to Myanmar and through India and Bangladesh.[76] In Bangladesh, displacement was reported in Cox's Bazar, the world's largest refugee settlement, which is home to over 900 000 Rohingya refugees from Myanmar.[77] More than 29 000 people were temporarily relocated.[78] In total, at least 156 lives were lost in Myanmar,[79] and over 270 000 buildings were damaged or destroyed.[80] At least 63 000 displacements took place in camps sheltering people already displaced by conflict and violence.[81] The e□ects of Cyclone *Mocha*, together with an intensification of conflict and record-high food prices, severely aggravated acute food insecurity, especially among the 3.4 million vulnerable people assessed as in need of humanitarian assistance.[82]

The largest reported economic loss from a single event in 2023 was from Hurricane Otis, which hit the Pacific coast of Mexico in late October. Otis reached hurricane intensity at 1200 Universal Time Coordinated (UTC) on 24 October, and within 15 hours had intensified to a category 5 system,[83] one of the most rapid rates of intensification observed in the satellite era. Shortly afterwards, it made landfall just west of Acapulco at near peak intensity, with maximum sustained winds of 260 km hr^{-1}, which might be the first known category 5 landfall on the Pacific coast of Mexico. The hurricane caused widespread destruction in Acapulco and surrounding areas, with economic losses estimated at 12 billion US dollars (USD).[84] At least 48 deaths were attributed to the hurricane,[85] with a further 32 people missing, mostly at sea.

The North Island of New Zealand su□ered repeated extreme rainfall and flooding events in January and February. The most significant was on 13–14 February, when Cyclone *Gabrielle* passed just east of North Island as a post-tropical system. Daily rainfalls exceeded 500 mm in parts of eastern North Island, and Auckland had its lowest air pressure (971.5 hPa) on record. Eleven deaths were reported because of *Gabrielle*, and four by more localized floods in Auckland on 27–28 January. Total economic losses from the two events were estimated at USD 5.3–USD 8.6 billion,86 by far the costliest non-earthquake disaster recorded in New Zealand.

Many significant heatwaves occurred in various parts of the world during 2023. Some of the most significant were in southern Europe and North Africa, especially in the second half of July, when severe and exceptionally persistent heat occurred. Italy was particularly a□ected, with temperatures reaching 48.2 °C on 24 July at Lotzorai and Jerzu, Sardinia; only 0.6 °C below the European record set in Sicily in 2021.[87] On 23 August, a mean daily temperature of 32.98 °C was reported at the Brera Observatory in Milan, the highest in a record dating back to 1763. Among the other locations experiencing record-high temperatures were Tunis (49.0 °C on 24 July), Tirana (43.0 °C on 25 July), Agadir (Morocco) (50.4 °C on 11 August) and Algiers (49.2 °C on 23 July). The extreme heat shifted to South-East Europe in late July, and further heatwaves a□ected West-Central Europe in late August and early September. Numerous locations in southern France, northern Spain and western Switzerland set records during these events, including Toulouse (France) (42.4 °C on 23 August[88]). There was also extensive wildfire activity during the summer, particularly in Greece (both on the mainland and islands). A fire in north-eastern Greece in late August and early September that burned 96 000 ha was the largest fire ever observed in the European Union.[89]

The 2023 wildfire season in Canada was well beyond any previously recorded. Significant fire activity began in late April, expanded during a very warm, dry May, and continued throughout the summer and into early autumn. The total area burned nationally for the year was 14.9 million ha, more than seven times the long-term average (1986–2022) and far above the previous record seasonal total of 6.7 million ha in 1989 (see Figure 24). Altogether 297 evacuation orders were issued for over 235 000 people.[90] The fires also resulted in significant and widespread smoke pollution, particularly in the heavily populated areas of eastern Canada and the north-eastern United States of America in the first half of June. Four deaths were directly attributed to fires, although the broader health impacts of the smoke are yet to be fully assessed.

The deadliest single wildfire of the year occurred in Hawaii (United States), on the western side of the island of Maui. Extreme fire weather conditions, with low humidity and strong, gusty winds driven by a pressure gradient between strong high pressure to the North and the circulation of Hurricane *Dora* well to the South, combined with pre-existing drought to favour the development and rapid spread of intense fires. The most a□ected region was around the town of Lahaina, which was largely destroyed with over 2 200 structures lost. Mandatory

evacuation notices were issued for 7 500 people across the area.[91] At least 100 deaths were reported,[92] the most in a wildfire in the United States for more than 100 years, with 400 homes destroyed[93] and estimated economic losses of USD 5.6 billion. Wildfires of such intensity and speed of movement are extremely rare in the tropics.

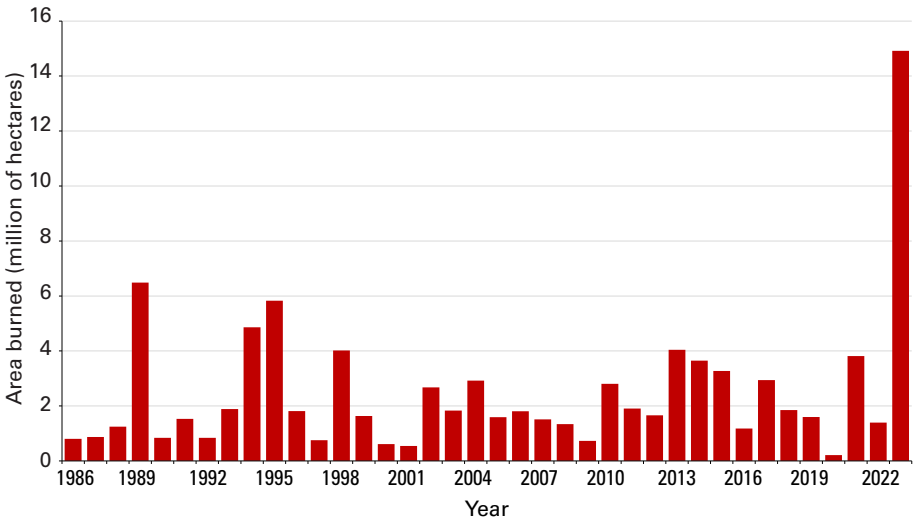


Figure 24. Figure 24. Annual area burned in Canada 1986–2023 (millions of ha)

Source: Data from Jain et al., 2024[94]

Long-term drought persisted in North-western Africa and parts of the Iberian Peninsula, as well as in parts of Central and South-West Asia, and intensified in many parts of Central America, northern South America and the southern United States. Among the most significant areas of drought was an area of subtropical South America, focused on northern Argentina and Uruguay. Rainfall from January to August was 20%–50% below average over much of northern and central Argentina, with some regions experiencing their fourth successive year of significantly below-average rainfall. In Uruguay, water storages reached critically low levels, badly a□ecting the quality of supplies to major centres, including Montevideo, although there was some improvement in the situation from August. Although there was some easing of drought conditions in subtropical South America later in the year, they intensified in many parts of the continent's interior, including in large parts of the Amazon basin. Eight Brazilian states recorded their lowest July–September rainfall in over 40 years. The Rio Negro at Manaus reached a record low level (observations started in 1902) on 26 October, 0.93 m below the previous record set in 2010.[95]

The Greater Horn of Africa region, which had been experiencing long-term drought, su□ered substantial flooding in 2023, particularly later in the year following heavy rains associated with El Niño and the positive Indian Ocean Dipole (IOD) (see Short-term climate drivers). The most badly a□ected area was the region encompassing south-eastern Ethiopia, north-eastern Kenya and the southern half of Somalia. During the Deyr rainy season (October and November), monthly rainfall in this region was widely 100–200 mm and locally exceeded 200 mm, several times the long-term averages. There were at least 352 deaths reported across the three countries.[96] Throughout Burundi, Ethiopia, Kenya, Somalia, South Sudan, Uganda and the United Republic of Tanzania, widespread and severe flooding displaced 1.8 million people,[97] in addition to the 3 million people already displaced internally or across borders by five consecutive seasons of drought[98] in Djibouti, Ethiopia, Kenya and Somalia. The wet conditions did lead to some recovery in pasture and crop conditions after the extended drought. Landslides and flooding in early December also resulted in at least 89 deaths in northern parts of the United Republic of Tanzania.[99] Pastoralist communities continued to be a□ected by asset losses after two consecutive years of drought, which continued to adversely a□ect agricultural production and reduced cereal production in 2023 compared with 2022.[100]

Socio-economic impacts

Food security, population displacements and impacts on vulnerable populations continued to be of mounting concern in 2023, with weather and climate hazards exacerbating the situation in many parts of the world.

Extreme weather and climate conditions continued to trigger new, prolonged and secondary displacement in 2023 and increased the vulnerability of many who had already been uprooted by complex multi-causal situations of conflict and violence.

The development and implementation of local disaster risk reduction strategies has increased since the adoption of the Sendai Framework for Disaster Risk Reduction.

One of the essential components for reducing the impact of disasters is to have effective multi-hazard early warning systems.

The events described above, and many others besides, occur in a broader context. Extreme weather and climate events interact with, and in some cases trigger or exacerbate, situations concerning water and food security, population mobility and environmental degradation.[101,102]

FOOD SECURITY

The number of people who are acutely food insecure worldwide has more than doubled, from 149 million people before the coronavirus disease (COVID-19) pandemic to 333 million people in 2023 (in 78 countries monitored by the World Food Programme (WFP)).[103] Although global hunger levels remained unchanged from 2021 to 2022, they are still far above pre-COVID 19 pandemic levels: in 2022, 9.2% of the global population (735.1 million people) were undernourished, compared with 7.9% (612.8 million people) in 2019 (see Figure 25).[104] The current global food and nutrition crisis is the largest in modern human history.[105] Protracted conflicts, economic downturns and high food prices are at the root of high global food insecurity levels. High food prices are exacerbated by the high costs of agricultural inputs, driven by ongoing and widespread conflict around the world, and high global food insecurity levels are aggravated by the e□ects of climate and weather extremes. In southern Africa, for example, weather extremes, including the passage of Cyclone *Freddy* in February 2023, have a□ected areas of Madagascar, southern Malawi, Mozambique and Zimbabwe. Flooding associated with the cyclone submerged extensive agricultural areas and inflicted severe damage on crops, which has exacerbated a slow economic recovery.[106]

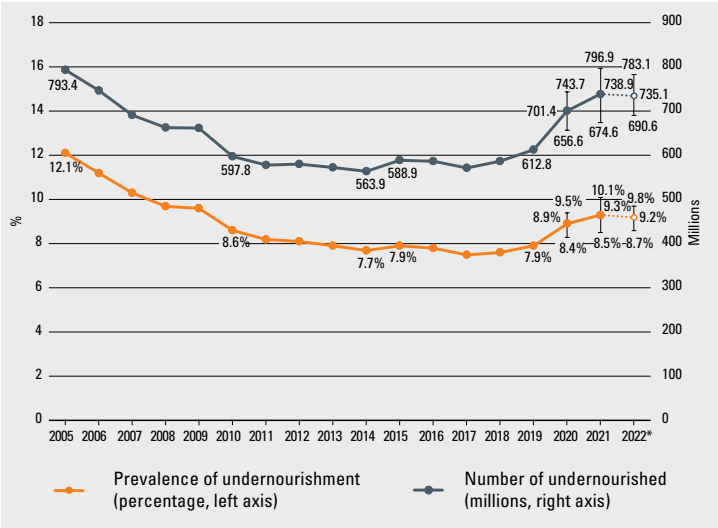


Figure 25. Global prevalence of undernourishment (as a percentage) and number of undernourished (in millions) since 2005

Source: The entire series has been updated to reflect new information released since the publication of *The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural–Urban Continuum*.[107]

Globally, annual economic losses from climate- and weather-related disasters have increased since the 2000s.[108] Between 2007 and 2022, 88 post-disaster needs assessment surveys conducted in 60 countries worldwide showed that over 65% of losses caused by droughts occur in the agriculture sector, including crop and livestock production losses. For floods, storms and cyclones, about 20% of losses are in agriculture.[109]

In early 2023, South Sudan continued to experience exceptional flooding, with water levels remaining high even during the dry season. Despite relatively dry conditions locally, flooding persisted owing to high flows from further upstream in the Nile basin and very slow drainage from earlier floods. The prolonged flooding made it difficult for people to access basic needs such as food, clean water and health care, and contributed to the near collapse of local livelihoods. Between April and July 2023, 7.8 million people, almost two thirds of the total population of South Sudan, were expected to experience severe acute food insecurity.[110]

Afghanistan experienced a substantial reduction in snowmelt and rainfall, resulting in another poor crop season. This led to widespread acute food insecurity, particularly in the north and north-eastern regions. Between May and October 2023, 15.3 million Afghans were estimated to face severe acute food insecurity.[111] In Yemen, 53% of the population were already classified as in a crisis level of acute food insecurity or worse between October and December 2022. High food and fuel prices, together with floods from March to September 2023, and protracted conflict, further aggravated food insecurity.

In Indonesia, a meteorological drought linked to El Niño and the positive phase of the Indian Ocean Dipole (IOD) (see Short-term climate drivers) occurred during the dry season, affecting 23 450 ha of paddy cultivation and causing 6 964 ha of crop failure as of August 2023. A decrease of 645 000 t of rice production was predicted by October 2023,[112] and crop planting in late 2023 was delayed.

In 2023, record maize production in Brazil compensated for below-average harvests due to prolonged dry spells elsewhere in South America, especially in Argentina, where drought conditions were expected to result in a 15% decrease in cereal production compared with the five-year average. The return of El Niño in 2023 led to adverse consequences through the entire crop cycle of maize in Central America and northern parts of South America, where water deficits and high temperature curtailed both planting area and yields with compounding negative impacts on final production, particularly for smallholders and more vulnerable households in the Dry Corridor. During the second part of the season, tropical storms and unexpected heavy rain events disrupted the normal growth of crops in certain areas near the Central America Pacific coast. In Haiti, irregular seasonal rainfall, including periods of high-intensity precipitation, contributed to decrease the production of primary crops In 2023, record maize production in Brazil compensated for below-average harvests due to prolonged dry spells elsewhere in South America, especially in Argentina, where drought conditions were expected to result in a 15% decrease in cereal production compared with the five-year average. The return of El Niño in 2023 led to adverse consequences through the entire crop cycle of maize in Central America and northern parts of South America, where water deficits and high temperature curtailed both planting area and yields with compounding negative impacts on final production, particularly for smallholders and more vulnerable households in the Dry Corridor. During the second part of the season, tropical storms and unexpected heavy rain events disrupted the normal growth of crops in certain areas near the Central America Pacific coast. In Haiti, irregular seasonal rainfall, including periods of high-intensity precipitation, contributed to decrease the production of primary crops.[113]

Oceania is expected to experience the sharpest annual reduction rate in cereal production worldwide, with a 31.1% decline in 2023 compared with 2022, although this largely reflects a reversion to near-average conditions after exceptionally high production in 2022, with 2023 only slightly below five-year averages.[114]

In September, Storm Daniel brought heavy rainfall to coastal and north-eastern Libya, flooding nearly 3 000 ha of cropland, particularly in the Al Marj and Derna regions. These constitute the main cropland areas in the eastern part of the country and are key sources of livelihoods. The collapse of dams in Derna affected the irrigation system, and the floods affected many parts of the agrifood value chain, damaging roads, cereal storage and overall market channels. According to the Food and Agriculture Organization of the United Nations (FAO) Global Information and Early Warning System (GIEWS), Libya was already in a state of food crisis and in need of external assistance in July 2023 before the floods.[115]

DISPLACEMENT

Across the globe, millions of people, including internally displaced persons, refugees and migrants, are on the move or have been forced to flee their homes and communities because of disasters exacerbated by climate stresses and shocks. Weather hazards continued to trigger new, prolonged and secondary displacement in 2023 and increased the vulnerability of many who had already been uprooted by complex multi-causal situations of conflict and violence. These trends are a clear indication of how vulnerability to climate shocks and stresses is undermining resilience and creating new protection risks, which threatens the achievements of the Sustainable Development Goals (SDGs).

An estimated 3.4 million refugees and internally displaced people in Egypt, Iraq, Jordan, Lebanon and the Syrian Arab Republic were in need of critical assistance to cope with extreme winter conditions in 2023.[116] In the north-west of the Syrian Arab Republic, snowstorms and floods triggered displacements between January and March, many of which were repeated movements of people already displaced by the country's long-running conflict. Similarly, in Yemen, heavy rains hit the country in April. Some sites for internally displaced people in Marib were damaged, leaving dozens of people dead and injured.[117]

Many migrants entering Somalia found themselves stranded in June and July 2023, mostly in the city of Bossaso, the main coastal crossing location to Yemen, as they were waiting for more favourable weather conditions to cross the Gulf of Aden. In Hargeisa, a group of migrants in transit su□ered from extreme heat, and some died from dehydration.[118]

In addition to new displacements caused by high-impact disasters in 2023, many people are still enduring the prolonged e□ects of climate-related displacements that took place in previous years. In Pakistan, the 2022 monsoon floods, which triggered the largest disaster displacement event in a decade, continued to have long-standing impacts in 2023. Displaced communities were still recovering when heavy rains hit some districts in June 2023, causing waterborne and vector-borne diseases.[119]

Displacement in the context of climate change and environmental degradation is often multi-causal. Most people move owing to a combination of social, political, economic, environmental and demographic drivers, all of which are and will continue to be a□ected by climate and environmental change. In Somalia alone, some 531 000 displacements were recorded related to the ongoing drought in 2023, in addition to 653 000 displacements primarily caused by conflict.[120] Subsequent flooding during the October–December rainy season a□ected more than 2.4 million individuals, displacing over 1 million people.[121] Estimates for Storm Daniel indicate close to 45 000 individuals displaced in north-eastern Libya.[122] Additionally, a substantial number of migrants were reported to be living in a low-lying area adjacent to Wadi Derna, raising concerns that the floods may have destroyed many of their settlements with significant loss of life.[123]

Climate-related shocks and stresses in migration and displacement contexts a□ect people's livelihoods, which entrenches poverty (SDG) 1[124] and hunger (SDG 2);[125] pose direct threats to lives and well-being (SDG 3);[126] widen inequality gaps (SDG 10);[127] and limit access to quality education (SDG 4),[128] water and sanitation (SDG 6),[129] as well as to clean energy (SDG 7).[130] Women and girls are among the worst a□ected (SDG 5)[131] owing to pre-existing gender and socioeconomic inequalities compounding their vulnerabilities.[132]

To better prepare for these contexts, governments, communities, civil society and the United Nations are engaged at all levels to strengthen climate resilience and e□ective disaster risk reduction. A main priority is the community level, where preparedness e□orts, including early warning systems and emergency preparedness, are accelerating.[133] A total of 126 countries are in possession of disaster risk management strategies, with 99 countries reporting to have local governments with disaster risk reduction strategies. The development and implementation of local disaster risk reduction strategies has increased since the adoption of the Sendai Framework for Disaster Risk Reduction in 2015.[134]

One of the essential components for reducing the impact of disasters is to have e□ective multi-hazard early warning systems (MHEWSs), and systems in place for generating disaster risk information and creating and disseminating early warnings, as well as having plans to act on the warnings. As at 2023, 102 countries reported having MHEWSs in place – more than half the countries in the world. The Early Warnings for All initiative was launched by the Secretary-General of the United Nations in March 2022 with the aim of ensuring that everyone on Earth is protected from hazardous weather, water or climate events through life-saving early warning systems by the end of 2027.

The State of Climate Finance

Climate Policy Initiative

In 2021–2022,[1] global climate flows reached almost 1.3 trillion US dollars (USD), nearly doubling compared with 2019–2020 levels (see Figure 26). TThis increase was primarily driven by a significant acceleration in mitigation finance, up by USD 439 billion compared with 2019–2020. The remainder of the observed growth in 2021–2022 stemmed from methodological improvements to, and additional data sources used in, the *Global Landscape of Climate Finance*. Despite this growing momentum in climate finance, tracked flows represented only approximately 1% of global gross domestic product (GDP).

Comparing tracked climate finance flows with estimated climate finance needs exposes a large financing gap. In an average scenario,[2] for a 1.5 °C pathway, annual climate finance investments need to grow by more than six times, reaching almost USD 9 trillion by 2030 and a further USD 10 trillion through 2050.

Despite the large financing gap, the cost of inaction is even higher.[3] Aggregating over the period 2025–2100, the total cost of inaction is estimated at USD 1 266 trillion; that is, the di□erence in losses under a business-as-usual scenario[4] and those incurred within a 1.5 °C pathway. This figure is, however, likely to be a dramatic underestimate of the true cost of inaction, since it does not capture losses to nature and biodiversity, and those induced by conflict and migration, among others. Indeed, the cost of inaction only promises to rise with insu□cient mitigation and inadequate adaptation.

Disaggregating global climate finance flows reveals that growth is neither su□cient nor consistent across sectors and regions. The growth in global climate finance in 2021–2022 largely stemmed from significant increases in clean energy investments in only a handful of geographies; China, Brazil, Europe, India, Japan and the United States of America together received 90% of the increase in funds. Other regions, including many climate-vulnerable countries, and other important sectors – for example, agriculture and industry – are being left behind, receiving disproportionately little finance given their significant mitigation potential. In addition, emerging mitigation technologies, including battery storage and hydrogen, are only beginning to attract private finance and are yet to be scaled up.

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[1] The Climate Policy Initiative (CPI) reports a biennial average to smooth out fluctuations in (annual) data.

[2] Climate finance needs are estimated as a range, including lower-bound, upper-bound and average needs, based on direct investments in climate-specific physical assets and excluding transition-related unabated fossil fuel finance..

[3] Inaction is defined here as the failure to stay within a 1.5 °C pathway; for further details, see Climate Policy Initiative (CPI), 2024: The Cost of Inaction, https://www.climatepolicyinitiative.org/the-cost-of-inaction/#:~:text=CPI's%20estimate%20of%20USD%201%2C266,%2C%20warming%20scenarios%2C%20and%20timeframes.

[4] A business-as-usual scenario is understood here as equivalent to a 3 °C pathway.

Of particular concern, adaptation finance continues to lag. Though adaptation finance reached an all-time high of USD 63 billion in 2021–2022, the global adaptation financing gap is widening, falling well short of the estimated USD 212 billion per year needed up to 2030 in developing countries alone. Tracked adaptation finance remains dominated by public actors (98%), while tracking challenges continue to impede a clear picture of adaptation action by the private sector. The majority of adaptation finance is directed to the water and wastewater sector, reflecting e□orts to build resilience to water stress, while other sectors with wide-ranging adaptation potential – for example, agriculture – continue to receive only minimal finance. Mainstreaming adaptation and resilience into development pathways is imperative, particularly in highly vulnerable developing countries.

Moving forward, all actors must urgently work to scale the quantity and quality of climate finance. Key priorities for ensuring more and better climate finance include transforming the financial system with an emphasis on concessional financing and de-risking; bridging climate and development needs; harnessing synergies to deliver co-benefits for both people and nature; mobilizing domestic capital, with an emphasis on enabling policies and regulatory frameworks; and improving the availability and accessibility of quality, granular data to measure and manage progress.

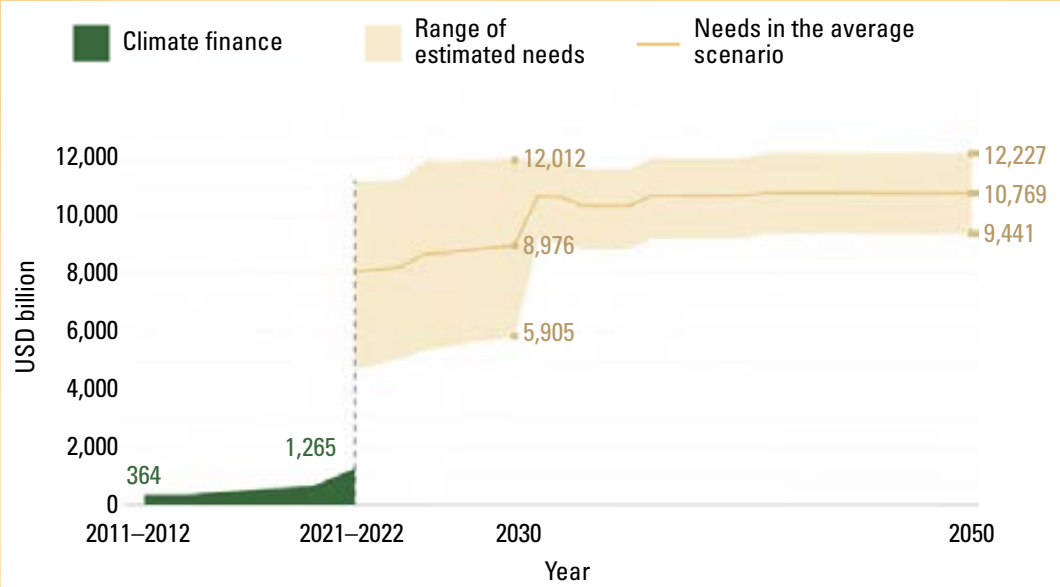

Figure 26. Global tracked climate finance and average estimated annual needs from 2011–2012 through 2050.

Source: Climate Policy Initiative (CPI)

Data sets and methods

GREENHOUSE GASES DATA

Estimated concentrations from 1750 are used to represent pre-industrial conditions. Calculations assume a pre-industrial mole fraction of 278.3 parts per million (ppm) for carbon dioxide (CO_2), 729.2 parts per billion (ppb) for methane (CH_4) and 270.1 ppb for nitrous oxide (N_2O).

World Data Centre for Greenhouse Gases (WDCGG) operated by the Japan Meteorological Agency (JMA), https://gaw.kishou.go.jp.

World Meteorological Organization (WMO). *WMO Greenhouse Gas Bulletin – No. 19: The State of Greenhouse Gases in the Atmosphere Based on Global Observations Through 2022*. Geneva, 2023.

GLOBAL TEMPERATURES DATA

GLOBAL MEAN TEMPERATURE SERIES

The method for calculating global mean temperature anomalies relative to an 1850–1900 baseline is based on the assessment of long-term change and its uncertainty made by Working Group I in its contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6 WG I). In 2021, the IPCC AR6 WG I assessed change from 1850–1900 to other periods based on an average of four datasets – HadCRUT5, Berkeley Earth, NOAA Interim, and Kadow et al., 2020 – which start in 1850 and are globally or near-globally complete in the modern period.

To include shorter datasets, which can help to better understand recent temperature changes, in the present publication, the estimate made by the Intergovernmental Panel on Climate Change (IPCC) for the temperature change between 1850–1900 and 1981–2010 is combined with estimated changes between 1981–2010 and the current year from six datasets to calculate anomalies for 2023 relative to 1850–1900. There is good agreement among the datasets on changes from 1981–2010 to the present, as this is a period with good observational coverage.

The additional uncertainty from the spread of the datasets is combined with that of the estimate of the IPCC of the uncertainty in the change from 1850–1900 to 1981–2010. Global mean temperature anomalies were calculated relative to an 1850–1900 baseline using the following steps, starting from the time series of global monthly mean temperatures for each dataset:

1. For each dataset, anomalies were calculated relative to the 1981–2010 average by subtracting the mean for the period 1981–2010 for each month separately.

2. An annual mean anomaly was calculated from the monthly mean anomalies.

3. The amount of 0.69 °C was added to each series, based on the estimated difference between 1850–1900 and 1981–2010, calculated using the method from IPCC AR6 WG I (see the caption for Figure 1.12 in the corresponding publication).

4. The mean and standard deviation of the estimates were calculated.

5. The uncertainty in the IPCC estimate was combined with the standard deviation, assuming the two are independent and assuming the IPCC uncertainty range (0.54 °C–0.79 °C) is representative of a 90% confidence range (1.645 standard deviations).

The number quoted in the present publication for 2023 (1.45 ± 0.12 °C) was calculated in this way, with 1.45 °C being the mean of the seven estimates, and 0.03 °C the standard deviation.

ANNUAL TEMPERATURE MAPS

For the map of temperature anomalies for 2023, a median of six datasets was used, re-gridded to the spatial grid of the lowest resolution datasets (NOAAGlobalTemp and HadCRUT5), which are presented on a 5° latitude by 5° longitude grid. The median is used in preference to the mean to minimize the e□ect of potential outliers in individual grid cells. The half-range of the datasets provides an indication of the uncertainty. The spread between the datasets is largest at high latitudes and in Central Africa, both regions with sparse data coverage.

GLOBAL MEAN TEMPERATURE ANOMALIES FOR 2023 RELATIVE TO OTHER PERIODS

Table 1 (see below) shows global mean temperature anomalies for individual datasets for 2023 relative to four di□erent baselines. The uncertainty indicated for the three modern baselines (1981–2010, 1991–2020 and 1961–1990) is the standard deviation of the available estimates multiplied by 1.645 to represent the 90% uncertainty range.

Table 1. Global mean temperature anomalies for individual datasets for 2023 for four di□erent baselines

Period	*1850–1900*	*1981–2010*	*1991–2020*	*1961–1990*
HadCRUT5	1.44	0.75	0.56	1.09
NOAAGlobalTemp	1.43	0.74	0.55	1.05
GISTEMP	1.44	0.75	0.56	1.07
Berkeley Earth	1.45	0.76	0.57	1.12
ERA5	1.48	0.79	0.60	1.12
JRA-55	1.43	0.74	0.56	1.07
Mean of the six datasets	1.45±0.12	0.76±0.03	0.57±0.03	1.09±0.04

The following six datasets were used, including four traditional datasets:

Berkeley Earth: Rohde, R.A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. *Earth System Science Data* **2020**, *12* (4), 3469–3479. https://doi.org/10.5194/essd-12-3469-2020.

GISTEMP v4: GISTEMP Team, 2022: *GISS Surface Temperature Analysis (GISTEMP), Version 4*. NASA Goddard Institute for Space Studies, https://data.giss.nasa.gov/gistemp/.

HadCRUT.5.0.2.0: Morice, C.P.; Kennedy, J.J.; Rayner, N.A. et al. An Updated Assessment of Near-surface Temperature Change from 1850: The HadCRUT5 Data Set. *Journal of Geophysical Research: Atmospheres* **2021**, *126* (3), e2019JD032361. https://doi.org/10.1029/2019JD032361. HadCRUT.5.0.2.0 data were obtained from http://www.meto□ce.gov.uk/hadobs/hadcrut5 on 17 January 2024 and are © British Crown Copyright, Met O□ce 2024, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

Lenssen, N.J.L.; Schmidt, G.A.; Hansen, J.E. et al. Improvements in the GISTEMP Uncertainty Model. *Journal of Geophysical Research: Atmospheres* **2019**, *124* (12), 6307–6326. https://doi.org/10.1029/2018JD029522.

NOAAGlobalTemp-Interim v5.1: Vose, R.S.; Huang, B.; Yin, X. et al. Implementing Full Spatial Coverage in NOAA's Global Temperature Analysis. *Geophysical Research Letters* **2021**, *48* (4), e2020GL090873. https://doi.org/10.1029/2020GL090873.

And two reanalyses:

ERA5: Hersbach, H.; Bell, B.; Berrisford, P. et al. *ERA5 Monthly Averaged Data on Single Levels from 1940 to Present*. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), 2023. https://cds.climate.copernicus.eu/cdsapp#!/dataset/10.24381/cds.f17050d7?tab=overview.

JRA-55: Kobayashi, S.; Ota, Y.; Harada, Y. et al. The JRA-55 Reanalysis: General Specifications and Basic Characteristics. *Journal of the Meteorological Society of Japan. Ser. II* **2015**, *93* (1), 5–48. https://doi.org/10.2151/jmsj.2015–001.

IPCC used an additional dataset. Combining the six datasets used in the present publication with Kadow et al., 2020 reduces the estimated global mean for 2023 by 0.01 °C and increases the uncertainty range by a similar amount:

Kadow, C.; Hall, D.M.; Ulbrich, U. Artificial Intelligence Reconstructs Missing Climate Information. *Nature Geoscience* **2020**, *13*, 408–413. https://doi.org/10.1038/s41561-020-0582-5.

A new reanalysis produced by JRA-3Q is now also available. JRA-55 was used in the present publication for consistency with the provisional statement released in December 2023. For comparison, the values for 2023 are shown relative to the four baselines for JRA-3Q and JRA-55 in Table 2 (see below). Note that the replacement of JRA-55 with JRA-3Q in the mean of the six datasets has a negligible e□ect on the global mean temperature for 2023.

Table 2. Global mean temperatures for 2023 relative to the four baselines for JRA-3Q and JRA-55

Period	*1850–1900*	*1981–2010*	*1991–2020*	*1961–1990*
JRA-3Q	1.47	0.78	0.58	1.11
JRA-55	1.43	0.74	0.56	1.07
Mean of the six datasets using JRA-3Q	1.45±0.12	0.76±0.03	0.57±0.03	1.09±0.04

LAND TEMPERATURES AND SEA-SURFACE TEMPERATURES

The land temperature assessment is based on three data sets:

Berkeley Earth: Rohde, R.A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. *Earth System Science Data* **2020**, *12* (4), 3469–3479. https://doi.org/10.5194/essd-12-3469-202.

CRUTEM.5.0.2.0: Osborn, T.J.; Jones, P.D.; Lister, D.H. et al. Land Surface Air Temperature Variations Across the Globe Updated to 2019: The CRUTEM5 Data Set. *Journal of Geophysical Research* **2021**, *126* (2), e2019JD032352. https://doi.org/10.1029/2019JD032352. CRUTEM.5.0.2.0 data were obtained from http://www.meto□ce.gov.uk/hadobs/crutem5 on 17 January 2024 and are © British Crown Copyright, Met O□ce 2024, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

GHCNv4: Menne, M.J.; Gleason, B.E.; Lawrimore, J. et al. *Global Historical Climatology Network – Monthly Temperature [Global mean]*. NOAA National Centers for Environmental Information, 2017. doi:10.7289/V5XW4GTH.

The sea-surface temperature (SST) assessment is based on two datasets:

HadSST.4.0.1.0: Kennedy, J.J.; Rayner, N.A.; Atkinson, C.P. et al. An Ensemble Data Set of Sea Surface Temperature Change from 1850: The Met O□ce Hadley Centre HadSST.4.0.0.0 Data Set. *Journal of Geophysical Research: Atmospheres* **2019**, *124* (14), 7719–7763. https://doi.org/10.1029/2018JD029867. HadSST.4.0.1.0 data were obtained from http://www.meto□ce.gov.uk/hadobs/hadsst4 on 17 January 2024 and are © British Crown Copyright, Met O□ce 2024, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

ERSSTv5: Huang, B.; Thorne, P.W.; Banzon, V.F. et al. *NOAA Extended Reconstructed Sea-Surface Temperature (ERSST), Version 5. [Global mean]*. NOAA National Centers for Environmental Information, 2017. doi:10.7289/V5T72FNM.

OCEAN HEAT CONTENT

The ensemble mean is an update of the outcome of a concerted international e□ort,[135] and all products used are referenced here. Note that global ocean heat content values are given for the ocean surface area between 60° S and 60° N and limited to areas deeper than 300 m in each product. The value for 2022 is based on a subset of the products for which updates are available. A baseline of 2005–2021 is used for the ocean heat content time series (see Figure 4), as near-global coverage is available for this period thanks to the network of Argo subsurface floats.

The 2023 value is based on the estimate from Minière et al., 2023 and Cheng et al., 2017 (see below):

Minière, A.; von Schuckmann, K.; Sallée, J.-B. et al. Robust Acceleration of Earth System Heating Observed Over the Past Six Decades. *Scientific Reports* **2023**, *13*, 22975. https://doi.org/10.1038/s41598-023-49353-1.

DATA USED UP TO 2022:

Cheng, L.; Trenberth, K.E.; Fasullo, J. et al. Improved Estimates of Ocean Heat Content from 1960 to 2015. *Science Advances* **2017**, *3* (3). https://doi.org/10.1126/sciadv.1601545.

Gaillard, F.; Reynaud, T.; Thierry, V. et al. In Situ–Based Reanalysis of the Global Ocean Temperature and Salinity with ISAS: Variability of the Heat Content and Steric Height. *Journal of Climate* **2016**, *29* (4), 1305–1323. https://doi.org/10.1175/JCLI-D-15-0028.1.

Ishii, M.; Fukuda, Y.; Hirahara, S. et al. Accuracy of Global Upper Ocean Heat Content Estimation Expected from Present Observational Data Sets. *SOLA* **2017**, *13*, 163–167. https://doi.org/10.2151/sola.2017–030.

Kuusela, M.; Giglio, D. *Global Ocean Heat Content Anomalies based on Argo data [2.0.0]*. Zenodo, 2023. https://doi.org/10.5281/zenodo.7562281.

Levitus, S.; Antonov, J.I.; Boyer, T.P. et al. World Ocean Heat Content and Thermosteric Level Change (0–2 000 m), 1955–2010. *Geophysical Research Letters* **2012**, *39* (10). https://doi.org/10.1029/2012GL051106.

Lyman, J.M.; Johnson, G.C. Estimating Global Ocean Heat Content Changes in the Upper 1 800 m since 1950 and the Influence of Climatology Choice. *Journal of Climate*, **2014**, *27* (5), 1945–1957. https://doi.org/10.1175/JCLI-D-12–00752.1.

von Schuckmann, K.; Le Traon, P.-Y. How Well Can We Derive Global Ocean Indicators from Argo Data? *Ocean Science* **2011**, *7* (6), 783–791. https://doi.org/10.5194/os-7-783-2011. Data available at: https://marine.copernicus.eu/access-data/ocean-monitoring-indicators.

IN ADDITION, DATA USED TO 2021:

Desbruyères, D.G.; Purkey, S.G.; McDonagh, E.L. et al. Deep and Abyssal Ocean Warming from 35 Years of Repeat Hydrography. *Geophysical Research Letters* **2016**, *43* (19), 10356–10365. https://doi.org/10.1002/2016GL070413.

Desbruyères, D.; McDonagh, E.L.; King, B.A. et al. Global and Full-depth Ocean Temperature Trends During the Early Twenty-first Century from Argo and Repeat Hydrography. *Journal of Climate* **2017**, 30 (6), 1985–1997. https://doi.org/10.1175/JCLI-D-16-0396.1.

Good, S.A.; Martin, M.J.; Rayner, N.A. EN4: Quality Controlled Ocean Temperature and Salinity Profiles and Monthly Objective Analyses with Uncertainty Estimates. *Journal of Geophysical Research: Oceans* **2013**, *118* (12), 6704–6716. https://doi.org/10.1002/2013JC009067.

Hong, L.; Xu, F.; Zhou, W. et al. Development of a Global Gridded Argo Data Set with Barnes Successive Corrections. *Journal of Geophysical Research: Oceans* **2017**, *122* (2), 866–889. https://doi.org/10.1002/2016JC012285.

Hosoda, S.; Ohira, T.; Nakamura, T. A Monthly Mean Dataset of Global Oceanic Temperature and Salinity Derived from Argo Float Observations. *JAMSTEC Report of Research and Development*, **2008**, *8*, 47–59. https://www.jstage.jst.go.jp/article/jamstecr/8/0/8_0_47/_article.

Kuusela M.; Stein, M.L. Locally Stationary Spatio-temporal Interpolation of Argo Profiling Float Data. *Proceedings of the Royal Society A* **2018**, *474*, 20180400. http://dx.doi.org/10.1098/rspa.2018.0400.

Roemmich, D.; Gilson, J. The 2004–2008 Mean and Annual Cycle of Temperature, Salinity, and Steric Height in the Global Ocean from the Argo Program. *Progress in Oceanography* **2009**, *82* (2), 81–100. https://doi.org/10.1016/j.pocean.2009.03.004.

Roemmich, D.; Church, J.; Gilson, J. et al. Unabated Planetary Warming and its Ocean Structure Since 2006. *Nature Climate Change* **2015**, *5*, 240–245. https://doi.org/10.1038/nclimate2513.

IN ADDITION, DATA USED UP TO 2020:

Church, J.A.; White, N.J.; Konikow, L.F. et al. Revisiting the Earth's Sea-level and Energy Budgets from 1961 to 2008. *Geophysical Research Letters* **2011**, *38* (18). https://doi.org/10.1029/2011GL048794.

Domingues, C.M.; Church, J.A.; White, N.J. et al. Improved Estimates of Upper-ocean Warming and Multi-decadal Sea-level Rise. *Nature* **2008**, *453*, 1090–1093. https://doi.org/10.1038/nature07080.

Li, Y.; Church, J.A.; McDougall, T.J. et al. Sensitivity of Observationally Based Estimates of Ocean Heat Content and Thermal Expansion to Vertical Interpolation Schemes. *Geophysical Research Letters* **2022**, *49* (24), e2022GL101079. https://doi.org/10.1029/2022GL101079.

Wij□els, S.; Roemmich, D.; Monselesan, D. et al. Ocean Temperatures Chronicle the Ongoing Warming of Earth. *Nature Climate Change* **2016**, *6*, 116–118. https://doi.org/10.1038/nclimate2924.

SEA LEVEL

Copernicus Climate Change Service (C3S), 2018: Sea Level Daily Gridded Data from Satellite Observations for the Global Ocean from 1993 to Present. C3S Climate Data Store (CDS), https://doi.org/10.24381/cds.4c328c78.

GMSL from CNES/+, https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level/data-acces.html#c12195.

MARINE HEATWAVE AND MARINE COLD SPELL

Marine heatwaves are categorized as moderate when the sea-surface temperature (SST) is above the ninetieth percentile of the climatological distribution for five days or longer. The subsequent categories are defined in respect of the di□erence between the SST and the climatological distribution average: “strong”, “severe” or “extreme”, if that di□erence is, respectively, more than two, three or four times the di□erence between the ninetieth percentile and the climatological distribution average.[136]

Marine cold spell categories are analogous but counting days below the tenth percentile, except for the “ice” category. This category is given to any marine cold spell when the threshold for the occurrence on any given day of the event is below –1.7 °C.[137] These are therefore considered to be conditions related to sea ice, and not extreme temperature fluctuations.

The baseline used for marine heatwaves and cold spells is 1982–2011, which is shifted by one year from the standard normal period of 1981–2010 because the first full year of the satellite SST series on which it is based is 1982. This period has not been updated to the current standard normal period of 1991–2020 because the shifting of the baseline has a significant e□ect on the results and would not allow for comparison of marine heatwaves/marine cold spells statistics with previous versions of the present publication.

All marine heatwaves and cold spells are detected using the NOAA 1/4° Daily Optimum Interpolation Sea Surface Temperature (OISST) v2.1 dataset (Huang et al., 2021).

Hobday, A. J.; Alexander, L. V.; Perkins, S. E. et al. A Hierarchical Approach to Defining Marine Heatwaves. *Progress in Oceanography* **2016**, *141*, 227–238. https://doi.org/10.1016/j.pocean.2015.12.014.

Hobday, A. J.; Oliver, E. C. J.; Sen Gupta, A. et al. Categorizing and Naming Marine Heatwaves. *Oceanography* **2018**, *31* (2), 1–13. https://www.jstor.org/stable/26542662.

Huang, B.; Liu, C.; Banzon, V. et al. Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1. *Journal of Climate* **2021**, *34 (8)*, 2923–2939. https://doi.org/10.1175/JCLI-D-20-0166.1.

Schlegel, R. W.; Darmaraki, S.; Benthuysen, J. A. et al. Marine Cold-Spells. *Progress in Oceanography* **2021**, *198*, 102684. https://doi.org/10.1016/j.pocean.2021.102684.

ICE SHEETS

Manko□, K.D.; Fettweis, X.; Langen, P.L. et al. Greenland Ice Sheet Mass Balance from 1840 Through Next Week. *Earth System Science Data* **2021**, *13* (10), 5001–5025. https://doi.org/10.5194/essd-13-5001-2021.

Manko□, K; Fettweis, X.; Solgaard, A., et al. *Greenland Ice Sheet Mass Balance from 1840 Through Next Week*: GEUS Dataverse, V791, 2021. https://doi.org/10.22008/FK2/OHI23Z.

Gravimetric (Gravity Recovery and Climate Experiment (GRACE)) ice mass time series for the Greenland and Antarctic ice sheets are calculated using spherical harmonics from JPL RL06v1, following Velicogna et al., 2020. The degree-1 geocentre terms are calculated using Sutterley and Velicogna, 2019 using C2,0 and C3,0 coe□cients from Loomis et al., 2019. The GRACE/GRACE Follow-on (GRACE-FO) data are corrected for the long-term trend of glacial isostatic adjustment (GIA) from the solid earth using the regional IJ05-R2 GIA model (Ivins et al., 2013) over Antarctica and the regional GIA model over Greenland (Simpson et al., 2009). These regional GIA models do not include realistic GIA signal outside the ice sheets. For this reason, outside Greenland and Antarctica, GIA corrections are based on Geruo et al., 2013 with the ICE6G ice history (Peltier et al., 2015).

Geruo, A.; Wahr, J.; Zhong, S. Computations of the Viscoelastic Response of a 3-D Compressible Earth to Surface Loading: An Application to Glacial Isostatic Adjustment in Antarctica and Canada. *Geophysical Journal International* **2013**, *192* (2), 557–572. https://doi.org/10.1093/gji/ggs030.

Ivins, E.R.; James, T.S.; Wahr, J. et al. Antarctic Contribution to Sea Level Rise Observed by GRACE with Improved GIA Correction. *Journal of Geophysical Research: Solid Earth* **2013**, *118* (6), 3126–3141. https://doi.org/10.1002/jgrb.50208.

Loomis, B.D.; Rachlin, K.E.; Luthcke, S.B. Improved Earth Oblateness Rate Reveals Increased Ice Sheet Losses and Mass-driven Sea Level Rise. *Geophysical Research Letters* **2019**, *46* (12), 6910–6917. https://doi.org/10.1029/2019GL082929.

Peltier, W.R.; Argus, D.F; Drummond, R. Space Geodesy Constrains Ice Age Terminal Deglaciation: The Global ICE-6G_C (VM5a) Model. *Journal of Geophysical Research: Solid Earth* **2015**, *120* (1), 450–487. https://doi.org/10.1002/2014JB011176.

Simpson, M.J.R; Milne, G.A.; Huybrechts, P. et al. Calibrating a Glaciological Model of the Greenland Ice Sheet from the Last Glacial Maximum to Present-day Using Field Observations of Relative Sea Level and Ice Extent. *Quaternary Science Reviews* **2009**, *28* (17–18), 1631–1657. https://doi.org/10.1016/j.quascirev.2009.03.004.

Sutterley, T.C.; Velicogna, I. Improved Estimates of Geocenter Variability from Time-variable Gravity and Ocean Model Outputs. *Remote Sensing* **2019**, *11* (18), 2108. https://doi.org/10.3390/rs11182108.

Velicogna, I.; Mohajerani, Y.; Geruo, A. Continuity of Ice Sheet Mass Loss in Greenland and Antarctica from the GRACE and GRACE Follow-on Missions. *Geophysical Research Letters* **2020**, *47* (8), e2020GL087291. https://doi.org/10.1029/2020GL087291.

GLACIERS

Global glacier monitoring information is provided by the World Glacier Monitoring Service (WGMS):

World Glacier Monitoring Service (WGMS), 2024: *Fluctuations of Glaciers (FoG) Database*, https://doi.org/10.5904/wgms-fog-2024-01.

SEA-ICE

Data are from the *European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Ocean and Sea Ice Satellite Application Facility Sea Ice Index v2p2*[138] and the National Snow and Ice Data Center (NSIDC) v3 Sea Ice Index.[139] Sea-ice concentrations are estimated from microwave radiances measured from satellites. Extent is the area of ocean grid cells where the sea-ice concentration exceeds 15%. There are modest di□erences in the absolute extent among datasets, but they agree well on year-to-year changes and trends. In the main text of the present publication, NSIDC values are reported for absolute extents, and rankings. Comparison figures for the Ocean and Sea Ice Satellite Application Facility are given in Table 3 (see below).

Table 3. NSIDC values compared with EUMETSAT Ocean and Sea Ice Satellite Application Facility figures for 2023

Metric	*NSIDC*	*Ocean and Sea Ice Satellite Application Facility*
Arctic daily minimum	4.23 million km², 19 September. Sixth lowest on record.	4.71 million km², 16 September. Sixth lowest on record.
Arctic daily maximum	14.62 million km², 6 March. Fifth lowest on record.	14.64 million km², 3 March
Antarctic daily minimum	1.79 million km², 21 February. Lowest on record.	2.00 million km², 16 February. Lowest on record.
Antarctic daily maximum	16.96 million km², 10 September. Lowest on record.	17.60 million km², 12 September. Lowest on record.

European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Ocean and Sea Ice Satellite Application Facility, 2023: *Sea-ice Index 1978-onwards, Version 2.2, OSI-420*. EUMETSAT Ocean and Sea Ice Satellite Application Facility, data extracted from Sea-ice index | OSI SAF (eumetsat.int).

Fetterer, F.; Knowles, K.; Meier, W.N. et al. *Sea Ice Index, Version 3*: National Snow and Ice Data Center (NSIDC), 2017. https://nsidc.org/data/G02135/versions/3.

Lavergne, T.; Sørensen, A.M.; Kern, S. et al. Version 2 of the EUMETSAT OSI SAF and ESA CCI Sea-ice Concentration Climate Data Records. *The Cryosphere* **2019**, *13* (1), 49–78. https://doi.org/10.5194/tc-139–2019.

PRECIPITATION

The following Global Precipitation Climatology Centre (GPCC) data sets were used in the analysis:

- First Guess Monthly, https://doi.org/10.5676/DWD_GPCC/FG_M_100
- Monitoring Product (Version 2022), https://doi.org/10.5676/DWD_GPCC/MP_M_V2022_100
- Full Data Monthly (Version 2022), https://doi.org/10.5676/DWD_GPCC/FD_M_V2022_100
- Precipitation Climatology (Version 2022), https://doi.org/10.5676/DWD_GPCC/CLIM_M_V2022_100

In Figure 22, Iceland is shown as being much drier than the long-term average and parts of China as much wetter. This is owing to a change in the way that real-time data are processed and is not reflective of actual conditions.

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UN AGENCIES

Food and Agriculture Organization of the United Nations (FAO); Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO); International Organization for Migration (IOM); O□ce of the United Nations High Commissioner for Refugees (UNHCR); United Nations Environment Programme (UNEP); United Nations O□ce for Disaster Risk Reduction (UNDRR); World Food Programme (WFP).

Endnotes

[1] Trewin, B.; Cazenave, A.; Howell, S. et al. Headline Indicators for Global Climate Monitoring, *Bulletin of the American Meteorological Society* **2021** *102* (1), E20–E37. https://doi.org/10.1175/BAMS-D-19-0196.1.

[2] World Meteorological Organization (WMO). *Climate Indicators and Sustainable Development: Demonstrating the Interconnections* (WMO-No. 1271). Geneva, 2021.

[3] World Meteorological Organization (WMO). *United in Science 2023*: Sustainable development edition; WMO: Geneva, 2023.

[4] United Nations; Department of Economic and Social A airs. *Synergy Solutions for a World in Crisis: Tackling Climate and SDG Action Together*; 2023. https://sdgs.un.org/synergy-solutions-world-crisis-tackling-climate-and-sdg-action-together.

[5] Betts, R. A.; Jones, C. D.; Knight, J. R. et al. El Niño and a Record CO_2 Rise. *Nature Clim Change* **2016**, *6* (9), 806–810. https://doi.org/10.1038/nclimate3063.

[6] National Oceanic and Atmospheric Administration (NOAA). *Trends in Atmospheric Carbon Dioxide*. https://gml.noaa.gov/ccgg/trends/mlo.html. Measurements at Mauna Loa were interrupted by a volcanic eruption and the measurement site was temporarily relocated to Maunakea observatories 21 miles to the north.

[7] Commonwealth Scientific and Industrial Research Organisation (CSIRO). *Latest Kennaook / Cape Grim greenhouse gas data. The latest greenhouse gas (GHG) data updated monthly from one of the cleanest air sources in the world*. https://www.csiro.au/greenhouse-gases/.

[8] For anomalies relative to other baselines see Global mean temperature anomalies for 2023 relative to other periods..

[9] Rantanen, M.; Laaksonen, A. The Jump in Global Temperatures in September 2023 Is Extremely Unlikely Due to Internal Climate Variability Alone. *npj Clim Atmos Sci* **2024**, *7* (1), 1–4. https://doi.org/10.1038/s41612-024-00582-9.

[10] Hansen, J.; Sato, M.; Kharecha, P. et al. Earth's Energy Imbalance and Implications. *Atmospheric Chemistry and Physics* **2011**, *11* (24), 13421–13449. https://doi.org/10.5194/acp-11-13421-2011.

[11] von Schuckmann, K.; Palmer, M. D.; Trenberth, K. E. et al. An Imperative to Monitor Earth's Energy Imbalance. *Nature Clim Change* **2016**, *6* (2), 138–144. https://doi.org/10.1038/nclimate2876.

[12] von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12(3), 2013–2041. https://doi.org/10.5194/essd-12–2013–2020

[13] Cheng, L.; Trenberth, K. E.; Fasullo, J. et al. Improved Estimates of Ocean Heat Content from 1960 to 2015. *Science Advances* **2017**, *3* (3), e1601545. https://doi.org/10.1126/sciadv.1601545.

[14] Intergovernmental Panel on Climate Change (IPCC), 2019: Summary for Policymakers. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* https://www.ipcc.ch/site/assets/uploads/sites/3/2022/03/01_SROCC_SPM_FINAL.pdf.

[15] Ocean heat content is measured in zettajoules. A zettajoule is 1 021 joules, which is 1 000 000 000 000 000 000 000 joules.

[16] Cheng, L.; Abraham, J.; Trenberth, K. E. et al. New Record Ocean Temperatures and Related Climate Indicators in 2023. *Adv. Atmos. Sci.* **2024**. https://doi.org/10.1007/s00376-024-3378-5.

[17] von Schuckmann, K.; Minière, A.; Gues, F. et al. Heat Stored in the Earth System 1960–2020: Where Does the Energy Go? *Earth System Science Data* **2023**, *15* (4), 1675–1709. https://doi.org/10.5194/essd-15-1675-2023. Loeb, N. G.; Johnson, G. C.; Thorsen, T. J. et al. Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate. *Geophysical Research Letters* **2021**, *48* (13), e2021GL093047. https://doi.org/10.1029/2021GL093047.

[18] Minière, A.; von Schuckmann, K.; Sallée, J.-B. et al. Robust Acceleration of Earth System Heating Observed over the Past Six Decades. *Sci Rep* **2023**, *13* (1), 22975. https://doi.org/10.1038/s41598-023-49353-1.

[19] Minière, A.; von Schuckmann, K.; Sallée, J.-B. et al. Robust Acceleration of Earth System Heating Observed over the Past Six Decades. *Sci Rep* **2023**, *13* (1), 22975. https://doi.org/10.1038/s41598-023-49353-1.

[20] Raghuraman, S. P.; Paynter, D.; Ramaswamy, V. Anthropogenic Forcing and Response Yield Observed Positive Trend in Earth's Energy Imbalance. *Nat Commun* **2021**, *12* (1), 4577. https://doi.org/10.1038/s41467-021-24544-4. Kramer, R. J.; He, H.; Soden, B. J. et al. Observational Evidence of Increasing Global Radiative Forcing. *Geophysical Research Letters* **2021**, *48* (7), e2020GL091585. https://doi.org/10.1029/2020GL091585.

[21] e.g., Loeb, N. G.; Johnson, G. C.; Thorsen, T. J. et al. Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate. *Geophysical Research Letters* **2021**, *48* (13), e2021GL093047. https://doi.org/10.1029/2021GL093047. Hakuba, M. Z.; Frederikse, T.; Landerer, F. W. Earth's Energy Imbalance From the Ocean Perspective (2005–2019). *Geophysical Research Letters* **2021**, *48* (16), e2021GL093624. https://doi.org/10.1029/2021GL093624.

[22] Purkey, S. G.; Johnson, G. C. Warming of Global Abyssal and Deep Southern Ocean Waters between the 1990s and 2000s: Contributions to Global Heat and Sea Level Rise Budgets. *Journal of Climate* **2010**, *23* (23), 6336–6351. https://doi.org/10.1175/2010JCLI3682.1.

[23] Cheng, L.; Abraham, J.; Trenberth, K. E. et al. Another Year of Record Heat for the Oceans. *Adv. Atmos. Sci.* **2023**, *40* (6), 963–974. https://doi.org/10.1007/s00376-023-2385-2. Cheng, L.; von Schuckmann, K.; Abraham, J. P. et al. Past and Future Ocean Warming. *Nat Rev Earth Environ* **2022**, *3* (11), 776–794. https://doi.org/10.1038/s43017-022-00345-1.

[24] Changes of these percentages from the provisional report reflect an update to the Cheng et al. dataset, see Cheng, L.; Abraham, J.; Trenberth, K. E. et al. New Record Ocean Temperatures and Related Climate Indicators in 2023. *Adv. Atmos. Sci.* **2024**. https://doi.org/10.1007/s00376-024-3378-5.

[25] Cheng, L.; Trenberth, K. E.; Fasullo, J. et al. Improved Estimates of Ocean Heat Content from 1960 to 2015. *Science Advances* **2017**, *3* (3), e1601545. https://doi.org/10.1126/sciadv.1601545.

[26] Cheng, L.; von Schuckmann, K.; Abraham, J. P. et al. Past and Future Ocean Warming. *Nat Rev Earth Environ* **2022**, *3* (11), 776–794. https://doi.org/10.1038/s43017-022-00345-1.

[27] Smale, D. A.; Wernberg, T.; Oliver, E. C. J. et al. Marine Heatwaves Threaten Global Biodiversity and the Provision of Ecosystem Services. *Nat. Clim. Chang.* **2019**, *9* (4), 306–312. https://doi.org/10.1038/s41558-019-0412-1.

[28] World Meteorological Organization (WMO). *WMO Greenhouse Gas Bulletin – No. 18: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2021.* Geneva, 2022.

[29] Friedlingstein, P.; O'Sullivan, M.; Jones, M. W. et al. Global Carbon Budget 2020. E*arth System Science Data* **2020**, *12* (4), 3269–3340. https://doi.org/10.5194/essd-12-3269-2020.

[30] Intergovernmental Panel on Climate Change (IPCC). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Core Writing Team, H. Lee and J. Romero, Eds.; IPCC: Geneva, Switzerland, 2023. https://doi.org/10.59327/IPCC/AR6–9789291691647.

[31] Intergovernmental Panel on Climate Change (IPCC), 2021: Climate Change 2021: The Physical Science Basis, Chapter 2, section 2.3.3.5 Ocean pH, https://www.ipcc.ch/report/ar6/wg1/.

[32] Numbers in main text are from National Snow and Ice Data Center (NSIDC). OSI SAF figures are provided in Data sets and methods. https://nsidc.org/arcticseaicenews/2023/03/arctic-sea-ice-maximum-at-fifth-lowest-on-satellite-record/, https://nsidc.org/arcticseaicenews/2023/04/polar-dawn-to-dusk/.

[33] National Snow and Ice Data Center (NSIDC). *Arctic sea ice minimum at sixth lowest extent on record*. https://nsidc.org/arcticseaicenews/2023/09/arctic-sea-ice-minimum-at-sixth/.

[34] Fast December expansion, Arctic Sea Ice News and Analysis (nsidc.org) https://nsidc.org/arcticseaicenews/2024/01/fast-december-expansion/

[35] 1981–2010 is the period used by NSIDC for their monitoring

[36] Liu, J.; Zhu, Z.; Chen, D. Lowest Antarctic Sea Ice Record Broken for the Second Year in a Row. *Ocean-Land-Atmosphere Research* **2023**, *2*, 0007. https://doi.org/10.34133/olar.0007.

[37] Purich, A.; Doddridge, E. W. Record Low Antarctic Sea Ice Coverage Indicates a New Sea Ice State. *Commun Earth Environ* **2023**, *4* (1), 1–9. https://doi.org/10.1038/s43247-023-00961-9.

[38] https://nsidc.org/arcticseaicenews/2023/09/antarctic-sets-a-record-low-maximum-by-wide-margin/.

[39] Fast December expansion, Arctic Sea Ice News and Analysis (nsidc.org) https://nsidc.org/arcticseaicenews/2024/01/fast-december-expansion/.

[40] The period 1981–2010 is used by NSIDC for their monitoring.

[41] Weyer, N. M., Ed. Annex I: Glossary. In IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Pörtner, H.-O.; Roberts, D. C.; Masson-Delmotte, V. et al., Eds.; Cambridge University Press: Cambridge, UK and New York, USA, 2019. https://www.ipcc.ch/srocc/chapter/glossary/. Note that the Antarctic ice sheet can be further subdivided into West Antarctic, East Antarctic and the Antarctic Peninsula, but is treated here as a single entity.

[42] Note that the Antarctic ice sheet can be further subdivided into West Antarctic, East Antarctic and Antarctic Peninsula, but is treated here as a single entity.

[43] Manko□, K. D.; Fettweis, X.; Langen, P. L. et al. Greenland Ice Sheet Mass Balance from 1840 through next Week. *Earth System Science Data* **2021**, *13* (10), 5001–5025. https://doi.org/10.5194/essd-13-5001-2021.

[44] National Snow and Ice Data Center (NSIDC). *Late-season melt spike*. https://nsidc.org/ice-sheets-today/analyses/late-season-melt-spike. *Sudden shift to southern heat*. https://nsidc.org/ice-sheets-today/analyses/sudden-shift-southern-heat.

[45] Cumulative melt-day area is the area of the ice sheet that experienced melting conditions each day (diagnosed by the presence of liquid water at the surface), summed over the number of days in the melt season.

[46] Summit Station is the highest point on the Greenland ice sheet, at an altitude of 3 216 m.

[47] https://www.dmi.dk/nyheder/2023/varmerekorder-pa-indlandsisen/

[48] Nghiem, S. V.; Hall, D. K.; Mote, T. L. et al. The Extreme Melt across the Greenland Ice Sheet in 2012. *Geophysical Research Letters* **2012**, *39* (20). https://doi.org/10.1029/2012GL053611.

[49] Otosaka, I. N.; Shepherd, A.; Ivins, E. R. et al. Mass Balance of the Greenland and Antarctic Ice Sheets from 1992 to 2020. *Earth System Science Data* **2023**, *15* (4), 1597–1616. https://doi.org/10.5194/essd-15-1597-2023.

[50] A gigatonne (Gt) is 1 000 000 000 t, and 1 Gt of ice corresponds to a volume of about 1.09 km^3.

[51] m w.e. is the depth of water equivalent to the change in ice thickness. Glacier ice is less dense than water, so the equivalent depth of water is slightly less than the thickness of ice lost.

[52] WGMS (2023): Global Glacier Change Bulletin No. 5 (2020-2021). Michael Zemp, Isabelle Gärtner-Roer, Samuel U. Nussbaumer, Ethan Z. Welty, Inès Dussaillant, and Jacqueline Bannwart (eds.), ISC (WDS) / IUGG (IACS) / UNEP / UNESCO / WMO, World Glacier Monitoring Service, Zurich, Switzerland, 134 pp. Based on database version https://doi.org/10.5904/wgms-fog-2023-09.

[53] Firn is multi-year snow, which has a higher albedo than glacier ice.

[54] LiDAR stands for Light Detection and Ranging, which uses a laser to determine the height of the glacier surface.

[55] Hugonnet, R.; McNabb, R.; Berthier, E. et al. Accelerated Global Glacier Mass Loss in the Early Twenty-First Century. *Nature* **2021**, *592* (7856), 726–731. https://doi.org/10.1038/s41586-021-03436-z.

[56] Parisien, M.-A.; Barber, Q. E.; Flannigan, M. D. et al. Broadleaf Tree Phenology and Springtime Wildfire Occurrence in Boreal Canada. *Global Change Biology* **2023**, *29* (21), 6106–6119. https://doi.org/10.1111/gcb.16820.

[57] Robinson, David A.; Estilow, Thomas W.; and NOAA CDR Program (2012): NOAA Climate Data Record (CDR) of Northern Hemisphere (NH) Snow Cover Extent (SCE), Version 1. NOAA National Centers for Environmental Information. https://doi.org/10.7289/V5N014G9.

[58] IEA (2024), Renewables 2023, IEA, Paris https://www.iea.org/reports/renewables-2023

[59] https://www.cop28.com/en/global-renewables-and-energy-e□ciency-pledge

[60] In general, a capacity factor is a measure of how often a power plant operates at its maximum capacity over a certain period, expressed as a percentage.

[61] World Meteorological Organization (WMO), International Renewable Energy Agency (IRENA). 2022 Year in Review: Climate-driven Global Renewable Energy Potential Resources and Energy Demand. Geneva, 2023.

[62] World Meteorological Organization (WMO). *WMO Greenhouse Gas Bulletin – No. 19: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2022.* Geneva, 2022.

[63] A Dobson unit is the depth (in units of 10 µm) of the pure gas you would get if it were extracted from the air column and reduced to standard temperature and pressure. 300 DU corresponds to 3mm.

[64] https://ozonewatch.gsfc.nasa.gov/

[65] https://atmosphere.copernicus.eu/monitoring-ozone-layer

[66] https://mausam.imd.gov.in/responsive/monsooninformation.php

[67] United Nations Environment Programme (UNEP). *Frontiers 2022: Noise, Blazes and Mismatches-Emerging Issues of Environmental Concern*. Nairobi, 2022.

[68] Fire weather is weather conducive to wildfires, including high temperatures, low humidity, and high winds.

[69] United Nations, 2022: *The Sustainable Development Goals Report 2022*, https://unstats.un.org/sdgs/report/2022/

[70] United Nations, 2023: *The Sustainable Development Goals Report 2023: Special Edition*, https://unstats.un.org/sdgs/report/2023/.

[71] https://www.mapa.gob.es/es/prensa/ultimas-noticias/el-146--del-territorio-est%C3%A1-en-emergencia-por-escasez-de-agua-y-el-274--en-alerta/tcm:30–659894

[72] https://www.unocha.org/publications/report/libya/libya-flood-response-humanitarian-update-15-december-2023

[73] https://reliefweb.int/report/greece/greece-severe-weather-and-floods-update-greek-civil-protection-hellenic-national-meteorological-service-copernicus-emsr-echo-daily-flash-11-september-2023

[74] https://www.preventionweb.net/media/87994/download?startDownload=true

[75] https://reliefweb.int/report/mozambique/unhcr-mozambique-cyclone-freddy-flash-update-3-24-march-2023

[76] https://story.internal-displacement.org/2023-mid-year-update/

[77] https://sentinel-asia.org/EO/2023/article20230514MM.html

[78] https://reliefweb.int/report/bangladesh/bangladesh-cyclone-mocha-humanitarian-response-situation-report-14-may-2023

[79] National contribution

[80] https://ahacentre.org/wp-content/uploads/2023/05/AHA-DRAFT-Situation_Report-9-TC-MOCHA-Myanmar-1.pdf

[81] https://story.internal-displacement.org/2023-mid-year-update/

[82] https://reporting.unhcr.org/myanmar-emergency-flash-update-2-cyclone-mocha.

[83] https://www.nhc.noaa.gov/data/tcr/EP182023_Otis.pdf

[84] Emergency Events Database (EM-DAT). See also https://www.fitchratings.com/research/insurance/mexico-re-insurers-not-materially-a□ected-by-hurricane-otis-31-10-2023.

[85] https://reliefweb.int/report/mexico/mexico-hurricane-otis-situation-report-no-01-8-november-2023

[86] https://www.treasury.govt.nz/sites/default/files/2023–04/impacts-from-the-north-island-weather-events.pdf

[87] Merlone, A.; Pasotti, L.; Musacchio, C. et al. Evaluation of the Highest Temperature WMO Region VI Europe (Continental): 48.8°C, Siracusa Sicilia, Italy on August 11, 2021. *International Journal of Climatology* **2024**, *44*, 721–728. https://doi.org/10.1002/joc.8361.

[88] https://meteofrance.com/actualites-et-dossiers/actualites/fortes-chaleurs-aout-2023

[89] https://atmosphere.copernicus.eu/2023-year-intense-global-wildfire-activity

[90] https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories/2023.html

[91] https://www.disastercenter.com/FEMA%20Daily%20Ops%20Briefing%20085–2023.pdf

[92] https://www.ncei.noaa.gov/access/billions/events/US/2023?disasters[]=wildfire

[93] https://www.fema.gov/sites/default/files/documents/PDAReport_FEMA4724DRexpedited-HI.pdf

[94] Piyush, J.; Barber, Q.E.; Taylor, S. et al. Canada Under Fire – Drivers and Impacts of the Record-Breaking 2023 Wildfire Season. *Ess Open Archive* **2024**. https://essopenarchive.org/users/747500/articles/719254-canada-under-fire-drivers-and-impacts-of-the-record-breaking-2023-wildfire-season.

[95] https://www.portodemanaus.com.br/?pagina=niveis-maximo-minimo-do-rio-negro

[96] Ethiopia: https://www.unocha.org/publications/report/ethiopia/ethiopia-oct-nov-dec-rainy-season-flash-update-1-18-december-2023. Kenya: https://www.unocha.org/publications/report/kenya/kenya-heavy-rains-and-floods-impact-and-response-20-december-2023. Somalia: https://www.unocha.org/publications/report/somalia/somalia-situation-report-26-dec-2023.

[97] https://dtm.iom.int/reports/east-and-horn-africa-flood-snapshot-july-november-2023

[98] https://dtm.iom.int/reports/horn-africa-drought-human-mobility-snapshot-january-june-2023

[99] National contribution.

[100] https://www.fao.org/3/cc6806en/cc6806en.pdf

[101] United Nations, 2022: *The Sustainable Development Goals Report 2022*, https://unstats.un.org/sdgs/report/2022/.

[102] United Nations, 2023: *The Sustainable Development Goals Report 2023: Special Edition*, https://unstats.un.org/sdgs/report/2023/.

[103] https://docs.wfp.org/api/documents/WFP-0000153758/download/?_ga=2.87190362.312982961.1705667005-702211395.16952869333.

[104] Food and Agriculture Organization of the United Nations (FAO); International Fund for Agricultural Development (IFAD); United Nations Children's Fund (UNICEF) et al., 2023: *The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural–Urban Continuum*, https://doi.org/10.4060/cc3017en.

[105] docs.wfp.org/api/documents/WFP-0000150404/download/

[106] Food and Agriculture Organization of the United Nations (FAO), 2023: *Crop Prospects and Food Situation – Quarterly Global Report No. 2, July 2023*, https://doi.org/10.4060/cc6806en.

[107] Food and Agriculture Organization of the United Nations (FAO); International Fund for Agricultural Development (IFAD); United Nations Children's Fund (UNICEF) et al., 2023: *The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural–Urban Continuum*, https://doi.org/10.4060/cc3017en.

[108] Food and Agriculture Organization of the United Nations (FAO), 2021: *The Impact of Disasters and Crises on Agriculture and Food Security: 2021*, https://doi.org/10.4060/cb3673en.

[109] Food and Agriculture Organization of the United Nations (FAO), 2023: *The Impact of Disasters on Agriculture and Food Security 2023: Avoiding and Reducing Losses through Investment in Resilience*, https://doi.org/10.4060/cc7900en.

[110] Food and Agriculture Organization of the United Nations (FAO), 2023: *Crop Prospects and Food Situation – Triannual Global Report No. 3, November 2023*, https://doi.org/10.4060/cc8566en.

[111] Ibid.

[112] World Food Programme (WFP), 2023: *Indonesia – Monitoring Bulletin: July–September (Q3) 2023*, https://www.wfp.org/publications/indonesia-monitoring-bulletin-july-september-q3-2023.

[113] O□ce for the Coordination of Humanitarian A□airs (OCHA), 2023: *Latin America & The Caribbean Weekly Situation Update (as of 4 September 2023)*, https://reliefweb.int/report/cuba/latin-america-caribbean-weekly-situation-update-4-september-2023.

[114] Food and Agriculture Organization of the United Nations (FAO), 2023: *Crop Prospects and Food Situation – Triannual Global Report No. 3, November 2023*, https://doi.org/10.4060/cc8566en.

[115] https://data-in-emergencies.fao.org/apps/e451e32a054847469b1c1c731a8e5c□/explore

[116] https://www.unhcr.org/news/briefing-notes/un-refugee-agency-warns-extreme-hardship-forcibly-displaced-families-winter

[117] https://go.ifrc.org/emergencies/6435, https://reliefweb.int/disaster/fl-2023-000068-yem

[118] https://dtm.iom.int/reports/migration-along-eastern-corridor-july-2023

[119] https://reliefweb.int/report/pakistan/early-needs-identification-report-monsoon-flood-a□ected-areas-pakistan-august-2023

[120] https://prmn-somalia.unhcr.org/yearly-displacement

[121] https://reliefweb.int/report/somalia/unhcr-somalia-factsheet-december-2023

[122] https://reliefweb.int/report/libya/libya-impact-storm-daniel-update-displacement-and-needs-november-2023

[123] https://dtm.iom.int/reports/libya-storm-daniel-flash-update-2-13-september-2023

[124] End poverty in all its forms everywhere

[125] End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

[126] Ensure healthy lives and promote well-being for all at all ages.

[127] Reduce inequality within and among countries.

[128] Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

[129] Ensure availability and sustainable management of water and sanitation for all.

[130] Ensure access to a□ordable, reliable, sustainable and modern energy for all.

[131] Achieve gender equality and empower all women and girls.

[132] https://www.unhcr.org/protection/environment/5f21565b4/gender-displacement-and-climate-change.html

[133] United Nations Environment Programme (UNEP), 2022: *Climate Change and Security Partnership Project – Final Report: March 2017–February 2022*, https://wedocs.unep.org/handle/20.500.11822/40549.

[134] https://sendaiframework-mtr.undrr.org/publication/report-midterm-review-implementation-sendai-framework-disaster-risk-reduction-2015–2030

[135] von Schuckmann, K.; Cheng, L.; Palmer, M.D. et al. Heat Stored in the Earth System: Where Does the Energy go? *Earth System Science Data* **2020**, *12* (3), 2013–2041. https://doi.org/10.5194/essd-12-2013-2020.

[136] Hobday, A.J.; Oliver, E.C.J; Gupta, A.S. et al. Categorizing and Naming Marine Heatwaves. *Oceanography* **2018**, *31* (2), 162–173. https://www.jstor.org/stable/26542662.

[137] Schlegel, R.W.; Darmaraki, S.; Benthuysen, J.A. et al. Marine Cold-spells. *Progress in Oceanography* **2021**, *198*, 102684. https://www.sciencedirect.com/science/article/abs/pii/S0079661121001683.

[138] Based on Lavergne, T.; Sørensen, A.M.; Kern, S. et al. Version 2 of the EUMETSAT OSI SAF and ESA CCI Sea-ice Concentration Climate Data Records. *The Cryosphere* **2019**, *13* (1), 49–78. https://doi.org/10.5194/tc-139–2019.

[139] Fetterer, F.; Knowles, K.; Meier, W.N. et al. *Sea Ice Index, Version 3*: National Snow and Ice Data Center (NSIDC), 2017. https://nsidc.org/data/G02135/versions/3.

Food and Agriculture Organization of the United Nations

UNHCR The UN Refugee Agency

IOM UN MIGRATION

WFP World Food Programme

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APPEAL EXHIBIT B

CENTER for BIOLOGICAL DIVERSITY Because life is good.

January 26, 2026

Sent via email

Scarlet Duggan
Lands Use Manager
Orange County Planning Commission
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Re: Subsequent EIR for Saddleback Meadows Project (SCH 1996121072)

Dear Ms. Duggan:

On behalf of the Center for Biological Diversity (Center), I am writing to urge you to require preparation of a subsequent environmental impact report (EIR) for the Saddleback Meadows Project (Project) prior to allowing issuance of any use permits or ground disturbing activities. The 2022 Project approvals were based on an EIR that was certified in 2002, more than two decades ago, before local mountain lions became provisionally listed under the California Endangered Species Act (CESA) in 2020 and before the California Department of Fish and Wildlife (CDFW) recommended local mountain lions be formally listed. New information which did not exist when the EIR was certified in 2002 has become available demonstrating that the mountain lion population in the Project area is facing an extinction vortex driven by habitat loss and fragmentation, vehicle strikes, rodenticide poisoning, disease, and other causes. The Project will further destroy habitat, degrade connectivity, and drive the local mountain lion population closer to extinction. Moreover, the EIR does not account for (nor could it have accounted for) the "new normal" of destructive wildfire in the wildland urban interface (WUI) in California driven by poorly planned development and climate change, nor does it account for scientific studies showing that development like the Project increases wildfire risk, endangers new and existing residents, and contributes to a feedback loop of increased wildfire and loss of biodiversity.

The EIR for the Project was certified in 2002 and contains no analysis of the Project's impacts to mountain lions, wildlife connectivity, and wildfire risk. A subsequent EIR will allow study of how the Project will impact the vulnerable local mountain lion population as well as consideration and adoption of mitigation measures and alternatives. In addition, a subsequent EIR that fully analyzes new information regarding the wildfire risk and climate change impacts of the Project is necessary to allow for informed decision-making, including whether large-scale development in this location is in the public interest.

I. Background on the Center for Biological Diversity

The Center for Biological Diversity (Center) is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 1.8 million members and online activists throughout California and the United States. The Center and its members have worked for many years to protect imperiled plants and wildlife, open space, air and water quality, and overall quality of life for people in Southern California.

II. New Information Regarding the Plight of Southern California Mountain Lions Has Emerged Since the EIR Was Certified in 2002.

CEQA and CESA require analysis and mitigation for impacts to local mountain lions. The California Environmental Quality Act (CEQA) states that a subsequent or supplemental EIR may be required when either (1) substantial changes occur with respect to the circumstances under which the project is being undertaken which will require major revisions in the environmental impact report or (2) new information, which was not known and could not have been known at the time the environmental impact report was certified as complete, becomes available. (Pub. Res. Code § 21166.)

New information that mountain lions in the Project area are facing an extinction vortex fits within both of these categories. Mountain lions in the Project area are part of the Santa Ana Mountains population, which were granted "candidacy status" in April 2020 under CESA, such that they are afforded the same protections as other CESA-listed species. And on December 10, 2025, the California Department of Fish and Wildlife ("CDFW") released their status review regarding the petition and recommended listing all six of the petitioned mountain lion populations as a threatened Southern California and Central Coast mountain lion distinct population segment (DPS) under CESA (CDFW, 2025).

CEQA requires a "mandatory finding of significance" when a project has the potential to impact a CESA-listed species. (CEQA Guidelines § 15065(a)(1); *Endangered Habitats League, Inc. v. County of Orange* (2005) 131 Cal.App.4th 777, 792 fn. 12.) And such a finding triggers a duty to consider and adopt all feasible alternatives or mitigation measures to reduce such impacts. (Pub. Res. Code § 21002.) Moreover, under CESA, the County may not approve projects that could jeopardize the continued existence of this population or result in destruction of essential habitat (Fish & Game Code § 2053(a)) and agencies must require that appropriate mitigation measures be implemented for projects that could destroy mountain lion habitat or impair connectivity (Fish & Game Code § 2054). The 2002 EIR does not address these issues.

A. Recent Scientific Studies Reveal That Mountain Lions in the Project Area are Threatened and the Project will Further Harm The Local Population.

Continued habitat loss and fragmentation has led to 10 genetically isolated populations within California (Gustafson et al., 2018, 2021). There are six identified mountain lion populations in the Southern California and Central Coast DPS, one of which includes local mountain lions in the Santa Ana Mountains population. This population is facing an extinction

vortex due to high levels of inbreeding, low genetic diversity, high human-caused mortality rates from car strikes on roads, depredation kills, rodenticide poisoning, poaching, disease, and increased human-caused wildfires (Benson et al., 2019; Gustafson et al., 2021; Vickers et al., 2015). The Santa Ana population has the lowest genetic diversity documented for the species aside from the endangered Florida panthers (Gustafson et al., 2021), and scientists predict that if further genetic isolation and inbreeding depression occur, this population has a 100% chance of becoming locally extinct within 50 years (and in as little as 12 years) (Benson et al., 2019). Alarmingly, researchers have documented physical and reproductive signs of inbreeding depression in these mountain lions (Huffmeyer et al., 2021). This emphasizes the importance of protecting the remaining Santa Ana Mountains population, specifically through maintaining and enhancing remaining habitat and wildlife connectivity.

Numerous studies highlight the impacts of human activities on mountain lions. Human-caused mortalities—including vehicle strikes, rodenticide poisoning, depredation kills, poaching, and wildfire—are the leading cause of death for mountain lions across California, exceeding natural mortality rates (Benson, Sikich, et al., 2020; Benson et al., 2023; Nisi et al., 2023; Vickers et al., 2015). In addition, human activities also alter these large carnivores' behavior in ways that likely further impede important movement and gene flow. For example, researchers found that mountain lions are so fearful of humans and noise generated by humans that they will abandon the carcass of a deer and forgo the feeding opportunity just to avoid humans (J. A. Smith et al., 2017). The authors concluded that even "non-consumptive forms of human disturbance may alter the ecological role of large carnivores by affecting the link between these top predators and their prey" (J. A. Smith et al., 2017). In addition, mountain lions have been found to respond fearfully upon hearing human vocalizations, avoiding the area and moving more cautiously when hearing humans (J. A. Smith et al., 2017; Suraci et al., 2019)..

Other studies have demonstrated other shifts in behavior and movement patterns of pumas in response to human activities, like increased avoidance behavior in areas with more roads and higher development densities and increased nocturnal activity as human presence (Bolas et al., 2025; Dougherty et al., 2025; Lucas, 2020; Nickel et al., 2020, 2021; Nisi et al., 2022, 2023; J. A. Smith et al., 2015, 2019; Y. Wang et al., 2017; Wilmers et al., 2013, 2021; Yovovich et al., 2020). Pumas have also been found to generally avoid areas with nearby night lighting (Barrientos et al., 2023). Thus, the increased human presence due to the Project's new roads and development could have significant negative impacts on puma survival and behavior, which could reduce the genetic health of the local population and ultimately diminish the long-term survival of the Santa Ana Mountains population.

Human activities can also affect mountain lion communication and reproductive behaviors that are important for their survival (Yovovich et al., 2020). Males prefer to use relatively flat areas away from human influence as scrape sites to delineate territories as well as attract potential mates (Allen et al., 2015, 2016; Yovovich et al., 2020). Similarly, when nursing females (with kittens less than 8 weeks old) shrink their home ranges to an average of 9 km^2 while their young were most vulnerable, they prefer undeveloped lands away from human disturbance, opting for habitat with protective cover and sufficient water and prey availability (Yovovich et al., 2020). The loss of adequate undisturbed communication and nursery habitat

could disrupt important communication and reproductive behaviors that facilitate social structure and overall survival.

In a study conducted from 2002 to 2019 in the Central Coast South (CC-S) puma population, scientists found high human-caused mortality rates in puma adults and high intraspecific mortalities among subadults (Benson, Sikich, et al., 2020). Most known causes of death among adults and subadults (14/20) were directly human-caused: vehicle strikes, rodenticide poisoning, poaching, and wildfire. The remaining six known (6/20) causes of deaths were intraspecific killing (Benson, Sikich, et al., 2020). And while intraspecific killings have been documented to naturally occur in mountain lion populations, it was likely exacerbated in the Santa Monica Mountains with the presence of significant movement barriers that prevent subadults from being able to adequately disperse, which likely led to increased conflicts with territorial males (Benson, Sikich, et al., 2020; Riley et al., 2014).

The Santa Monica Mountains puma population is relatively small, extremely isolated, and geographically limited. Demographic and environmental stochasticity and high mortality rates increase the risk of local extinction, particularly when combined with small population size, low density, female-biased sex ratios, and skewed male reproductive success (Benson et al., 2016, 2019; Ernest et al., 2014; Riley et al., 2014; Vickers et al., 2015). Increased human-caused mortalities of adult males could lead to occasional male extinctions, which would disrupt reproduction and could severely limit the short- and long-term viability of a population (Benson et al., 2016, 2019). The Santa Ana Mountains puma population is similarly small, isolated, and geographically limited, which suggests that further encroachment into remaining habitat and connectivity areas could drive the population closer to extirpation. This highlights the need to reduce human-caused mortalities, in part, by protecting existing intact habitats and improving connectivity within and between subpopulations.

There are many scientific studies that provide insights on the profound impacts human activities and infrastructure have on mountain lion survival, and they emphasize the need to adequately assess and mitigate impacts to these CESA candidate species in the Project area. These studies add to the accumulating evidence that mountain lions require a habitat mosaic that provides sufficient room to roam away from human-disturbed areas and connected to expansive, intact, heterogeneous habitats (Dickson et al., 2005; Dickson & Beier, 2002; Kertson et al., 2011; Zeller et al., 2017). Continued construction of roads and development in mountain lion habitat with little regard for their movement and behavioral needs has direct and indirect lethal and sublethal impacts that threaten the persistence of Southern California and Central Coast puma populations. CEQA requires a subsequent EIR that adequately analyzes these potential impacts.

Mountain lions are a key indicator species of wildlife connectivity and healthy ecosystems. As the last remaining wide-ranging large carnivore in Southern California, the ability to move through large swaths of interconnected habitat is vital for genetic connectivity and their long-term survival. Local extinction of mountain lions in the region could have severe ecological consequences. Many scavengers, including many raptors, foxes, and numerous insects, would lose a reliable food source (Barry et al., 2019; Elbroch et al., 2017; Labarge et al., 2022; Ruth & Elbroch, 2014). Fish, birds, amphibians, reptiles, rare native plants, and butterflies could potentially diminish if this apex predator were lost (Ripple et al., 2014; Ripple & Beschta,

2006, 2008). Loss of this ecosystem engineer and important predator-prey dynamics could have cascading effects on other plant and animal species, potentially leading to a decrease in biodiversity and diminished overall ecosystem function (Barry et al., 2019; Benson, Mahoney, et al., 2020; Elbroch et al., 2017; Ripple et al., 2014).

B. The 2002 EIR for the Project Does Not Adequately Address the Project's Impacts to Mountain Lions and Wildlife Connectivity.

Virtually all of the studies cited above regarding the extinction vortex faced by mountain lions in Southern California were conducted and released after the EIR was certified in 2002. As such, the 2002 EIR does not—and cannot—adequately analyze or mitigate impacts of the Project on mountain lions, a CESA provisionally-listed species. This fact alone necessitates recirculation of a new EIR before the County undergoes any approvals or issuance of any type of permits for the Project. Here, a subsequent EIR for the Project can and should contain analysis of how the Project can avoid, minimize, and mitigate impacts to mountain lions and wildlife movement. The subsequent EIR should also document the presence of mountain lions in the Project area. Indeed, researchers from UC Davis have documented mountain lions in and near the Project area (Figure 1) (Vickers et al., 2015). The new EIR must also consider alternatives to the Project that do not harm mountain lions and adopt all feasible mitigation measures to reduce impacts.

To adequately assess impacts to local mountain lions, the new EIR must also adequately assess and mitigate the Project's impacts to wildlife connectivity, including but not limited to the riparian corridor in the Project area. The January 28, 2026 staff report's conclusion that constructing the project will somehow enhance wildlife connectivity by "providing for improved connectivity and wildlife movement from the Aliso Creek Corridor to O'Neill Regional Park and the Cleveland National Forest" (staff report at 7) is a misrepresentation of the Project's impacts, and such characterization of the Project is egregious green-washing. Although the "Proposed Area Plan (181 Units)" reduces impacts to wildlife connectivity compared to the "Modified Project (266 Units)," the staff report fails to acknowledge that the construction of the "Proposed Area Plan (181 Units)" does not improve regional connectivity compared to current conditions. The Project will destroy and degrade more than 200 acres of intact habitat within a sensitive area where development continues to encroach on dwindling mountain lion habitat.

CDFW's 2025 status review provides management and recovery action recommendations to prevent local extinction with the Southern California and Central Coast DPS, emphasizing the following overarching goals (CDFW, 2025):

- Maintaining and enhancing landscape connectivity between robust core populations and the smaller, more isolated populations within the proposed threatened Central Coast and Southern California DPS
- Protecting important patches of remaining habitat within the DPS from development and enhancing degraded habitats where feasible
- Reducing human-related mortality rates within the populations of the DPS

A subsequent EIR is needed to adequately assess and mitigate the Project's impacts to mountain lions and wildlife connectivity.

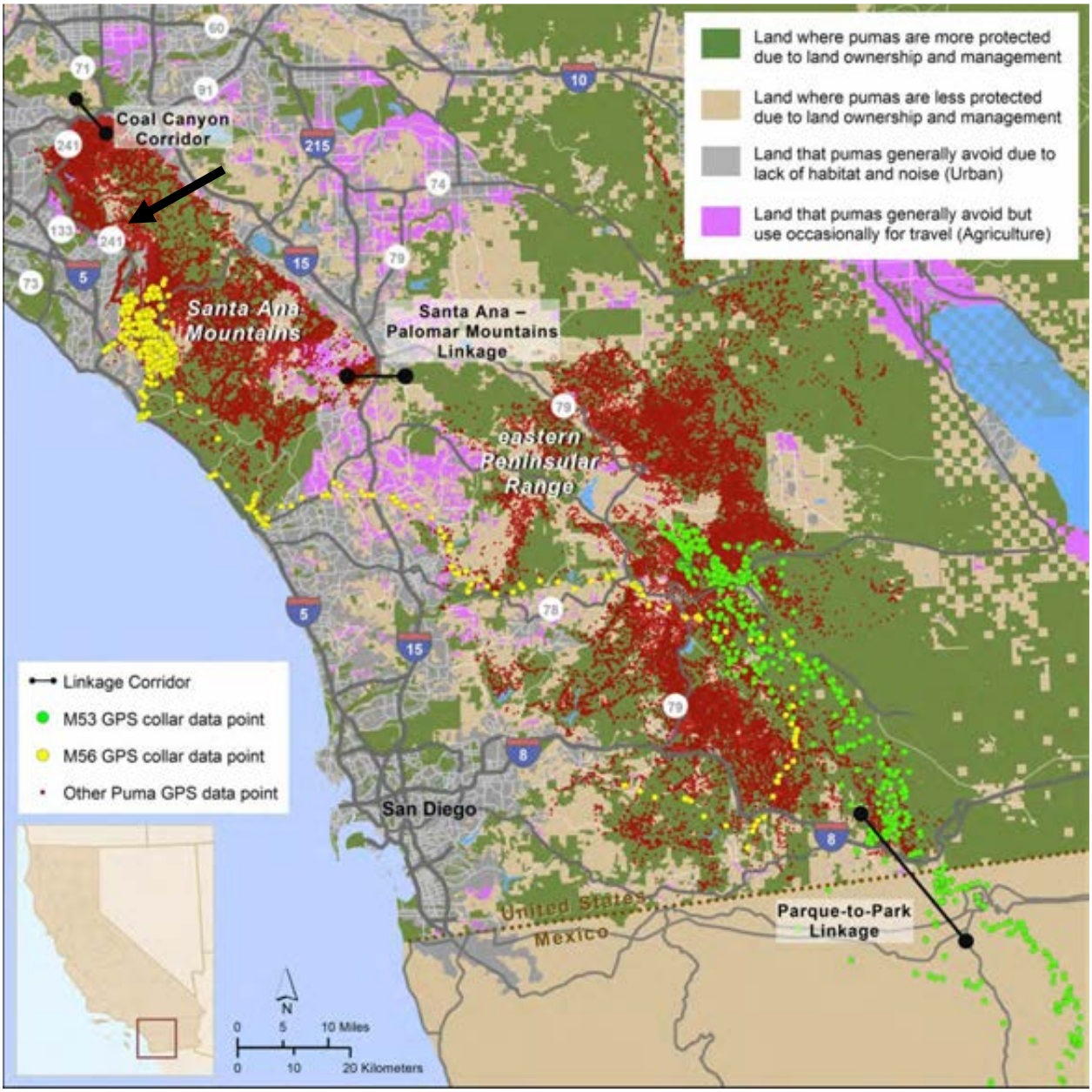

Figure 1. Puma GPS collar data points collected from 2001–2013 in southern California, USA. The black arrow indicates the Project location. The red, yellow, and green indicate locations where collared mountain lions have been documented. Source: Vickers et al., 2015.

As detailed in a 2021 Center Report (Yap et al., 2021), roads and development create barriers that lead to habitat loss and fragmentation, which harms native wildlife like mountain lions, plants, and people. As barriers to wildlife movement, poorly-planned development and roads can affect an animal's behavior, movement patterns, reproductive success, and physiological state, which can lead to significant impacts on individual wildlife, populations, communities, landscapes, and ecosystem function (Brehme et al., 2013; Ceia-Hasse et al., 2018; Haddad et al., 2015; Marsh & Jaeger, 2015). For example, habitat fragmentation from roads and

development has been shown to cause mortalities and harmful genetic isolation in mountain lions in Southern California and along the Central Coast (Ernest et al., 2014; Gustafson et al., 2021; Riley et al., 2014; Vickers et al., 2015), increase local extinction risk in amphibians and reptiles (Brehme et al., 2018; Cushman, 2006)., cause high levels of avoidance behavior and mortality in birds and insects (Benítez-López et al., 2010; Kantola et al., 2019; Loss et al., 2014), and alter pollinator behavior and degrade habitats (Aguilar et al., 2008; Goverde et al., 2002; Trombulak & Frissell, 2000).

Habitat loss and fragmentation also severely impacts plant communities. An 18-year study found that reconnected landscapes had nearly 14% more plant species compared to fragmented habitats, and that number is likely to continue to rise as time passes (Damschen et al., 2019). The authors conclude that efforts to preserve and enhance connectivity will pay off over the long-term (Damschen et al., 2019). In addition, connectivity is important to allow for range shifts and species migrations as climate changes (Cushman et al., 2013; Heller & Zavaleta, 2009; Krosby et al., 2018). Loss of wildlife connectivity decreases biodiversity and degrades ecosystems.

Edge effects like traffic, noise, light, and pollutants from Project construction and operation will have impacts on wildlife and wildlife movement in an area that is already constrained. This is important to consider when open space and connectivity enhancement projects are nearby, as numerous wildlife, including mountain lions (see discussion above), have been found to be sensitive to edge effects. New information regarding edge effects on other species have also come to light since the EIR was certified in 2002. For example, field observations and controlled laboratory experiments have shown that traffic noise can significantly degrade habitat value for migrating songbirds (Ware et al., 2015). Subjects exposed to 55 and 61 dBA (simulated traffic noise) exhibited decreased feeding behavior and duration, as well as increased vigilance behavior (Ware et al., 2015). Such behavioral shifts increase the risk of starvation, thus decreasing survival rates. Another study found a 28% decrease in bird abundance in areas when traffic noise was present compared to when there was no traffic noise (McClure et al., 2013). Negative edge effects of roads and development have been documented in wide-ranging predators, such as mountain lions and bobcats (Crooks, 2002; Lee et al., 2012; Riley et al., 2006; Serieys et al., 2021; J. A. Smith et al., 2015), as well as smaller species with poor dispersal abilities, such as song birds, small mammals, and herpetofauna (Benítez-López et al., 2010; Cushman, 2006; Delaney et al., 2010, 2021; Kociolek et al., 2011; Slabbekoorn & Ripmeester, 2008).

It is widely recognized that the continuing fragmentation of habitat by humans threatens biodiversity and diminishes our (humans, plants, and animals) ability to adapt to climate change. In a report for the International Union for Conservation of Nature (IUCN), world-renown scientists from around the world stated that "[s]cience overwhelmingly shows that interconnected protected areas and other areas for biological diversity conservation are much more effective than disconnected areas in human-dominated systems, especially in the face of climate change" and "[i]t is imperative that the world moves toward a coherent global approach for ecological connectivity conservation, and begins to measure and monitor the effectiveness of efforts to protect connectivity and thereby achieve functional ecological networks" (Hilty et al.,

2020). A subsequent EIR is needed to assess and mitigate the Project's impacts to mountain lions and wildlife connectivity.

III. New Information Regarding Wildfire Risk Necessitates a New EIR.

New information regarding the risk of building new large-scale development in fire zones has emerged since certification of the EIR in 2002, which necessitates preparation of a subsequent EIR. CEQA requires an EIR to identify and analyze a project's significant environmental impacts, including those impacts caused or exacerbated "by bringing development and people into the area affected." (Pub. Resources Code, §§ 21002, 21002.1, subd. (a); CEQA Guidelines, § 15126.2, subd. (a).) The impacts of development in areas prone to wildfire specifically require consideration: "the EIR should evaluate any potentially significant direct, indirect, or cumulative environmental impacts of locating development in areas susceptible to hazardous conditions (e.g., floodplains, coastlines, *wildfire risk areas*), including both short-term and long-term conditions, as identified in authoritative hazard maps, risk assessments or in land use plans addressing such hazard areas." (CEQA Guidelines, § 15126.2, subd. (a), emphasis added.)

A California Court of Appeal recently blocked development over wildfire concerns because the county failed to assess wildfire risk. (*See People ex rel. Bonta v. County of Lake* (2024) 105 Cal.App.5th 1222, 1235 [finding that EIR must sufficiently discuss the project's potential adverse effect of human-cause ignitions and analyze in some detail how the project's design or mitigation measures alleviates such risks, and lead agency failed to utilize industry standard modeling tools or appropriate methodologies for its conclusory findings]).

As detailed below, new research has emerged on the link between development and ignition risk in fire-prone areas; the impacts of climate change on wildfire risk; the social, public health and economic costs associated with fires in the wildland urban interface (WUI), the impacts of wildfires in the WUI on native wildlife; and the role of Indigenous communities historically and presently in wildfire management. The proposed Project is located in a "Very High Fire Hazard Severity Zone," as identified by the California Department of Forestry and Fire Protection (CalFire), where wildfires have burned in the past. A subsequent EIR is required to thoroughly analyze and mitigate the Project's impacts to wildfire risk and the aftermath of a wildfire when it burns through communities in and near the Project area. Analyses must include the area's fire history, the various ecosystems' fire ecology, and potential mitigation measures to reduce risk of fire ignition and spread within and adjacent to the Project area. Mitigation should also include adequate evacuation planning, support, and recovery should a wildfire occur.

A. Development in High Fire-prone Areas Increases Ignition Risk and Puts More People in Harm's Way.

Wildfires are a natural and necessary process in many of California's ecosystems, and many areas need beneficial fire to restore ecosystem health and cultural connection to the land. However, the last decade of unprecedented wildfires in the WUI has been devastating for people and wildlife. Poor land-use planning plays a primary role in destructive wildfire.

Since 2015 California wildfires have killed more than 230 people and destroyed more than 75,000 structures in the WUI. Hundreds of thousands of people have had to evacuate their homes and endure power outages, and millions have been exposed to unhealthy levels of smoke and toxic air, soil, and water pollution. Meanwhile costs for fire suppression, loss of life, medical expenses, property damage, and indirect economic losses are in the hundreds of billions of dollars.

On January 7, 2025 the world watched Los Angeles go up in flames. In a matter of just three days, fires killed at least 30 people, destroyed more than 16,000 structures, and burned more than 34,000 acres of shrublands and oak woodlands. Post-fire rains caused flooding, mudslides, and debris flows, which threatened communities and polluted nearby waters. Toxic debris plagues the landscape, with dangerously high levels of lead, arsenic, and other metals in soils within and near the fire footprint.

The Project would bring more development and human activity into fire-prone areas, thereby increasing ignition risk and endangering the lives of new residents and existing communities. Our collective understanding of wildfire risk has grown significantly since the EIR was certified in 2002, so the DSEIR must include an updated analysis of wildfire risk and mitigation of potential impacts.

According to a 2019 report from Governor Gavin Newsom's Office, construction of more homes in the WUI is one of the main factors that "magnify the wildfire threat and place substantially more people and property at risk than ever before" (Governor Newsom's Strike Force, 2019). Another 2019 study found that housing and human infrastructure in fire-prone wildlands are the main drivers of fire ignitions and structure loss (Syphard et al., 2019). Sprawl developments extending into habitats that are prone to fire have led to more frequent wildfires caused by human ignitions, like power lines, arson, improperly disposed cigarette butts, debris burning, fireworks, campfires, or sparks from cars or equipment (Alexandre et al., 2016; Balch et al., 2017; Bistinas et al., 2013; Keeley & Syphard, 2018; Radeloff et al., 2018; Syphard, Rustigian-Romsos, et al., 2019).

Almost all destructive wildfires are ignited by humans or human infrastructure near roads and development (Balch et al., 2024; Chen & Jin, 2022; Syphard, Rustigian-Romsos, et al., 2019). For example, the 2018 Camp and Woolsey fires and 2017 Tubbs and Thomas fires were sparked by powerlines or electrical equipment and the 2017 Carr fire was caused by car sparks. And although still under investigation, embers from a previous fire ignited by fireworks is suspected to have caused the Palisades Fire and a spark from a Southern California Edison powerline likely caused the Eaton Fire. All of these fires are in the top 20 most destructive wildfires in California history. Placing more homes and people in high fire-prone areas will increase the potential likelihood of these ignition sources, as has been documented in multiple scientific studies (Balch et al., 2017; Bistinas et al., 2013; Keeley & Syphard, 2018; Radeloff et al., 2018; Syphard et al., 2007; Syphard, Rustigian-Romsos, et al., 2019).

A 2019 study discusses a poignant and cautionary example: the 2017 Tubbs Fire and the 1964 Hanly Fire had very similar burned area footprints, yet the Tubbs fire burned over 5500

structures and killed at least 22 people while the 1964 Hanly Fire only burned about 100 structures and no one died (Keeley & Syphard, 2019). The authors suggest that the increased population and human infrastructure in the area led to an increased chance of human-caused ignitions during an extreme wind event (the Tubbs fire was caused by faulty electrical equipment on private property) and the sprawl development over the decades since 1964 put more people at risk (Keeley & Syphard, 2019). Such an example should be a glaring warning to the County's decisionmakers when development is being proposed in a high fire-prone area where wildfires have previously burned, like the proposed Project. Wildfire experts are now constantly and unambiguously pointing out the dangers of placing communities in fire-prone areas.

Most destruction to human communities from fire has been caused by wind-driven, human-ignited fires in mixed shrublands and grasslands (Balch et al., 2024; Radeloff et al., 2023). Although the winds do not ignite the fires, ignitions in the WUI often coincide with strong wind events (Abatzoglou et al., 2018; Hantson et al., 2022; Mietkiewicz et al., 2020). Almost always ignited by humans and human infrastructure in dry shrublands and grasslands, these wildfires spread quickly and are difficult to contain during windy conditions, which amplifies their negative impacts to people and ecosystems (Hantson et al., 2022).

The three most destructive wildfires in California history were driven by wind. Earlier this year, the Eaton Fire burned more than 10,000 acres within just 16 hours of ignition, damaging more than 9,000 structures and killing at least 19 people. The Palisades Fire burned more than 17,000 acres in the first 36 hours of ignition and resulted in almost 7,000 structures burning and at least 12 people dying. And in 2018 the Camp Fire burned more than 50,000 acres in its first day, eventually becoming California's deadliest and most destructive wildfire, killing 85 people and destroying almost 19,000 structures.

The Project will bring more people and increased human activity into fire-prone landscapes and will therefore increase ignition risk. Such a project requires addressing that there is a combination of factors driving destructive wildfires in the WUI. California's landscape and climate are conducive to fire, poor land-use planning fuels more destructive wildfire, and climate change is increasing extreme weather conditions and wildfire risk. These factors must be considered in a subsequent EIR to adequately assess the Project's impacts to wildfire risk. Analyses must also include the area's fire history, the various ecosystems' fire ecology, and potential mitigation measures to reduce risk of fire ignition and spread within and adjacent to the Project area. Mitigation should also include adequate evacuation planning, support, and recovery should a wildfire occur. The 2002 EIR was certified before recent studies outlining the risk of building in fire zones were available, and before year-round wildfires became the "new normal" in California. A subsequent EIR is required.

B. Recent Scientific Studies Reveal Climate Change is Amplifying Wildfire Risk.

The 2002 EIR lacks new information regarding how progressively hotter, drier conditions and more extreme weather events due to climate change are making it easier for wildfires to ignite and spread (Barnes et al., 2025). Climate change is exacerbating extreme weather conditions and wildfire impacts (Williams et al., 2019). The number of days with extreme fire weather conditions in California has doubled since 1980, and further climate change will amplify

that trend (Goss et al., 2020). Hotter and drier conditions combined with later and shorter rainy seasons are making the landscape more conducive to wildfire ignitions and spread while lengthening the fire season (Dong et al., 2022; Goss et al., 2020; Luković et al., 2021; Ma et al., 2021; Madakumbura, Moritz, et al., 2025; Madakumbura, Thackeray, et al., 2025; Swain, 2021).

Experts claim that climate change is responsible for intensifying what would have already been extreme fires in Altadena and Pacific Palisades. Two very wet years in a row (winters of 2022-2023 and 2023-2024) contributed about 10% of vegetation on the landscape, and the following uncharacteristically hot summer, a record-breaking fall heatwave, and a very dry start to the rainy season likely made the vegetation 25% drier (Madakumbura, Thackeray, et al., 2025). Combined with extreme seasonal winds and human ignitions, the Eaton and Palisades fires ravaged unexpecting communities. Experts estimated that the hotter, drier conditions and extreme fire weather due to climate change made these devastating fires 35% more likely and 6% more intense (Barnes et al., 2025). Continued climate change and increasing fire conditions will lead to more intense and more destructive wildfires (Barnes et al., 2025; MacDonald et al., 2023).

Researchers have also found that fires are spreading faster. Between 2001 and 2020 the maximum daily growth rate of wildfires in the U.S. more than doubled, and California fires grew almost 400% faster (Balch et al., 2024). Experts suggest that this trend could be due to warming temperatures, habitat conversion to more flammable vegetation (i.e., nonnative grasses), and/or the co-occurrence of high winds with increasing human-related ignitions (Balch et al., 2024).

Scientists predict that climate change will continue trends of hotter and drier conditions and shorter rainy seasons, which will increase the flammability of vegetation, lengthen the fire season, increase extreme fire weather, heighten wildfire risk, and lead to more intense wildfires (Barnes et al., 2025; MacDonald et al., 2023). This must be considered in a new EIR.

C. Traditional Ecological Knowledge and Indigenous Science Must be Considered in Wildfire Analyses.

A subsequent EIR must adequately analyze the area's historical fire regimes and the role Indigenous communities likely played in shaping the fire ecology of habitats in and adjacent to the Project area. Indigenous communities should be included in discourse over climate change and wildfire. They are disproportionately impacted by wildfire. Native Americans were found to be six times more likely than other groups to live in high fire-prone areas, and high vulnerability due to socioeconomic barriers makes it more difficult for these communities to recover after a large wildfire (Davies et al., 2018). In addition, farmworkers, who are majority people of color and often include migrant workers that come from Indigenous communities, often have less access to healthcare due to immigration or economic status. They are more vulnerable to the health impacts of poor air quality due to increased exposure to air pollution as they work. Yet farmworkers often have to continue working while fires burn, and smoke fills the air, or risk not getting paid (Herrera, 2018; Kardas-Nelson et al., 2020; Parshley, 2018).

Ramos (2022) states, "Indigenous communities have often been marginalized in the sciences through research approaches that are not inclusive of their cultures and histories."

Traditional ecological knowledge ("TEK") is often excluded from analyses or distilled to conform to Western science (Ramos, 2022). EIRs, like this one, often fail to acknowledge that Indigenous communities and cultural burning played a role in California's historical fire activity and often only mention previous wildfires in the area in CalFire records. This perpetuates the exclusion and marginalization of Indigenous communities and TEK. Consultation with local Native Tribes and incorporation of Indigenous science, including but not limited to oral histories, ethnographies (that may include burn scars and charcoal records), and archeological data should be incorporated in fire history analysis. As a society, we need to work towards integrative research that "transcends disciplinary boundaries" and employs a range of methodological options to get a deeper understanding of the relationship between people and ecosystems (Ramos, 2022). Doing so will help inform fire management strategies and mitigation measures that work towards reducing harms of wildfire to people while facilitating beneficial fire for the appropriate ecosystems.

D. Wildfires in the WUI Threaten Vulnerable Wildlife.

The 2002 EIR fails to consider wildfire impacts to vulnerable species. Wildfires are a natural and necessary process in many of California's ecosystems, and many areas need beneficial fire to restore ecosystem health and cultural connection to the land. However, the last decade of unprecedented wildfires in the wildland urban interface ("WUI") are pushing fragmented populations of sensitive species to the brink. Wildlife, including genetically isolated mountain lions, remnant populations of frogs and fish, resident and migratory birds, nearby marine life, and more are all vulnerable to direct and indirect impacts from wildfire. They can suffer burns, smoke-induced asphyxiation, heat stress, traumatic injuries, and death (Garcês & Pires, 2023).

For example, two mountain lion deaths in the Santa Monica Mountains were attributed to the 2018 Woolsey Fire. Although mountain lions are highly mobile and generally able to move away from wildfires, these lions were unable to escape to safety because they were boxed in by roads and development. In addition, researchers found that after a large wildfire in an urbanized region, mountain lions avoided burn areas and increased risky behavior that could lead to more conflict with people, increased mortality, and extinction risk (Blakey et al., 2022). Such deaths can further destabilize small mountain lion populations that are already facing numerous other threats, including low genetic diversity, vehicle strikes and rodenticide poisoning, and make them more vulnerable to local extinction (Benson et al., 2016, 2019).

Smoke inhalation from wildfires can lead to negative health effects, like carbon monoxide poisoning, damage to lung tissue, and weakened immune response, in both terrestrial and aquatic wildlife (Sanderfoot et al., 2021). Smoke exposure can also cause shifts in animal behavior and stress levels, which could influence short- and long-term health and survival (Sanderfoot et al., 2021). One study found that increased smoke exposure led to decreased body condition (i.e., lower body mass) of wild birds in California, which suggests that they expend more energy while coping with sub-lethal health effects of smoke exposure (Nihei et al., 2024).

Heavy rains after wildfire can trigger landslides and debris flows that threaten small populations of sensitive, less mobile species that have been diminished due to habitat loss and

fragmentation from sprawl development, dams, disease, non-native predators, and other threats. After the 2020 Bobcat Fire, biologists were desperate to rescue remnant populations of yellow-legged frogs, Santa Ana suckers, unarmored threespine stickleback fish, speckled dace, arroyo chub and arroyo chub because they were concerned that post-fire debris flows due to winter rains would wipe out their populations in the fire zone (Sahagun, 2020). Biologists conducted similar rescue missions for the last-known populations of Southern California steelhead and northern tidewater gobies in the Santa Monica Mountains after the 2025 Palisades Fire (Seidman, 2025a, 2025b, 2025c).

Historically, these species would have been able to recolonize from neighboring populations after the loss of individuals or populations to fire impacts. Unfortunately, that ability is now limited by the species' currently small and fragmented population structure. Continued alteration of historical fire regimes due to sprawl development will further endanger remnant populations.

Devastation caused by wildfire in the WUI is far-reaching and long-lasting. We have yet to uncover the full extent of harm such wildfires due to wildlife and the habitats they rely on, but it is certain that careless land use planning and policy are causing death and destruction in the natural world. A subsequent EIR must adequately assess and mitigate the Project's impacts on wildfire risk and how increased ignitions will impact biological resources.

E. Wildfires in the WUI Harm People.

The 2002 EIR fails to adequately consider wildfire impacts to human health and safety. When wildfires burn through communities, they threaten homes, livelihoods, lives, and health. In addition to the immediate impacts of lives and homes lost, evacuations and displacement, impacts from air pollution, soil contamination, lost jobs, and the trauma of escape and recovery extend well beyond the fire footprint and last long after the fire is extinguished. Impacts to wildlife are also potentially long-lasting. The Project will bring more people and increased human activity into fire-prone landscapes and increase ignition risk. Such a project requires careful and comprehensive analyses of the Project's impacts to public health and evacuation safety due to increasing ignition risk. In addition, an EIR must provide potential mitigation measures to reduce risk of ignition and fire within and adjacent to the Project area and spreading to nearby communities.

i. Wildfire Crises Overburden Wildfire Protection Services and Threaten Public Safety.

New projects in fire-prone areas must consider the additional burden on local agencies to protect communities from wildfire. Local governments and the wildfire protection services they provide can become overwhelmed during crises.

An after action review of the 2018 Woolsey Fire, which resulted in three deaths and more than 1,600 structures destroyed in Los Angeles and Ventura counties, identified that the responding agencies were "overwhelmed" by the fire's "speed and weight of impact" and lacked sufficient trained staff, clear policies and protocols, crisis communication, inter-agency and inter-

jurisdictional collaboration, situational awareness, real-time data availability with coordinated response tools, emergency preparedness, and evacuation plans (Citygate Associates, 2019). According to the review, "the size and speed of the Woolsey Fire, at times, outpaced the early efforts of some of the largest and most experienced and capable agencies in the United States" (Citygate Associates, 2019). The review also highlights the need to manage the public's "unrealistic expectations" of agency abilities to protect communities from fire, stating, "[w]e cannot expect that all population growth in Very High or High Fire Hazard Severity areas can be protected simply by increasing resiliency [hardening buildings, fuels treatment, and vegetation management] to wildfire and by adding more fire engines" (Citygate Associates, 2019).

These issues are widespread. They have come up in other wildfire disasters throughout the state that have occurred, including the 2017 Tubbs Fire (County of Sonoma, 2018) and 2018 Camp Fire (Constant Associates, 2020). Despite these reports on lessons learned from fires that occurred seven years ago, the County of Los Angeles and likely many other counties have failed to make the necessary improvements. This is evident with the response to the Eaton and Palisades fires. The County was plagued with the same problems as previous fires, which led to fatal errors and destruction (Jarvie, 2025; McChrystal Group, 2025). Lack of funding, insufficient staffing, unclear and outdated evacuation protocols, limited firefighting resources, insufficient communications and alerts, and more resulted in the death of at least 31 people, the destruction of more than 17,000 structures, and the loss and upheaval of many communities that will be recovering for years to come.

Despite these reports on lessons learned from fires that occurred seven years ago, the County of Los Angeles and likely many other counties have failed to make the necessary improvements. This is evident with the response to the Eaton and Palisades fires. The County was plagued with the same problems as previous fires, which led to fatal errors and destruction (Jarvie, 2025; McChrystal Group, 2025). Lack of funding, insufficient staffing, unclear and outdated evacuation protocols, limited firefighting resources, insufficient communications and alerts, and more resulted in the death of at least 31 people, the destruction of more than 17,000 structures, and the loss and upheaval of many communities that will be recovering for years to come.

ii. Wildfires Impact Human Health.

When wildfires burn through communities, they threaten homes, livelihoods, lives, and health. In addition to the immediate impacts of lives and homes lost, evacuations and displacement, impacts from air pollution, soil contamination, lost jobs, and the trauma of escape and recovery extend well beyond the fire footprint and last long after the fire is extinguished. Impacts to wildlife are also potentially long-lasting. Impacts of wildfire disproportionately affect vulnerable communities with less adaptive capacity to respond to and recover from hazards like wildfire. Low-income and minority communities, especially Native American, Black, Latinx, and Southeast Asian communities, are the most marginalized groups when wildfires occur (Davies et al., 2018).

Those in at-risk populations (*e.g.*, low-income, elderly, disabled, non-English-speaking, unhoused) often have limited resources for disaster planning and preparedness (Richards, 2019).

Vulnerable groups also have fewer resources to have cars to evacuate, buy fire insurance, implement fire-resilient retrofits, maintain defensible space around their homes, or rebuild, and they have less access to disaster relief during recovery (Davis, 2018; Fothergill & Peak, 2004; Harnett, 2018; Morris, 2018; Ong, Pech, Frasure, et al., 2025; Richards, 2019; Vives & Castillo, 2025). And survivors are left without resources to cope with the death of loved ones, physical injuries and emotional trauma from the chaos that wildfires have inflicted on their communities.

Emergency services often miss at-risk individuals when disasters happen because of limited capacity or language constraints (Richards, 2019). This was the case for both the Palisades and Eaton fires. Many elderly and disabled community members unable to evacuate on their own were left stranded as the wildfires advanced, and the median age of those who died in the fires was 77 (Ellis, 2025; Jarvie et al., 2025). Meanwhile, delayed evacuation alerts and limited fire trucks in western Altadena, a predominantly Black and Latino neighborhood, resulted in 18 of the 19 deaths from the wildfire (Castleman, 2025; Ellis & Greene, 2025; Toohey & Jarvie, 2025).

In the aftermath of wildfires and other environmental disasters, news stories have repeatedly documented the lack of multilingual evacuation warnings leaving non-English speakers in danger (Axelrod, 2017; Banse, 2018; Gerety, 2015; Ong, Pech, Ong, et al., 2025; Richards, 2019). This was exemplified during the Eaton and Palisades fires; evacuation alerts were only sent in English and Spanish, leaving more than 12,000 Asian Americans with limited English proficiency in the evacuation zones without potentially life-saving information (Ong, Pech, Ong, et al., 2025).

Health impacts from wildfires can have both acute and long-term health effects that disproportionately affect vulnerable populations, like children, the elderly, pregnant women and fetuses, those with underlying chronic disease, low-income communities, and communities of color. A recent study found that wildfire smoke now accounts for up to 50% of ambient fine particle pollution ($PM_{2.5}$) in the western United States (Burke et al., 2021).

Increased exposure to fine particulates in wildfire smoke has been linked with increased hospital visits for respiratory symptoms (*e.g.*, asthma, acute bronchitis, pneumonia, or chronic obstructive pulmonary disease) and cardiovascular symptoms (*e.g.*, congestive heart failure, ischemic heart disease, and myocardial infarction) (Delfino et al., 2009; Künzli et al., 2006; Liu et al., 2015; Rappold et al., 2012; Reid et al., 2016; Viswanathan et al., 2006). It has also been linked to higher rates of dementia (B. Zhang et al., 2023; Z. Zhang et al., 2023). And experts have also found that greater exposure to wildfire smoke and excessive heat during the month before conception and the first trimester of pregnancy is linked with greater risk of both short- and long-term health problems (Evans et al., 2022; Khalili et al., 2025). Researchers estimated that between 2008 and 2018 more than 50,000 premature deaths were caused by California wildfire smoke (Connolly et al., 2024). As climate change intensifies, scientists predicted that wildfire smoke could cause approximately 700,000 excess deaths between 2025-2055 (Qiu et al., 2025).

Wildfires in the WUI can lead to other harmful public health impacts due to increased exposure to toxic contaminants from burned buildings, cars, electronics, and more. Buildings and

infrastructure often contain plastic materials, heavy metals, benzene, and carcinogenic gases. These toxic chemicals pose a threat in the burn area and they can travel long distances.

During the 2018 Camp Fire that burned 19,000 structures, the smoke caused dangerously high levels of air pollution in the Sacramento Valley and Bay Area and the California Air Resources Board found that high levels of heavy metals like lead and zinc traveled more than 150 miles (CARB, 2021). And unsafe levels of lead, arsenic, and other dangerous metals have been documented in and downwind of the Eaton and Palisades fire footprints (Champlin, 2025; Smith & Briscoe, 2025).

Families living or working in or near the burn area also risk increased exposure to hazardous chemicals. After the Eaton Fire, some families with no other options returned to live in homes deemed "uninhabitable" by insurance companies, surrounded by toxic debris (Vives & Castillo, 2025). Almost 50% of schools where students had returned to in the Pasadena Unified School District had elevated levels of lead and arsenic in their soils due to toxic ash, which can have damaging effects on the nervous system, cardiovascular system, and kidneys (Haggerty & Briscoe, 2025). And farmworkers often have to continue working while fires burn and pollutants fill the air, or risk not getting paid (Herrera, 2018; Kardas-Nelson et al., 2020; Parshley, 2018). Wildfire victims have also had to deal with lack of funding and support for cleanup as well as improper cleanup, "adding to the trauma" they have already endured (Briscoe, 2025; Briscoe et al., 2025).

Service workers also face increased risk. Firefighters are suffering disproportionately high rates of cancer and other serious diseases (Dreier, 2025; Hwang et al., 2023; Johnson & Lam, 2023) as well as mental health issues due to extended fire seasons and working extended shifts away from their families (Ashton et al., 2018; Bransford et al., 2018; Del Real & Kang, 2018; Greene, 2018; Gutierrez, 2018; Simon, 2018). And firefighters who fought blazes in the LA wildfires had high levels of lead and mercury in their blood, (Hernandez, 2025). Fire cleanup workers also risk increased exposure to harmful chemicals; they often do not use appropriate protective gear as they remove toxic debris from the burn area (Haggerty, 2025).

Scientists are continuing to uncover the devastating health impacts of wildfires in the WUI. In a study that included more than 1,100 participants that were affected by the 2023 wildfires in Maui, Hawai'i, researchers found that six to 14 months after the wildfires more than 20% of participants had reduced lung function and almost 50% had clinical symptoms of depression (Juarez et al., 2025). The majority of participants reported food insecurity, economic hardship, and displacement due to the wildfires (Juarez et al., 2025), and in the month of the wildfires, the suicide and overdose rate doubled (Purtle et al., 2025). Other experts attributed more than 400 additional deaths to the LA wildfires, likely due to poor air quality, delays in health care, and other factors (Paglino et al., 2025).

Science unequivocally shows that California wildfires in the WUI are increasing negative health impacts within and beyond their footprint. Proper analyses and mitigation of the Project's impacts on wildfire ignition, wildfire spread, and the negative health impacts associated with wildfire are needed. A subsequent EIR is needed to analyze and mitigate these impacts.

iii. Guaranteed Wildfire Insurance for New Residents and Owners is Needed.

California is facing an insurance crisis. Many private insurers are leaving California or otherwise refusing to insure homes built in the wildland-urban interface (like the Proposed Project), and this has resulted in an addition of approximately one half of a *trillion* dollars of added assets being "covered" under California's FAIR Plan, which was designed to be a wildfire insurance of last resort for homeowners otherwise unable to obtain coverage (and is owned and managed by the State) (Saleh, 2025). In turn, this has caused a major uptick in premiums on the State's FAIR Plan, which has led some homeowners to forego wildfire insurance altogether. (*Id*.) And many of the homeowners that have been able to retain private wildfire insurance have been unable to actually be reimbursed through their insurers' claims process (Overland, 2025 [discussing litigation filed by victims of the recent fires in Los Angeles against their insurer for failing to pay out valid claims resulting from those fires]).

A subsequent EIR should therefore analyze whether the residences contemplated will be insurable through private insurers or will require access to the California FAIR Plan and what each home's premium ought to be. (*Laurel Heights Improvement Assn.*, 47 Cal. 3d at 392.) In undertaking that analysis, the Project proponent must also take into account that many private insurers have a documented practice of underinsuring homes when contracting for wildfire insurance, and that this practice of underinsurance has resulted in many homeowners receiving far less than their home's worth from their insurer after their homes are destroyed by wildfire (Neilson, 2025). Moreover, the RPFSEIR should include a mitigation measure requiring the Project proponent to financially cover the wildfire insurance for the homes being sold or otherwise disclose accurate and helpful information regarding the availability of private or public wildfire insurance, the costs thereof, and the risks inherent in obtaining such insurance and, more importantly, in foregoing to do so when advertising and selling the residences contemplated under the Proposed Project and Specific Plan. (14 C.C.R. § 15021(a).) In fact, the State is working on preparing and publishing a tool that would help facilitate that process (Rahim, 2025).

F. More Ignitions Due to Development in Fire Zones Increases Firefighting and Economic Costs and Strain on Firefighters.

The 2002 EIR fails to consider the impacts of wildfire on firefighters and costs. As noted above, the vast majority of wildfires in California are ignited by people in poorly-planned development in high fire prone areas (Balch et al., 2017; Keeley & Syphard, 2018). More development in high fire hazard areas will increase ignitions and associated fire suppression, damage, and recovery costs. is also harming firefighters' health and well-being. A subsequent EIR is needed to analyze and mitigate these impacts.

The 2002 EIR lacks new information regarding how more development in fire-prone areas will necessitate significant firefighting costs from both state and local authorities. The California Department of Forestry and Fire (CalFire) is primarily responsible for addressing wildfires when they occur, and its costs have continued to increase as wildfires in the wildland-urban interface have grown more destructive. The cost of fire suppression in areas managed by CalFire has skyrocketed from $114 million in the 2000-2001 fiscal year to close to $3 billion for the 2020-2021 and 2021-2022 fiscal years combined (CalFire 2022). The Legislative Analyst's

Office (LAO) reported that CalFire used an estimated $3.3 billion for wildfire protection and suppression in the 2022-2023 fiscal year (LAO 2023). This does not include the cost of lives lost, property damages, or clean up.

Economic costs of wildfires are also skyrocketing. Researchers found that the 2018 California wildfires, which included the Camp Fire that burned through Paradise and the Woolsey Fire that burned through Ventura and Santa Barbara, resulted in $148.5 billion in in capital losses, health costs related to air pollution exposure, and indirect losses due to broader economic disruption cascading along regional and national supply chains (D. Wang et al., 2021). Experts estimate the costs of the 2025 Los Angeles fires could be between $250 and $275 billion when considering damage to homes, businesses, and infrastructure and the costs of health impacts, evacuation, cleanup and recovery, and economic losses (Danielle, 2025). Costs could continue to rise as we learn more about the extent of the damage and the long-term impacts of exposure to toxic air pollutants, contaminated waters and soils, and the trauma of fleeing wildfires and/or losing homes, schools, and communities.

Climate change is increasing extreme weather and fire conditions, which, in combination with poorly planned development, has led to more ignitions and longer fire seasons that are increasing strain on over-burdened firefighters and first responders. According to Captain Michael Feyh of the Sacramento Fire Department, California no longer has a fire season (Simon, 2018); wildfires in California are now year-round because of increased human ignitions in fire-prone areas. Emergency calls to fire departments have tripled since the 1980s (Gutierrez & Cassidy, 2018), and firefighters (and equipment) are being spread thin throughout the state. Firefighters often work 24- to 36-hour shifts for extended periods of time (often weeks at a time), and are being kept away from their homes and families for more and more days out of the year (Ashton et al., 2018; Bransford et al., 2018; Del Real & Kang, 2018; Greene, 2018; Gutierrez, 2018; Simon, 2018). In addition, the firefighting force often must rely on volunteers to battle fires year-round. At its peak, more than 16,000 firefighters from the U.S., Canada, and Mexico, including from prison systems, were combatting the 2025 LA wildfires.

The extended fire season is taking a toll on the physical, mental, and emotional health of firefighters, as well as the emotional health of their families (Ashton et al., 2018; Del Real & Kang, 2018; Simon, 2018). As mentioned above, wildland firefighters are suffering disproportionately high rates of cancer and other serious diseases, likely due to extreme smoke exposure (Hwang et al., 2023; Johnson & Lam, 2023). For those fighting urban conflagrations, exposure to hazardous pollutants are even higher. In a preliminary study conducted on firefighters who fought the LA wildfires, lead and mercury blood levels were five and three times higher compared to firefighters who fought vegetation wildfires (Hernandez, 2025). In addition, the physical and mental fatigue of endlessly fighting fires and experiencing trauma can lead to exhaustion, which can cause mistakes in life-or-death situations while on duty, and the constant worry and aftermath that family members endure when their loved ones are away working in life-threatening conditions can be harrowing (Ashton et al., 2018). According to psychologist Dr. Nancy Bohl-Penrod, the strain of fighting fires without having sufficient breaks can impact firefighters' interactions with their families, their emotions, and their personalities (Bransford et al., 2018). There have also been reports that suicide rates and substance abuse have increased among firefighters (Cart, 2022; Greene, 2018; Simon, 2018).

IV. Conclusion

As outlined above, the County is required under CEQA to prepare a subsequent EIR given the substantial new information and changes in potential impacts to mountain lions, wildlife connectivity, and wildfire risk since the EIR was certified in 2002. We respectfully urge the County to postpone the issuance of any use permits on the Project unless and until a new EIR is prepared that thoroughly analyzes the Project's impacts on mountain lions, wildlife connectivity, and wildfire risk.

Please add the Center to your notice list for all future updates to the Project, using the contact information below, and do not hesitate to contact the Center with any questions.

Sincerely,

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References (submitted via OneDrive)

Abatzoglou, J. T., Balch, J. K., Bradley, B. A., & Kolden, C. A. (2018). Human-related ignitions concurrent with high winds promote large wildfires across the USA. *International Journal of Wildland Fire*, *27*(6), 377.

Aguilar, R., Quesada, M., Ashworth, L., Herrerias-Diego, Y., & Lobo, J. (2008). Genetic consequences of habitat fragmentation in plant populations: Susceptible signals in plant traits and methodological approaches. *Molecular Ecology*, *17*, 5177–5188.

Alexandre, P. M., Stewart, S. I., Keuler, N. S., Clayton, M. K., Mockrin, M. H., Bar-Massada, A., Syphard, A. D., & Radeloff, V. C. (2016). Factors related to building loss due to wildfires in the conterminous United States. *Ecological Applications*, *26*(7), 2323–2338.

Allen, M. L., Wittmer, H. U., Houghtaling, P., Smith, J., Elbroch, L. M., & Wilmers, C. C. (2015). The role of scent marking in mate selection by female pumas (Puma concolor). *PLoS ONE*, *10*(10), e0139087–e0139087.

Allen, M. L., Yovovich, V., & Wilmers, C. C. (2016). Evaluating the responses of a territorial solitary carnivore to potential mates and competitors. *Scientific Reports*, *6*.

Anderson, K. (2018). The Use of Fire by Native Americans in California. In J. W. Van Wagtendonk, N. G. Sugihara, S. L. Stephens, A. E. Thode, K. E. Shaffer, & J. A. Fites-Kaufman (Eds.), *Fire in California's Ecosystems*.

Ashton, A., Lillis, R., & Ramirez, W. (2018, August). 249 nights away at California fires: Firefighter families cope with a 'new normal.' *The Sacramento Bee*.

Axelrod, J. (2017, December). California Wildfires Spark Issues of Bilingual Emergency Communications. *American City and County*.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Nagy, R. C., Fusco, E. J., & Mahood, A. L. (2017). Human-started wildfires expand the fire niche across the United States. *Proceedings of the National Academy of Sciences*, *114*(11), 2946–2951.

Balch, J. K., Iglesias, V., Mahood, A. L., Cook, M. C., Amaral, C., DeCastro, A., Leyk, S., McIntosh, T. L., Nagy, R. C., St. Denis, L., Tuff, T., Verleye, E., Williams, A. P., & Kolden, C. A. (2024). The fastest-growing and most destructive fires in the US (2001 to 2020). *Science*, *386*(6720), 425–431.

Banse, T. (2018, April). How Do You Say 'Evacuate' in Tagalog? In a Disaster, English Isn't Always Enough. *Northwest Public Broadcasting*.

Barnes, C., Keeping, T., Madakumbura, G., Abatzoglou, J. T., Williams, P., AghaKhouchak, A., Pinto, I., Thompson, V., Vautard, R., Lampe, S., Thiery, W., Pietroiusti, R., Otto, F. E. L., Vahlberg, M., Singh, R., Lambrou, N., Blakely, E., Zhu, Y., Li, J., … Arrighi, J. (2025). *Climate change increased the likelihood of wildfire disaster in highly exposed Los Angeles area* (p. 59).

Barrientos, R., Vickers, W., Longcore, T., Abelson, E. S., Dellinger, J., Waetjen, D. P., Fandos, G., & Shilling, F. M. (2023). Nearby night lighting, rather than sky glow, is associated with habitat selection by a top predator in human-dominated landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *378*(1892), 20220370.

Barry, J. M., Elbroch, L. M., Aiello-lammens, M. E., Sarno, R. J., Seelye, L., Kusler, A., & Quigley, H. B. (2019). Pumas as ecosystem engineers: Ungulate carcasses support beetle assemblages in the Greater Yellowstone Ecosystem. *Oecologia*, *189*, 577–586.

Benítez-López, A., Alkemade, R., & Verweij, P. A. (2010). The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. *Biological Conservation*, *143*, 1307–1316.

Benson, J. F., Dougherty, K. D., Beier, P., Boyce, W. M., Cristescu, B., Gammons, D. J., Garcelon, D. K., Higley, J. M., Martins, Q. E., Nisi, A. C., Riley, S. P. D., Sikich, J. A., Stephenson, T. R., Vickers, T. W., Wengert, G. M., Wilmers, C. C., Wittmer, H. U., & Dellinger, J. A. (2023). The ecology of human-caused mortality for a protected large carnivore. *Proceedings of the National Academy of Sciences*, *120*(13), e2220030120.

Benson, J. F., Mahoney, P. J., Sikich, J. A., Serieys, L. E. K., Pollinger, J. P., Ernest, H. B., & Riley, S. P. D. (2016). Interactions between demography, genetics, and landscape connectivity increase extinction probability for a small population of large carnivores in a major metropolitan area. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1837), 20160957–20160957.

Benson, J. F., Mahoney, P. J., Vickers, T. W., Sikich, J. A., Beier, P., Riley, S. P. D., Ernest, H. B., & Boyce, W. M. (2019). Extinction vortex dynamics of top predators isolated by urbanization. *Ecological Applications*, *29*(3), e01868–e01868.

Benson, J. F., Mahoney, P. J., Vickers, T. W., Sikich, J. A., Beier, P., Riley, S. P. D., Ernest, H. B., & Boyce, W. M. (2020). Conserving ecological roles of top predators in isolated mountains. *Ecological Applications*, *30*, e02029–e02029.

Benson, J. F., Sikich, J. A., & Riley, S. P. D. (2020). Survival and competing mortality risks of mountain lions in a major metropolitan area. *Biological Conservation*, *241*, 108294–108294.

Bistinas, I., Oom, D., Sá, A. C. L., Harrison, S. P., Prentice, I. C., & Pereira, J. M. C. (2013). Relationships between human population density and burned area at continental and global scales. *PLoS ONE*, *8*(12), 1–12.

Blakey, R. V., Sikich, J. A., Blumstein, D. T., & Riley, S. P. D. (2022). Mountain lions avoid burned areas and increase risky behavior after wildfire in a fragmented urban landscape. *Current Biology*, *32*(21), 4762-4768.e5.

Bohlman, G. N., Underwood, E. C., & Safford, H. D. (2018). Estimating Biomass in California's Chaparral and Coastal Sage Scrub Shrublands. *Madroño*, *65*(1), 28–46.

Bolas, E. C., Pingatore, A. D., Mathur, M., Blumstein, D. T., Sikich, J. A., Smith, J. A., Benson, J. F., Riley, S. P. D., & Blakey, R. V. (2025). Human recreation influences activity of a large carnivore in an urban landscape. *Biological Conservation*, *301*, 110812.

Bransford, S., Medina, J., & Del Real, J. A. (2018, July). Firefighters Reflect on a Job Now 'Twice as Violent'. *The New York Times*.

Brehme, C. S., Hathaway, S. A., & Fisher, R. N. (2018). An objective road risk assessment method for multiple species: Ranking 166 reptiles and amphibians in California. *Landscape Ecology*, *33*, 911–935.

Brehme, C. S., Tracey, J. A., Clenaghan, L. R. M. C., & Fisher, R. N. (2013). Permeability of roads to movement of scrubland lizards and small mammals. *Conservation Biology*, *27*(4), 710–720.

Burke, M., Driscoll, A., Xue, J., Heft-Neal, S., Burney, J., & Wara, M. (2021). The changing risk and burden of wildfire in the United States. *Proceedings of the National Academy of Sciences*, *118*(2), e2011048118–e2011048118.

CARB. (2021). *Camp Fire Air Quality Data Analysis*.

CARB. (2022). *2022 Progress Report California's Sustainable Communities and Climate Protection Act*. California Air Resources Board.

Cart, J. (2022, June 13). Trial by fire: The trauma of fighting California's wildfires. *Cal Matters*. https://calmatters.org/series/california-firefighters-trauma-wildfires/

Castleman, T. (2025, July 22). Six months after LA's firestorms, the remains ofa 31st victim are found in Altadena. *LA Times*.

Cayan, D. R., DeHaan, L. L., Gershunov, A., Guzman-Morales, J., Keeley, J. E., Mumford, J., & Syphard, A. D. (2022). Autumn precipitation: The competition with Santa Ana winds in determining fire outcomes in southern California. *International Journal of Wildland Fire*, *31*(11), 1056–1067.

CDFW. (2025). *A Status Review of the Petitioned Southern California/Central Coast Evolutionarily Significant Unit (ESU) of Mountain Lion (Puma concolor cougar) in California*. California Department of Fish and Wildlife.

Ceia-Hasse, A., Navarro, L. M., Borda-de-Água, L., & Pereira, H. M. (2018). Population persistence in landscapes fragmented by roads: Disentangling isolation, mortality, and the effect of dispersal. *Ecological Modelling*, *375*, 45–53.

Champlin, C. (2025, April 11). The Eaton Fire hit Caltech scientists close to home. Now, they're studying the toxic aftermath. *KQED*. https://www.kqed.org/news/12035344/the-eaton-fire-hit-caltech-scientists-close-to-home-now-theyre-studying-the-toxic-aftermath

Chen, B., & Jin, Y. (2022). Spatial patterns and drivers for wildfire ignitions in California. *Environmental Research Letters*, *17*(5), 055004.

Climate Action Tracker. (2023). *Warming Projections Global Update*.

Connolly, R., Marlier, M. E., Garcia-Gonzales, D. A., Wilkins, J., Su, J., Bekker, C., Jung, J., Bonilla, E., Burnett, R. T., Zhu, Y., & Jerrett, M. (2024). Mortality attributable to PM 2.5 from wildland fires in California from 2008 to 2018. *Science Advances*, *10*(23), eadl1252. https://doi.org/10.1126/sciadv.adl1252

Crooks, K. R. (2002). Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation Biology*, *16*(2), 488–502.

Cushman, S. A. (2006). Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological Conservation*, *128*, 231–240.

Cushman, S. A., McRae, B., Adriaensen, F., Beier, P., Shirley, M., & Zeller, K. (2013). Biological corridors and connectivity. In D. W. Macdonald & K. J. Willis (Eds.), *Key Topics in Conservation Biology 2* (First Edition, pp. 384–403). John Wiley & Sons, Ltd.

Cuthrell, R. Q. (2013). Archaeobotanical Evidence for Indigenous Burning Practices and Foodways at CA-SMA-113. *California Archaeology*, *5*(2), 265–290.

Damschen, E. I., Brudvig, L. A., Burt, M. A., Jr, R. J. F., Haddad, N. M., Levey, D. J., Orrock, J. L., Resasco, J., & Tewksbury, J. J. (2019). Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment. *Science*, *365*(6460), 1478–1480.

Danielle, M. (2025, January 16). AccuWeather estimates more than $250 billion in damages and economic loss from LA wildfires. *Accuweather*.

Davies, I. P., Haugo, R. D., Robertson, J. C., & Levin, P. S. (2018). The unequal vulnerability of communities of color to wildfire. *PLoS ONE*, *13*(11), 1–15.

Davis, M. (2018, December). A tale of two wildfires: Devastation highlights California's stark divide. *The Guardian*.

Del Real, J. A., & Kang, I. (2018, July). California Today: The Increasing Strain on State Firefighters. *The New York Times*. https://www.nytimes.com/2018/07/30/us/california-today-firefighters.html

Delaney, K. S., Busteed, G., Fisher, R. N., & Riley, S. P. D. (2021). Reptile and Amphibian Diversity and Abundance in an Urban Landscape: Impacts of Fragmentation and the Conservation Value of Small Patches. *Ichthyology and Herpetology*, *109*(2), 424–435.

Delaney, K. S., Riley, S. P. D., & Fisher, R. N. (2010). A rapid, strong, and convergent genetic response to urban habitat fragmentation in four divergent and widespread vertebrates. *PLoS ONE*, *5*(9), e12767.

Delfino, R. J., Brummel, S., Wu, J., Stern, H., Ostro, B., Lipsett, M., Winer, A., Street, D. H., Zhang, L., Tjoa, T., & Gillen, D. L. (2009). The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. *Occupational and Environmental Medicine*, *66*(3), 189–197.

Dickson, B. G., & Beier, P. (2002). Home-range and habitat selection by adult cougars in Southern California. *The Journal of Wildlife Management*, *66*(4), 1235–1245.

Dickson, B. G., Jennes, J. S., & Beier, P. (2005). Influence of Vegetation, Topography, and Roads on Cougar Movement in Southern California. *Journal of Wildlife Management*, *69*(1), 264–276.

Dong, C., Williams, A. P., Abatzoglou, J. T., Lin, K., Okin, G. S., Gillespie, T. W., Long, D., Lin, Y.-H., Hall, A., & MacDonald, G. M. (2022). The season for large fires in Southern California is projected to lengthen in a changing climate. *Communications Earth & Environment*, *3*, 1–10.

Dougherty, K. D., Dellinger, J. A., Cristescu, B., Gammons, D. J., Garcelon, D. K., Higley, J. M., Martins, Q. E., Riley, S. P. D., Sikich, J. A., Stephenson, T. R., Vickers, T. W., Wengert, G. M., Wilmers, C. C., Wittmer, H. U., & Benson, J. F. (2025). A Functional Response in Resource Selection Links Multiscale Responses of a Large Carnivore to Human Mortality Risk. *Ecology Letters*, *28*(1), e70035.

Dreier, H. (2025, August 17). Wildfire Fighters, Unmasked in Toxic Smoke, Are Getting Sick and Dying. *The New York Times*.

Elbroch, L. M., O'Malley, C., Peziol, M., & Quigley, H. B. (2017). Vertebrate diversity benefiting from carrion provided by pumas and other subordinate, apex felids. *Biological Conservation*, *215*, 123–131.

Ellis, R. (2025, January 22). Many residents with disabilities can't flee fires on their own. *LA Times*.

Ellis, R., & Greene, S. (2025, July 23). A Times Investigation: As west Altadena burned, LA county fire trucks stayed elsewhere. *LA Times*.

Ernest, H. B., Vickers, T. W., Morrison, S. A., Buchalski, M. R., & Boyce, W. M. (2014). Fractured genetic connectivity threatens a Southern California puma (Puma concolor) population. *PLoS ONE*, *9*(10).

Evans, J., Bansal, A., Schoenaker, D. A. J. M., Cherbuin, N., Peek, M. J., & Davis, D. L. (2022). Birth Outcomes, Health, and Health Care Needs of Childbearing Women following Wildfire Disasters: An Integrative, State-of-the-Science Review. *Environmental Health Perspectives*, *130*(8). https://ehp.niehs.nih.gov/doi/10.1289/EHP10544

Fothergill, A., & Peak, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural Hazards*, *34*, 89–110.

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Bakker, D. C. E., Hauck, J., Landschützer, P., Le Quéré, C., Luijkx, I. T., Peters, G. P., Peters, W., Pongratz, J., Schwingshackl, C., Sitch, S., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S. R., Anthoni, P., … Zheng, B. (2023). Global Carbon Budget 2023. *Earth System Science Data*, *15*(12), 5301–5369. https://doi.org/10.5194/essd-15-5301-2023

Friedrich, J., Ge, M., Pickens, A., & Vigna, L. (2023). *This Interactive Chart Shows Changes in the World's Top 10 Emitters*. World Resources Institute.

Gerety, R. M. (2015, September). Farm Workers in Wildfire Areas Aren't Always Aware of Evacuation Plans. *National Public Radio Morning Edition*.

Goss, M., Swain, D. L., Abatzoglou, J. T., Sarhadi, A., Kolden, C. A., Williams, A. P., & Diffenbaugh, N. S. (2020). Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. *Environmental Research Letters*, *15*.

Goverde, M., Schweizer, K., Baur, B., & Erhardt, A. (2002). Small-scale habitat fragmentation effects on pollinator behaviour: Experimental evidence from the bumblebee Bombus veteranus on calcareous grasslands. *Biological Conservation*, *104*, 293–299.

Governor Newsom's Strike Force. (2019). *Wildfires and Climate Change: California's Energy Future*.

Greene, D. (2018, August). California Firefighters Battle Exhaustion. *National Public Radio*. https://www.npr.org/2018/08/08/636603563/california-firefighters-battle-exhaustion

Gustafson, K. D., Gagne, R. B., Buchalski, M. R., Vickers, T. W., Riley, S. P. D., Sikich, J. A., Rudd, J. L., Dellinger, J. A., LaCava, M. E. F., & Ernest, H. B. (2021). Multi-population puma connectivity could restore genomic diversity to at-risk coastal populations in California. *Evolutionary Applications*.

Gustafson, K. D., Gagne, R. B., Vickers, T. W., Riley, S. P. D., Wilmers, C. C., Bleich, V. C., Pierce, B. M., Kenyon, M., Drazenovich, T. L., Sikich, J. A., Boyce, W. M., & Ernest, H. B. (2018). Genetic source–sink dynamics among naturally structured and anthropogenically fragmented puma populations. *Conservation Genetics*, *20*(2), 215–227.

Gutierrez, M. (2018, July). California blazes tax budgets, firefighters: 'Fatigue is starting to set in'. *SFChronicle*. https://www.sfchronicle.com/california-wildfires/article/California-blazes-tax-budgets-firefighters-13121282.php

Gutierrez, M., & Cassidy, M. (2018, August). As California burns, volunteer firefighters become harder to find. *SFChronicle*. https://www.sfchronicle.com/california-wildfires/article/As-California-burns-volunteer-firefighters-13148559.php?psid=1dxrO

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C. N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2), e1500052.

Hantson, S., Andela, N., Goulden, M. L., & Randerson, J. T. (2022). Human-ignited fires result in more extreme fire behavior and ecosystem impacts. *Nature Communications*, *13*(1), 2717.

Harnett, S. (2018, September). Low-Income Communities Struggle to Recover After a Wildfire. *KQED*.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, *142*, 14–32.

Hernández, D. L., Vallano, D. M., Zavaleta, E. S., Tzankova, Z., Pasari, J. R., Weiss, S., Selmants, P. C., & Morozumi, C. (2016). Nitrogen Pollution Is Linked to US Listed Species Declines. *BioScience*, *66*(3), 213–222.

Hernandez, S. (2025, March 27). Palisades and Eaton firefighters had elevated levels of mercury, lead in their blood. *LA Times*.

Herrera, J. (2018, November). As Wildire Smoke Fills the Air, Farmworkers Continue to Labor in the Fields. *Pacific Standard*.

Hilty, J. A., Worboys, G., Keeley, A., Woodley, S., Lausche, B., Locke, H., Carr, M., Pulsford, I., Pittock, J., White, W., Theobald, D., Levine, J., Reuling, M., Watson, J., Ament, R., & Tabor, G. (2020). *Guidelines for conserving connectivity through ecological networks and corridors*. International Union for Conservation of Nature.

Huffmeyer, A. A., Sikich, J. A., Vickers, T. W., Riley, S. P. D., & Wayne, R. K. (2021). First reproductive signs of inbreeding depression in Southern California male mountain lions (Puma concolor). *Theriogenology*, *177*, 157–164.

Hwang, J., Chong, N.-S., Zhang, M., Agnew, R. J., Xu, C., Li, Z., & Xu, X. (2023). Face-to-face with scorching wildfire: Potential toxicant exposure and the health risks of smoke for wildland firefighters at the wildland-urban interface. *The Lancet Regional Health - Americas*, *21*, 100482.

IPCC. (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*.

IPCC. (2023). *Climate Change 2023: Synthesis Report*.

Jarvie, J., Castleman, T., & Lin, S. (2025, March 29). Elderly, disabled were left stranded during LA fires as evacuation plans broke down. *LA Times*.

Johnson, J., & Lam. (2023, August 29). California's wildland firefighters are being poisoned by smoke. And we're doing little to protect them. *San Francisco Chronicle*. https://www.sfchronicle.com/projects/2023/firefighter-health/

Juarez, R., Phankitnirundorn, K., Ozorio Dutra, S. V., Bond-Smith, D., Lee, A. G., & Maunakea, A. K. (2025). Health and Social Support in the Aftermath of the Maui Wildfires. *JAMA Network Open*, *8*(8), e2525430.

Kantola, T., Tracy, J. L., Baum, K. A., Quinn, M. A., & Coulson, R. N. (2019). Spatial risk assessment of eastern monarch butterfly road mortality during autumn migration within the southern corridor. *Biological Conservation*, *231*, 150–160.

Kardas-Nelson, M., Alvarenga, J., & Tuirán, R. A. (2020, October). Farmworkers forced to put harvest over health during wildfires. *Investigate West*.

Keeley, J. E. (2005). Fire history of the San Francisco East Bay region and implications for landscape patterns. *International Journal of Wildland Fire*, *14*(3), 285–296.

Keeley, J. E. (2006). Fire management impacts on invasive plants in the western United States. *Conservation Biology*, *20*(2), 375–384. https://doi.org/10.1111/j.1523-1739.2006.00339.x

Keeley, J. E., Flannigan, M., Brown, T. J., Rolinski, T., Cayan, D., Syphard, A. D., Guzman-Morales, J., & Gershunov, A. (2024). Climate and weather drivers in southern California Santa Ana Wind and non-Santa Wind fires. *International Journal of Wildland Fire*, *33*(8).

Keeley, J. E., Franklin, J., & D'Antonio, C. (2011). Fire and Invasive Plants on California Landscapes. In D. McKenzie, C. Miller, & D. A. Falk (Eds.), *The Landscape Ecology of Fire*. Springer.

Keeley, J. E., & Syphard, A. D. (2018). Historical patterns of wildfire ignition sources in California ecosystems. *International Journal of Wildland Fire*, *27*(12), 781–781.

Keeley, J. E., & Syphard, A. D. (2019). Twenty-first century California, USA, wildfires: Fuel-dominated vs. Wind-dominated fires. *Fire Ecology*, *15*(24).

Kertson, B. N., Spencer, R. D., Marzluff, J. M., Hepinstall-Cymerman, J., & Grue, C. E. (2011). Cougar space use and movements in the wildland—Urban landscape of western Washington. *Ecological Applications*, *21*(8), 2866–2881.

Khalili, R., Liu, Y., Xu, Y., O'Sharkey, K., Pavlovic, N., McClure, C., Lurmann, F., Yang, T., Chen, X., Vigil, M., Grubbs, B., Al Marayati, L., Lerner, D., Lurvey, N., Marsit, C. J., Johnston, J., Bastain, T. M., Breton, C. V., Farzan, S. F., & Habre, R. (2025). Adverse Birth Outcomes Associated with Heat Stress and Wildfire Smoke Exposure During Preconception and Pregnancy. *Environmental Science & Technology*, *59*(25), 12458–12471.

Kimmerer, R. W., & Lake, F. K. (2001). The role of indigenous burning in land management. *Journal of Forestry*, *99*(11), 36–41.

Kociolek, A. V., Clevenger, A. P., St. Clair, C. C., & Proppe, D. S. (2011). Effects of Road Networks on Bird Populations. *Conservation Biology*, *25*(2), 241–249.

Koteen, L. E., Baldocchi, D. D., & Harte, J. (2011). Invasion of non-native grasses causes a drop in soil carbon storage in California grasslands. *Environmental Research Letters*, *6*.

Krosby, M., Theobald, D. M., Norheim, R., & McRae, B. H. (2018). Identifying riparian climate corridors to inform climate adaptation planning. *PLoS ONE*, *13*(11), e0205156.

Künzli, N., Avol, E., Wu, J., Gauderman, W. J., Rappaport, E., Millstein, J., Bennion, J., McConnell, R., Gilliland, F. D., Berhane, K., Lurmann, F., Winer, A., & Peters, J. M. (2006). Health effects of the 2003 Southern California wildfires on children. *American Journal of Respiratory and Critical Care Medicine*, *174*, 1221–1228.

Labarge, L. R., Planck, M., Behavior, A., & Elbroch, L. M. (2022). Pumas Puma concolor as ecological brokers: A review of their biotic relationships. *Mammal Review*.

Lee, J. S., Ruell, E. W., Boydston, E. E., Lyren, L. M., Alonso, R. S., Troyer, J. L., Crooks, K. R., & Vandewoude, S. (2012). Gene flow and pathogen transmission among bobcats (Lynx rufus) in a fragmented urban landscape. *Molecular Ecology*, *21*(7), 1617–1631.

Liu, J. C., Pereira, G., Uhl, S. A., Bravo, M. A., & Bell, M. L. (2015). A systematic review of the physical health impacts from non- occupational exposure to wildfire smoke. *Environmental Research*, *136*, 120–132. https://doi.org/10.1016/j.envres.2014.10.015.A

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *Journal of Wildlife Management*, *78*, 763–771.

Lucas, E. (2020). Recreation-related disturbance to wildlife in California-better planning for and management of recreation are vital to conserve wildlife in protected areas where recreation occurs. *California Fish and Wildlife, Recreation Special Issue*, 29–51.

Luković, J., Chiang, J. C. H., Blagojević, D., & Sekulić, A. (2021). A Later Onset of the Rainy Season in California. *Geophysical Research Letters*, *48*(4), e2020GL090350.

Ma, W., Zhai, L., Pivovaroff, A., Shuman, J., Buotte, P., Ding, J., Christoffersen, B., Knox, R., Moritz, M., Fisher, R. A., Koven, C. D., Kueppers, L., & Xu, C. (2021). Assessing

climate change impacts on live fuel moisture and wildfire risk using a hydrodynamic vegetation model. *Biogeosciences*, *18*(13), 4005–4020.

MacDonald, G., Wall, T., Enquist, C. A. F., LeRoy, S. R., Bradford, J. B., Breshears, D. D., Brown, T., Cayan, D., Dong, C., Falk, D. A., Fleishman, E., Gershunov, A., Hunter, M., Loehman, R. A., Van Mantgem, P. J., Middleton, B. R., Safford, H. D., Schwartz, M. W., & Trouet, V. (2023). Drivers of California's changing wildfires: A state-of-the-knowledge synthesis. *International Journal of Wildland Fire*, *32*(7), 1039–1058.

Maclean, I. M. D., & Wilson, Robert. J. (2011). Recent ecological responses to climate change support predictions of high extinction risk. *Proceedings of the National Academy of Sciences*, *108*(30), 12337–12342.

Madakumbura, G. D., Moritz, M. A., McKinnon, K. A., Williams, A. P., Rahimi, S., Bass, B., Norris, J., Fu, R., & Hall, A. (2025). Anthropogenic warming drives earlier wildfire season onset in California. *Science Advances*, *11*.

Madakumbura, G. D., Thackeray, C., Hall, A., Williams, P., Norris, J., & Sukhdeo, R. (2025). *Climate Change A Factor In Unprecedented LA Fires*. UCLA.

Marsh, D. M., & Jaeger, J. A. G. (2015). Direct effects of roads on small animal populations. In *Roads and ecological infrastructure: Concepts and applications for small animal* (pp. 42–56).

Matzek, V., Lewis, D., O'Geen, A., Lennox, M., Hogan, S. D., Feirer, S. T., Eviner, V., & Tate, K. W. (2020). Increases in soil and woody biomass carbon stocks as a result of rangeland riparian restoration. *Carbon Balance and Management*, *15*(16), 1–15.

McClure, C. J. W., Ware, H. E., Carlisle, J., Kaltenecker, G., & Barber, J. R. (2013). An experimental investigation into the effects of traffic noise on distributions of birds: Avoiding the phantom road. *Proceedings of the Royal Society B: Biological Sciences*, *280*.

Mietkiewicz, N., Balch, J. K., Schoennagel, T., Leyk, S., St. Denis, L. A., & Bradley, B. A. (2020). In the Line of Fire: Consequences of Human-Ignited Wildfires to Homes in the U.S. (1992–2015). *Fire*, *3*(3), 50. https://doi.org/10.3390/fire3030050

Morris, B. (2018, April). *How the Ultra-Wealthy are Making Themselves Immune to Natural Disasters*.

National Academy of Sciences & Royal Society. (2020). *Climate Change: Evidence and Causes: Update 2020* (p. 25733). National Academies Press. https://doi.org/10.17226/25733

Nickel, B. A., Suraci, J. P., Allen, M. L., & Wilmers, C. C. (2020). Human presence and human footprint have non-equivalent effects on wildlife spatiotemporal habitat use. *Biological Conservation*, *241*, 108383–108383.

Nickel, B. A., Suraci, J. P., Nisi, A. C., & Wilmers, C. C. (2021). Energetics and fear of humans constrain the spatial ecology of pumas. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(5), 1–8.

Nisi, A. C., Benson, J. F., King, R., & Wilmers, C. C. (2023). Habitat fragmentation reduces survival and drives source–sink dynamics for a large carnivore. *Ecological Applications*, *33*(4), e2822.

Nisi, A. C., Benson, J. F., & Wilmers, C. C. (2022). Puma responses to unreliable human cues suggest an ecological trap in a fragmented landscape. *Oikos*, *2022*(5), e09051.

Ong, P., Pech, C., Frasure, L., Comandur, S., Lee, E., & González, S. R. (2025). *LA Wildfires: Impacts on Altadena's Black Community*. UCLA Ralph J. Bunche Center.

Ong, P., Pech, C., Ong, J., de La Cruz-Viesca, M., Gonzalez, S. R., & Enzo Morales, B. (2025). *Data Brief: Asian American Language Needs in LA Wildfires*. UCLA.

Paglino, E., Raquib, R. V., & Stokes, A. C. (2025). Excess deaths attributable to the Los Angeles wildfires from Jan 5 to Feb 1, 2025. *JAMA*.

Parshley, L. (2018, December). The Lingering Effects of Wildfires Will Disproportionately Hurt People of Color. *Vice*, 1–11.

Phuleria, H. C., Fine, P. M., Zhu, Y., & Sioutas, C. (2005). Air quality impacts of the October 2003 Southern California wildfires. *Journal of Geophysical Research*, *110*. https://doi.org/10.1029/2004JD004626

Purtill, C., & Xia, R. (2025, January 29). LA fires wreaked havoc on land. Scientists are racing to learn what they've done to the sea. *LA Times*.

Purtle, J., Machavariant, E., Rivera-Gonzalez, A. C., Mauri, A. I., Stimpson, J. P., Kaholokula, J. K., & Ortega, A. N. (2025). Increases in suicides and overdoses during the 2023 wildfires in Maui. *JAMA*.

Radeloff, V. C., Helmers, D. P., Kramer, H. A., Mockrin, M. H., Alexandre, P. M., Bar-Massada, A., Butsic, V., Hawbaker, T. J., Martinuzzi, S., Syphard, A. D., & Stewart, S. I. (2018). Rapid growth of the US wildland-urban interface raises wildfire risk. *Proceedings of the National Academy of Sciences*, *115*(13), 3314–3319.

Radeloff, V. C., Mockrin, M. H., Helmers, D., Carlson, A., Hawbaker, T. J., Martinuzzi, S., Schug, F., Alexandre, P. M., Kramer, H. A., & Pidgeon, A. M. (2023). Rising wildfire risk to houses in the United States, especially in grasslands and shrublands. *Science*, *382*(6671), 702–707.

Ramos, S. C. (2022). Understanding Yurok traditional ecological knowledge and wildlife management. *The Journal of Wildlife Management*, 1–21.

Rappold, A. G., Cascio, W. E., Kilaru, V. J., Stone, S. L., Neas, L. M., Devlin, R. B., & Diaz-Sanchez, D. (2012). Cardio-respiratory outcomes associated with exposure to wildfire smoke are modified by measures of community health. *Environmental Health: A Global Access Science Source*, *11*(71). https://doi.org/10.1186/1476-069X-11-71

Reid, C. E., Brauer, M., Johnston, F. H., Jerrett, M., Balmes, J. R., & Elliott, C. T. (2016). Critical review of health impacts of wildfire smoke. *Environmental Health Perspectives*, *124*(9), 1334–1343.

Reid-Wainscoat, E., Rose, J. P., Yap, Tiffany A., & Prabhala, A. (2024). *The True Cost of Sprawl: Bad Planning Harms People, Wildlife and the Climate*. Center for Biological Diversity.

Richards, R. (2019, July). After the Fire: Vulnerable Communities Respond and Rebuild. *Center for American Progress*.

Riley, S. P. D., Pollinger, J. P., Sauvajot, R. M., York, E. C., Bromley, C., Fuller, T. K., & Wayne, R. K. (2006). A southern California freeway is a physical and social barrier to gene flow in carnivores. *Molecular Ecology*, *15*, 1733–1741.

Riley, S. P. D., Serieys, L. E. K., Pollinger, J. P., Sikich, J. A., Dalbeck, L., Wayne, R. K., & Ernest, H. B. (2014). Individual behaviors dominate the dynamics of an urban mountain lion population isolated by roads. *Current Biology*, *24*(17), 1989–1994.

Ripple, W. J., & Beschta, R. L. (2006). Linking a cougar decline , trophic cascade , and catastrophic regime shift in Zion National Park. *Biological Conservation*, *133*, 397–408.

Ripple, W. J., & Beschta, R. L. (2008). Trophic cascades involving cougar, mule deer, and black oaks in Yosemite National Park. *Biological Conservation*, *141*, 1249–1256.

Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D., & Wirsing, A. J. (2014). Status and ecological effects of the world's largest carnivores. *Science*, *343*, 1241484–1241484.

Ruth, T. K., & Elbroch, L. M. (2014). The carcass chronicles: Carnivory, nutrient flow, and biodiversity. *Wild Felid Monitor*, 14–19.

Safford, H. D., & Van de Water, K. M. (2014). Using Fire Return Interval Departure (FRID) analysis to map spatial and temporal changes in fire frequency on National Forest lands in California. *Pacific Southwest Research Station - Research Paper PSW-RP-266*, *January*, 1–59.

Sahagun, L. (2020, November). Rescue operations underway in the San Gabriel Mountains for rare species marooned by wildfire. *Los Angeles Times*, *2020*.

Seidman, L. (2025a, January 23). Hundreds of endangered fish rescued from Palisades burn area—In the nick of time. *LA Times*.

Seidman, L. (2025b, February 1). Nearly 300 trout rescued from Palisades Fire burn scar. *LA Times*.

Seidman, L. (2025c, June 18). Endangered fish saved from the Palisades fire were just returned to their Malibu home. *LA Times*.

Serieys, L. E. K., Rogan, M. S., Matsushima, S. S., & Wilmers, C. C. (2021). Road-crossings, vegetative cover, land use and poisons interact to influence corridor effectiveness. *Biological Conservation*, *253*, 108930–108930.

Shin, Y., Midgley, G. F., Archer, E. R. M., Arneth, A., Barnes, D. K. A., Chan, L., Hashimoto, S., Hoegh-Guldberg, O., Insarov, G., Leadley, P., Levin, L. A., Ngo, H. T., Pandit, R., Pires, A. P. F., Pörtner, H., Rogers, A. D., Scholes, R. J., Settele, J., & Smith, P. (2022). Actions to halt biodiversity loss generally benefit the climate. *Global Change Biology*, *28*(9), 2846–2874. https://doi.org/10.1111/gcb.16109

Simon, S. (2018, August). Constant Wildfires Leave California Firefighters Strained. *National Public Radio*.

Slabbekoorn, H., & Ripmeester, E. A. P. (2008). Birdsong and anthropogenic noise: Implications and applications for conservation. *Molecular Ecology*, *17*, 72–83.

Smith, H., & Briscoe, T. (2025, April 11). LA County soil testing near Eaton, Palisades fires shows significant contamination. *LA Times*.

Smith, J. A., Duane, T. P., & Wilmers, C. C. (2019). Moving through the matrix: Promoting permeability for large carnivores in a human-dominated landscape. *Landscape and Urban Planning*, *183*, 50–58.

Smith, J. A., Suraci, J. P., Clinchy, M., Crawford, A., Roberts, D., Zanette, L. Y., & Wilmers, C. C. (2017). Fear of the human 'super predator' reduces feeding time in large carnivores. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1857), 20170433.

Smith, J. A., Wang, Y., & Wilmers, C. C. (2015). Top carnivores increase their kill rates on prey as a response to human-induced fear. *Proceedings of the Royal Society B: Biological Sciences*, *282*, 20142711.

Stephens, S. L., Martin, R. E., & Clinton, N. E. (2007). Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands. *Forest Ecology and Management*, *251*(3), 205–216.

Suraci, J. P., Clinchy, M., Zanette, L. Y., & Wilmers, C. C. (2019). Fear of humans as apex predators has landscape-scale impacts from mountain lions to mice. *Ecology Letters*, *22*(10), 1578–1586.

Swain, D. L. (2021). A Shorter, Sharper Rainy Season Amplifies California Wildfire Risk. *Geophysical Research Letters*, *48*(5), e2021GL092843.

Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2018). Chaparral Landscape Conversion in Southern California. In *Valuing Chaparral* (pp. 323–346).

Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2019). Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. *Diversity and Distributions*, *25*, 90–101.

Syphard, A. D., Radeloff, V. C., Hawbaker, T. J., & Stewart, S. I. (2009). Conservation threats due to human-caused increases in fire frequency in mediterranean-climate ecosystems. *Conservation Biology*, *23*(3), 758–769.

Syphard, A. D., Radeloff, V. C., Keeley, J. E., Hawbaker, T. J., Clayton, M. K., Stewart, S. I., Hammer, R. B., Syphard, A. D., Radeloff, V. C., Keeley, J. E., Hawbaker, T. J., Stewart, S. I., & Hammer, R. B. (2007). Human influence on California fire regimes. *Ecological Society of America*, *17*(5), 1388–1402.

Syphard, A. D., Rustigian-Romsos, H., Mann, M., Conlisk, E., Moritz, M. A., & Ackerly, D. (2019). The relative influence of climate and housing development on current and projected future fire patterns and structure loss across three California landscapes. *Global Environmental Change*, *56*, 41–55.

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., de Siqueira, M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Peterson, A. T., Phillips, O. L., & Williams, S. E. (2004). Extinction risk from climate change. *Nature*.

Toohey, G., & Jarvie, J. (2025, May 21). Signs point to human error in Altadena evacuation failure—Los Angeles Times.pdf. *LA Times*.

Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, *14*(1), 18–30.

Turco, M., Abatzoglou, J. T., Herrera, S., Zhuang, Y., Jerez, S., Lucas, D. D., AghaKouchak, A., & Cvijanovic, I. (2023). Anthropogenic climate change impacts exacerbate summer forest fires in California. *Proceedings of the National Academy of Sciences*, *120*(25), e2213815120.

Urban, M. C. (2015). Accelerating extinction risk from climate change. *Science*, *348*(6234), 571–573. https://doi.org/10.1126/science.aaa4984

US Environmental Protection Agency. (2021). *Climate Adaptation Action Plan*.

US Global Change Research Program. (2023). *Fifth National Climate Assessment*.

Vickers, T. W., Sanchez, J. N., Johnson, C. K., Morrison, S. A., Botta, R., Smith, T., Cohen, B. S., Huber, P. R., Ernest, H. B., & Boyce, W. M. (2015). Survival and mortality of pumas (Puma concolor) in a fragmented, urbanizing landscape. *PLoS ONE*, *10*(7), 1–18.

Viswanathan, S., Eria, L., Diunugala, N., Johnson, J., & Mc Clean, C. (2006). An analysis of effects of San Diego wildfire on ambient air quality. *Journal of the Air and Waste Management Association*, *56*(1), 56–67.

Vives, R., & Castillo, A. (2025, March 20). Their homes survived Eaton fire. But living there has been hell, residents say. *LA Times*.

Wang, D., Guan, D., Zhu, S., Kinnon, M. M., Geng, G., Zhang, Q., Zheng, H., Lei, T., Shao, S., Gong, P., & Davis, S. J. (2021). Economic footprint of California wildfires in 2018. *Nature Sustainability*, *4*, 252–260.

Wang, Y., Smith, J. A., & Wilmers, C. C. (2017). Residential development alters behavior, movement, and energetics in a top carnivore. *PlosOne*, *12*(10), e0184687.

Ware, H. E., Mcclure, C. J. W., Carlisle, J. D., & Barber, J. R. (2015). A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. *Proceedings of the National Academy of Sciences*, *112*(39), 12105–12109.

Weinhold, B. (2011). Fields and forests in flames: Vegetation smoke and human health. *Environmental Health Perspectives*, *119*(9), A386–A393.

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., Hyde, K. J. W., Morelli, T. L., Morisette, J. T., Muñoz, R. C., Pershing, A. J., Peterson, D. L., Poudel, R., Staudinger, M. D., Sutton-Grier, A. E., Thompson, L., Vose, J., Weltzin, J. F., & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Science of The Total Environment*, *733*, 137782.

Wiens, J. J. (2016). Climate-related local extinctions are already widespread among plant and animal species. *PLoS Biology*, *14*(12), 1–18.

Williams, A. P., Abatzoglou, J. T., Gershunov, A., Guzman-Morales, J., Bishop, D. A., Balch, J. K., & Lettenmaier, D. P. (2019). Observed impacts of anthropogenic climate change on wildfire in California. *Earth's Future*, *7*, 892–910.

Wilmers, C. C., Nisi, A. C., & Ranc, N. (2021). COVID-19 suppression of human mobility releases mountain lions from a landscape of fear. *Current Biology*, *31*(17), 3952-3955.e3. https://doi.org/10.1016/j.cub.2021.06.050

Wilmers, C. C., Wang, Y., Nickel, B., Houghtaling, P., Shakeri, Y., Allen, M. L., Kermish-Wells, J., Yovovich, V., & Williams, T. (2013). Scale dependent behavioral responses to human development by a large predator, the puma. *PLoS ONE*, *8*(4).

Yap, T. A., Prabhala, A., & Anderson, I. (2023). *Hidden in Plain Sight: California's Native Habitats are Valuable Carbon Sinks*. Center for Biological Diversity.

Yap, T. A., Rose, J. P., Anderson, I., & Prabhala, A. (2021). *California Connections: How Wildlife Connectivity Can Fight Extinction and Protect Public Safety*.

Yovovich, V., Allen, M. L., Macaulay, L. T., & Wilmers, C. C. (2020). Using spatial characteristics of apex carnivore communication and reproductive behaviors to predict responses to future human development. *Biodiversity and Conservation*, *29*(8), 2589–2603.

Zeller, K. A., Vickers, T. W., Ernest, H. B., & Boyce, W. M. (2017). Multi-level, multi-scale resource selection functions and resistance surfaces for conservation planning: Pumas as a case study. *PLoS ONE*, *12*(6), 1–20.

Zhang, B., Weuve, J., Langa, K. M., D'Souza, J., Szpiro, A., Faul, J., Mendes De Leon, C., Gao, J., Kaufman, J. D., Sheppard, L., Lee, J., Kobayashi, L. C., Hirth, R., & Adar, S. D. (2023). Comparison of Particulate Air Pollution From Different Emission Sources and Incident Dementia in the US. *JAMA Internal Medicine*.

Zhang, Z., Chen, L., Wang, X., Wang, C., Yang, Y., Li, H., Cai, M., & Lin, H. (2023). Associations of Air Pollution and Genetic Risk With Incident Dementia: A Prospective Cohort Study. *American Journal of Epidemiology*, *192*(2), 182–194.

APPEAL EXHIBIT C

ADVERTISEMENT

CALIFORNIA

How climate change is fueling record-breaking California wildfires, heat and smog

Smoke and haze from wildfires hovered Thursday over San Francisco, as much of California was blanketed in smoke from a siege of wildfires and poor air quality. (Eric Risberg / Associated Press)

By SUSANNE RUST, TONY BARBOZA

SEP. 13, 2020 6 AM PT

In 2001, a team of international scientists projected that during the next 100 years, the planet's inhabitants would witness higher maximum temperatures, more hot days and heat waves, an increase in the risk of forest fires and "substantially degraded air quality" in large metropolitan areas as a result of climate change.

In just the past month, nearly two decades after the third United Nations Intergovernmental Panel on Climate Change report was issued, heat records were busted across California, more than 3 million acres of land burned , and in major metropolitan areas, such as Los Angeles and San Francisco, air pollution has skyrocketed.

"This shouldn't come as a surprise to anyone," said Michael Gerrard, director of the Sabin Center for Climate Change Law at Columbia University. "Maybe we underestimated the magnitude and speed" at which these events would occur, he said, but "we've seen this long freight train barreling down on us for decades, and now the locomotive is on top of us, with no caboose in sight."

In a matter of weeks, California has experienced six of the 20 largest wildfires in modern history and toppled all-time temperature records from the desert to the coast. Millions are suffering from some of the worst air quality in years due to heat-triggered smog and fire smoke. A sooty plume has blanketed most of the West Coast, blotting out the sun and threatening people's lungs during a deadly pandemic.

California is being pushed to extremes. And the record heat, fires and pollution all have one thing in common: They were made worse by climate change. Their convergence is perhaps the strongest signal yet that the calamity climate scientists have warned of for years isn't far off in the future; it is here today and can no longer be ignored.

"What we've been seeing in California are some of the clearest events where we can say this is climate change — that climate change has clearly made this worse," said Zeke Hausfather, a climate scientist at the Breakthrough Institute, an Oakland-based think tank. "People who have lived in California for 30, 40 years are saying this is unprecedented, it has never been this hot, it has never been this smoky in all the years I've lived here."

CALIFORNIA

Los Angeles suffers worst smog in almost 30 years

Sep. 10, 2020

Unprecedented, yes. But not unexpected.

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Since the 1980s, government and oil industry scientists have been anticipating the events that have transpired across the state this past month.

As one 1988 internal Shell Oil Co. document noted, "by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation."

"I'm only sorry that in 1989, I could not get an audience for what I wanted to communicate," said Jim Hansen, a retired NASA researcher and early climate change scientist, of testimony he made to Congress about the issue.

Record temperatures

Each of the extremes Californians are living through right now is fueled, at least in part, by the gradual warming of the planet, which is accelerating as greenhouse gas emissions continue to rise.

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California summers are 2.5 degrees warmer than they were in the 1970s and are on track to heat up an additional 4.5 degrees by the end of the century if the world's current emissions trajectory continues, said Hausfather.

While precise attribution studies on the extreme heat waves in California in recent weeks will take time to complete, he said, they are clear examples of how climate change compounds natural weather variability to increase the likelihood of what once would have been a rare event.

"In a world without climate change, it still would have been a hot August; we still would have had some fires. But it's clear that climate change has made things notably worse," he said. "An extreme heat event that would have been 100 degrees is now 102.5 or 103 degrees, and that is actually a pretty big difference in terms of the impacts on people."

Attachment A

During the mid-August heat wave, Death Valley soared to 130 degrees, one of the hottest temperatures ever recorded on Earth.

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Another ferocious heat wave over the Labor Day weekend brought Death Valley-like heat to other areas. Los Angeles County had its hottest temperature on record when Woodland Hills hit 121 degrees Sept. 6. At Cal Poly San Luis Obispo, it reached 120 degrees, the highest reading since record-keeping began in 1869, in an area that is less than 10 miles from the Pacific Ocean.

CALIFORNIA

A sizzling summer: Hottest August on record in California

Sep. 10, 2020

John Lindsey, a marine meteorologist with Pacific Gas and Electric, said the mercury rose to unprecedented levels in San Luis Obispo due to hot, downslope winds blowing from the northeast. They are known locally as Santa Lucia winds and can increase temperatures by 5.5 degrees for every 1,000 feet they descend.

“It was just rip-roaring hot,” said Lindsey, who has forecast weather along the Central Coast since 1991. “You just don’t expect Death Valley temperatures along coastal California.”

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Lindsey, who acknowledges that he was a bit of a climate skeptic in the past, said seeing the increase in seawater temperatures, in particular, over many years "was a real epiphany or wake-up call."

"By now, there's no doubt in most people's minds that the atmosphere is warming and the ocean is warming," he said. "With the way greenhouse gases are increasing, in my mind, there's no doubt that we're causing this. It's human activity that's causing this. So I'm concerned about the future. And that's somebody who's very skeptical."

Global warming has increased the odds of unprecedented heat extremes across more than 80% of the planet and "has doubled or even, in some areas, tripled the odds of record-setting hot events" in California and the Western U.S., said Stanford University climate scientist Noah Diffenbaugh.

An unprecedented firestorm

When it comes to wildfires, "what we've had in California over the last three to four weeks is unprecedented in our historical experience," Diffenbaugh said.

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"This is more extreme than any other year in living memory," he said, and is consistent with the impact of global warming.

Research by Diffenbaugh and colleagues that was published last month found that the number of days with extreme wildfire weather in California has more than doubled since the early 1980s, primarily due to warming temperatures drying out vegetation.

"It means that even with no change in the frequency of strong wind events, even with no change in the frequency of lightning, the risk of wildfire and risk of large, rapidly growing wildfires goes up as a result of the effect of that warming," he said.

California wildfires map: What's burning now

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And it's that atmospheric warming that has set the stage for the fires raging throughout the western U.S., said Park Williams, a hydroclimatologist at Columbia University's Lamont-Doherty Earth Observatory.

"If we think of the atmosphere as a giant sponge that's always trying to extract water from the landscape, then temperature increases the sponginess," he said.

As soils become drier, heat waves become more intense. That's because the energy in the atmosphere is no longer being used in evaporation but is just building up heat. And as heat increases and soils — and, therefore, fuel for fires — dry out, the risk grows, laying the foundation for the type of wild and destructive fires we are now observing.

"That's why, I think, you keep reading quotes from these firefighters who say they are seeing fire behavior unlike anything they've seen before," he said. "As we go out in the future, in a world with this exponentially growing risk … we're going to see fires far different than we've seen before."

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He noted that fires are not unusual in California — they are an integral part of the state's history and landscape. Bad forest management, combined with human behavior — intentional and unintentional starting of fires — have contributed to the problem. But the effect of climate change is real and growing.

"We have seen the rapid warming of California summers really turbocharge the type of conditions that are suitable for rapid growth of wildfires," Hausfather said. "We see fires growing from essentially nothing to a quarter of a million acres in one day. And that's because the conditions are ripe, and temperature plays a large role."

Attachment A

John Abatzoglou, associate professor in the Department of Management of Complex Systems at UC Merced, agreed.

"What we are seeing play out does indeed have human fingerprints on it, including those from climate change," he said.

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"We can see how warm and dry years catalyze these fires," he said, adding, however, that for fires to start, "they need to have ignitions. But the heat and dryness have absolutely set the table for widespread fire activity."

Dreadful air quality

It was no coincidence that ozone pollution levels in downtown Los Angeles spiked to their highest levels since the mid-1990s on a day in which temperatures reached an all-time high for the county, said Cesunica Ivey, an assistant professor of chemical and environmental engineering at UC Riverside who studies air quality.

The global rise in temperatures observed over decades is also occurring locally, she said, "and these frequently occurring heat waves, this upward trend in basin-wide average temperature, is contributing to ozone exacerbation."

CALIFORNIA

Rarely have so many Californians been exposed to such gloomy, unhealthy air

Sep. 10, 2020

Southern California regulators have seen decades of progress fighting smog stymied in recent years by hotter weather and stronger, more persistent inversion layers that trap pollution near the ground. Their efforts are being hindered by rising temperatures from climate change, according to air quality experts.

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That's because hotter weather speeds up the photochemical reactions that turn pollutants from vehicle tailpipes and other sources into ozone, the invisible, lung-damaging gas in summer smog. Studies show that ozone levels are about two parts per billion higher than they would be without global warming.

What precisely is driving changes such as elevated smog levels can be hard to tease out in the middle of an extreme event because so much is happening at once, with multiple hazards piling on top of each other in a vicious feedback loop.

The recent heat spells, for instance, both fueled smog formation and led to power outages. Gov. Gavin Newsom suspended air quality rules on power plants and other polluters to ease strain on the grid, allowing more emissions to sully the air. The COVID-19 pandemic has added an additional layer of complexity at a time when Californians are trying to protect their homes, lungs and bodies from threats that seem to be coming from all sides.

"When you add COVID, extreme heat, wildfires and air pollution all together, they're all detrimental to public health, and it just makes things worse," said Yifang Zhu, a professor of environmental health sciences at UCLA Fielding School of Public Health who studies air pollution and its effects. "These stressors are happening at the same time. So the impact is cumulative and maybe even synergistic to each other."

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That cascading effect, in which one extreme compounds another, is a feature of global warming that experts have long warned about.

Ivey, of UC Riverside, said she and other scientists aren't surprised to see so many extremes hitting simultaneously, "but to see it playing out is scary."

"It's one of those moments where ozone converged with record acres burned and a heat wave," she said. "If the writing isn't on the wall, then I don't know what to tell folks."

Attachment A

Global warming is also fueling increases in wildfire pollution, a mix of soot particles and gases that can fuel ozone formation and dramatically worsen smog. Those added emissions are only going to get worse as the severity and frequency of fires increases.

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"People may not directly connect local air pollution to global climate change, but they are intertwined," said Zhu. "They are two sides of the same coin."

What this year's extreme heat, fire and air quality degradation is showing, said Columbia's Williams, is that we are, in a sense, blindly stepping off a cliff from a world in which we could somewhat predict what was going to happen, based on decades and centuries of data.

"We're finding that we've lost complete control," he said. "The baselines we've used for decades no longer apply. There really isn't a normal anymore."

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Susanne Rust is an award-winning investigative reporter specializing in environmental issues. She is based in the Bay Area.

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E&E NEWS

CLIMATE

Fast-Moving California Wildfires Boosted by Climate Change

Nearly two dozen large blazes have burnt more than 1 million acres of the state

By Anne C. Mulkern, E&E News on August 24, 2020

Embers blow off a burned tree after the LNU Lightning Complex Fire burned through the area on August 18, 2020 in Napa, California. Credit: Justin Sullivan *Getty Images*

Firefighters battled nearly two dozen wildfires in California yesterday after a week of raging blazes blackened more than 1 million acres across the state.

The fast-moving fires, which are seen by many scientists as a sign of climate change, have killed five people, destroyed more than 1,000 structures and forced thousands to flee. More than 238,000 people either evacuated or were ready to go as more thunderstorms threatened to light new fires yesterday afternoon, according to officials.

Still-active fires are affecting at least 23 counties in Northern California, stretching from Butte to Fresno. Two of the blazes rank among the largest in state history.

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The LNU Lightning Complex Fire, a group of fires centered in Napa and Sonoma counties, has grown into the second-largest blaze ever seen in California. The SCU Lightning Complex Fire, a cluster of blazes in Santa Clara, Alameda and nearby counties, is the third-largest.

Altogether, the fires have burned an area the size of Rhode Island.

"The scope [of the damage] is absolutely astonishing," said Daniel Swain, a climate scientist at UCLA. It's "hard to impress on people just how vast the acreage burned is, especially considering there were no strong offshore winds" to drive the spread.

President Trump on Saturday issued a major disaster declaration to fulfill a request by Gov. Gavin Newsom (D) to bolster the state's emergency resources. Meanwhile, the National Weather Service issued a red flag warning for more thunderstorms and lightning through today.

The racing flames show how climate change is affecting the nation's most populous state, experts said. Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation. Climate change also affects how much moisture is in the air, Swain said.

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"It's actually drying out the air during these extreme heat events," which zaps plants of additional moisture, Swain said. That left much of the state a tinderbox when hundreds of lightning strikes scorched the countryside last week.

"This is really a testament to how dry the vegetation is, in terms of how quickly these fires spread when they were ignited by lightning," he said.

The amount of land burned last week is more than the total burned in all of 2018, and more than double the amount burned in 2017, according to data released by the California Department of Forestry and Fire Protection (Cal Fire).

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The fires on Saturday burned part of the oldest state park in California, Big Basin Redwoods State Park in Santa Cruz County. Flames damaged historic buildings, the campground and "all of the infrastructure," said Christine McMorrow, a spokeswoman with Cal Fire. It wasn't known whether redwood trees were engulfed.

The blazes threaten to outpace the state's ability to respond. Nearly all of Cal Fire's crews are in the field, with some working 72-hour shifts. Oregon, Washington, Nevada, New Mexico, Texas and other states sent firefighters, equipment or both. Officials said more than 13,000 fire personnel were on the scene.

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"We have more people, but it's not enough," Newsom said at a Friday news conference. "We have more air support, but it's not enough."

REPEAT FIRE TRAUMA

Fires erupted beginning Aug. 15 when more than 1,200 lightning strikes hit the baking landscape within 72 hours.

Those came "the exact week that we were experiencing some of the hottest temperatures ever recorded in human history, 130-degree temperatures in the southern part of the state," Newsom said. It was "maybe the hottest modern recorded temperature in the history of the world," he said.

He was referring to the temperature of 130 degrees Fahrenheit on Aug. 16 in Death Valley, a high not reached on Earth in 89 years. The highest temperature ever recorded on the planet is 134 Fahrenheit. It was reached in 1913 in Death Valley. Its accuracy is

disputed by some observers because there was a lack of modern technology (*Climatewire*, Aug. 18).

Altogether, more than 12,000 lightning strikes hit California last week, igniting over 600 fires. Firefighters knocked down smaller ones, but others merged into major "complex" fires.

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The week was filled with horror stories and heroic efforts. Volunteers helped evacuate senior citizens from a Vacaville retirement home in the middle of the night as a fire raced toward the facility. Others helped rescue "dozens and dozens of individuals with intellectual disabilities" in Santa Clara, Newsom said.

Hundreds saw their homes destroyed.

"Tuesday night when I went to bed, I had a beautiful home on a beautiful ranch," Hank Hanson, 81, of Vacaville, told the Associated Press. "By Wednesday night, I have nothing but a bunch of ashes."

State Assemblywoman Cecilia Aguiar-Curry, who represents the Napa wine region, said at a news conference Friday that she has "half a dozen really good friends who don't have a home right now."

The American Red Cross, wary of the coronavirus pandemic, put some survivors in hotel rooms so they could be separated from other evacuees, said Jim Burns, a Red Cross spokesman. Others went to evacuation shelters where protocols were in place to keep people spaced out. The Red Cross was also talking to colleges to see whether dorm rooms were available.

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The fires swept across heavily populated cities that have endured major fires in recent years. Susan Gorin, a Sonoma County supervisor, lost her home in the 2017 Tubbs Fire, a blaze that killed 22 people. She built a new house in the same location; on Friday, she found ashes on her patio from a nearby firestorm.

"It just seems so terrifyingly familiar," Gorin said as she traveled to Lake Tahoe to escape the smoke and mayhem. "This is now the third major fire in four years. We are battle-weary."

CLIMATE CONNECTION SCRUTINIZED

Swain with UCLA and other scientists earlier this year published a study that said climate change has doubled the number of extreme-risk days for California wildfires.

It said temperatures statewide rose 1.8 degrees Fahrenheit since 1980, while precipitation dropped 30%. That doubled the number of autumn days that offer extreme conditions for the ignition of wildfires (*Climatewire*, April 3).

The heat is expected to get worse with time. Climate models estimate that average state temperatures will climb 3 degrees Fahrenheit by 2050 unless the world makes sharp cuts in greenhouse gas emissions, said Michael Wehner, a senior scientist at Lawrence Berkeley National Laboratory.

Even with emissions cuts, average temperatures would rise 2 degrees by midcentury, he said.

Jon Keeley, a senior scientist at the U.S. Geological Survey Western Ecological Research Center, argued that the study from Swain and others failed to show that hotter temperatures are driving wildfires.

"Show us data that shows that level of temperature increase is actually associated with increased fire activity," Keeley said. "They don't show that."

Keeley added, "We ought to be much more concerned with ignition sources than a 1- to 2-degree change in temperature."

A big contributor to large California fires is that the state has focused on extinguishing blazes for about a century rather than allowing for controlled burns, he said. That has caused dead vegetation to accumulate.

Trump has accused California of failing to "sweep" its forests, which he has linked to fires in the state.

Keeley said that "we don't sweep forests here in the U.S., but what we do is prescription burning. ... It's potentially the same thing. It's modifying the fuels prior to a fire."

Swain, the UCLA climate scientist, said global warming is affecting how big fires get and how fast they move.

"What happens when they start burning, what is the character of those fires, and is it changing?" Swain asked. "The answer is yes."

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APPEAL EXHIBIT E

2020

Wildfire Activity Statistics

Thomas W. Porter
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Governor
State of California

Attachment A

2020 Wildfire Activity Statistics

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Acknowledgements
We wish to acknowledge and thank all who supplied data, resources, professional expertise, and assisted in the review of the reports.

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FOREWORD
WILDFIRE ACTIVITY STATISTICS

The California Department of Forestry and Fire Protection (CAL FIRE), under the direction of the State Board of Forestry and Fire Protection, provides the annual Wildfire Activity Statistics report. Although it contains other information, this report is primarily a statistical record of wildfire incidents responded to by CAL FIRE personnel and resources, performing the State/CAL FIRE mission, using State funding within CAL FIRE Direct Protection Area (DPA).

The existing overall fire protection system involving CAL FIRE and California as a whole is rather complex. A number of technical terms are utilized, and the use of fire statistics typically presupposes some understanding of the overall framework. A description of this framework can be found at (https://www.fire.ca.gov/programs/communications/); and in the Glossary of terms at the end of this document.

The first Forest Fire Summary (RED BOOK) was published in 1943 and has continued to this date. Prior to 1989, data and statistics were tabulated manually; today, statistics are derived from an automated database. CAL FIRE began electronically entering incident data into the Emergency Activity Reporting System (EARS) on July 1, 1989. Starting at the end of 2006, CAL FIRE began reporting incidents using a web-based subscription service called California All Incident Reporting System (CAIRS). In 2020, CAL FIRE began reporting incidents using a web-based subscription service called CAL FIRE Incident Reporting System (CALFIRS). This data is imported into the California Incident Data and Statistics (CalStats) database by CAL FIRE staff and the data is uploaded annually to the National Database maintained by the United States Fire Administration (USFA). **Due to the changes in data collection, methods, and systems over the years, information may not always be comparable and data may be of differing accuracy or completeness.**

Throughout this report, the statistics are displayed by **who** provides the wildfire protection. Forces include CAL FIRE personnel and resources, CAL FIRE employees working under a local government agreement, Contract County personnel, and federal firefighting resources. The second part of the statistical reporting is **where** the protection is provided. Areas are categorized as State Responsibility Area (SRA) or DPA.

SRA is State and privately-owned forest, watershed, and rangeland for which the primary financial responsibility of preventing and suppressing wildfires rests with the State (Map 1).

The term “Direct Protection Area” is applied to indicate when a particular fire protection organization has the primary responsibility for responding to an uncontrolled fire and for directing the suppression activity. Thus, in addition to lands in SRA, CAL FIRE may have “direct protection” responsibility on lands in federal jurisdiction. At the same time, federal agencies, such as the U.S. Forest Service, may have “direct protection” responsibility for lands in SRA. The lands in SRA and federal areas for which CAL FIRE has “direct protection” responsibility for fire protection responses are depicted on Map 2.

The State contracts with six counties to provide protection of SRA within their boundaries. These counties [Kern, Los Angeles, Marin, Orange, Santa Barbara, and Ventura] are referred to as Contract Counties.

Attachment A

CAL FIRE provides fire protection services to many California citizens through the administration of 150 cooperative fire protection agreements in cities, districts, and 36 of the State's 58 counties. Wildfire statistics associated with incidents where local government reimburses CAL FIRE for services are displayed in Table 1.

This report also includes a statewide summary of California wildfires and a listing of wildfires over three hundred acres for all wildfire agencies (Table 5). The statistical information in this report is gathered from data in the previously defined CALFIRS and Incident Status Summaries (ICS-209) on the National Fire and Aviation Management (FAMWEB) website http://fam.nwcg.gov/fam-web/ .

Beginning mid-August, dry conditions, combined with severe lighting storms sparked what became known as the “2020 Fire Siege.” These resulting wildfires led to over 4 million acres burned, making 2020 one of the worst fire seasons on record. Many of these incidents originated and burned in Federal Responsibility Area (FRA) and as such, not all fires and acres burned in the Siege are reflected in tables 8 through 21. More detailed information on the 2020 Fire Siege from the perspective of CAL FIRE can be found at this link: https://www.fire.ca.gov/media/hsviuuv3/cal-fire-2020-fire-siege.pdf

Additional Wildfire Activity Statistics for previous years can be found at the following website: https://www.fire.ca.gov/stats-events/ .

Attachment A

2020 STATEWIDE FIRE SUMMARY

During 2020, wildfire firefighting agencies responded to 8,648 fires that burned 4,304,379 acres. For wildfire agencies, this represents a 21% increase in the number of fires and a 1,452% increase in acres burned from 2019. CAL FIRE, through State funded and local government contracts, reported 6,350 wildfire incidents that burned 1,475,943 acres, which represents an 8% increase in fires and a 976% increase in acres burned from 2019.

Table 1. Protection Areas by Wildfire Agency—Fires and Acres

Direct Protection Area	Fires	Acres Burned
CAL FIRE – (State Responsibility)	3,501	1,458,881
CAL FIRE – (Local Government Contracts)	2,849	17,062
Contract Counties	466	54,762
United States Forest Service	1,421	2,520,946
Bureau of Land Management	217	142,201
National Park Service	79	76,796
Bureau of Indian Affairs	97	22,210
United States Fish and Wildlife Service	13	45
Military	5	11,476
2020 Total	8,648	4,304,379
5 Year Average (2016-2020) All Agencies	**8,198**	**1,794,819**
5 Year Average CAL FIRE (2016-2020) Includes Local Govt. Contracts	**5,903**	**634,018**

Federal agencies provide their fire statistics as a courtesy to CAL FIRE.

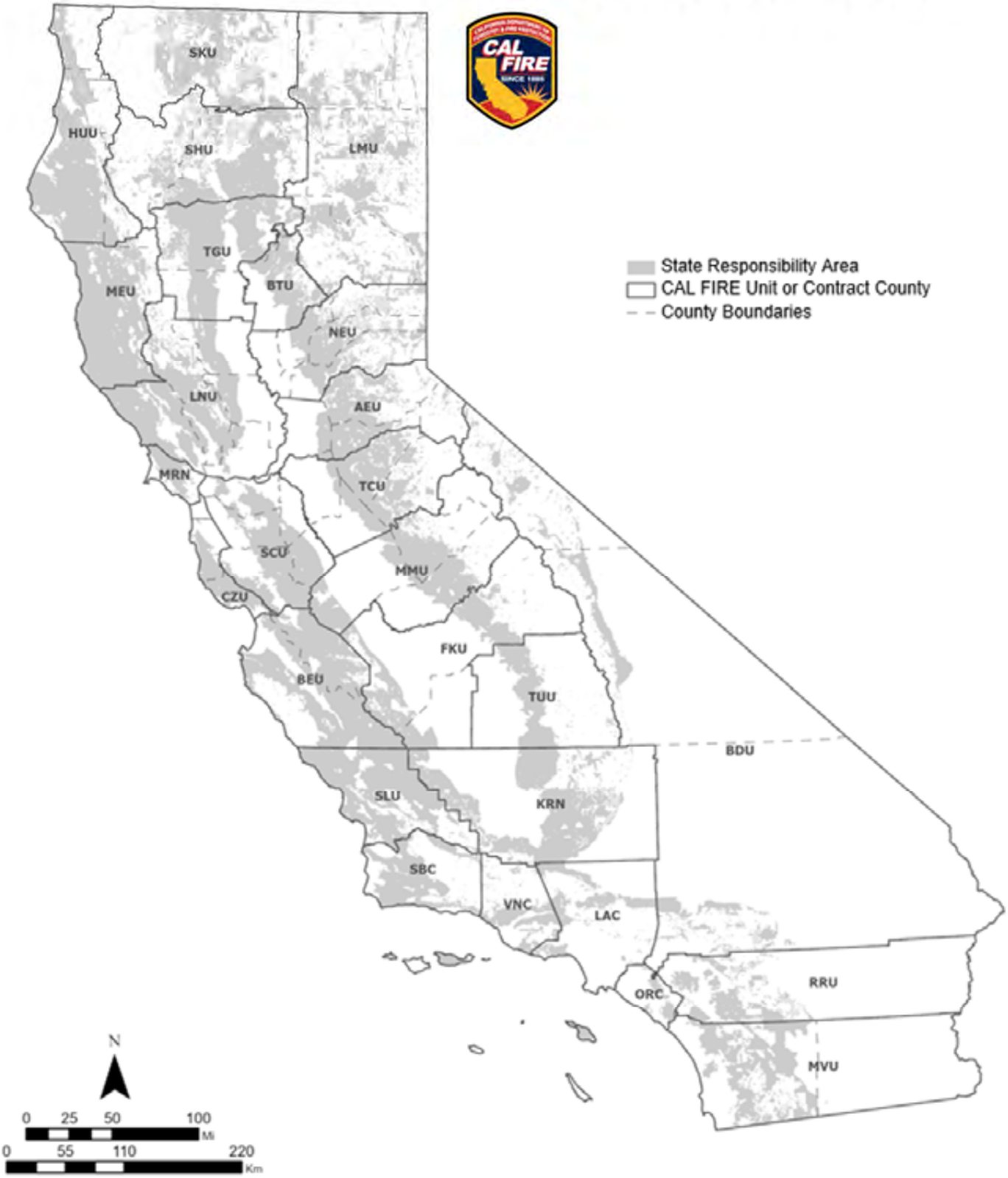
Table 2. The Top Five Fires for 2020 by Acreage Burned

Fire Name	County	Start Date	Acres Burned	Fire Cause	Structures Destroyed
August Complex (Includes West Zone)	Trinity, Tehama, Glenn, Lake, Mendocino	08/17/21	1,032,648	Lightning	89
SCU Lightning Complex	Contra Costa, Santa Clara, Alameda, San Joaquim, Stanislaus	08/16/21	396,625	Lightning	225
Creek	Fresno, Madera	09/04/21	379,895	Undetermined	858
LNU Lightning Complex	Napa, Lake, Sonoma, Solano	08/17/21	363,220	Lightning	1,491
North Complex	Butte, Plumas	08/17/21	318,935	Lightning	2,352

Source: Redbook, Table 5, Large Fires 300 Acres and Greater – State and Contract Counties Direct Protection Areas and Table 6, Large Fires 300 Acres and Greater - Other Agencies Direct Protection Areas.

Attachment A

STATE RESPONSIBILITY AREA (SRA)



Source: SRA20_1

Attachment A

Table 3. State Responsibility Area, Acres Protected by State and Other Agencies (2020)*

COUNTY	CAL FIRE	USFS	BLM	NPS	CC	Other FED	TOTAL
Alameda	246,200	0	0	0	0	0	246,200
Alpine	0	34,000	400	0	0	0	34,400
Amador	279,700	8,400	0	0	0	0	288,100
Butte	500,800	35,300	0	0	0	0	536,100
Calaveras	524,400	2,300	0	0	0	0	526,700
Colusa	241,500	5,100	0	0	0	0	246,600
Contra Costa	193,200	0	0	0	0	0	193,200
Del Norte	172,600	16,700	0	800	0	0	190,100
El Dorado	404,900	143,600	0	0	0	0	548,500
Fresno	774,800	28,900	0	0	0	0	803,700
Glenn	290,100	7,400	0	0	0	0	297,500
Humboldt	1,542,800	69,400	0	400	0	0	1,612,600
Imperial	1,800	0	0	0	0	0	1,800
Inyo	308,100	11,600	16,900	0	0	0	336,600
Kern	0	29,300	152,000	0	1,642,600	0	1,823,900
Kings	149,000	0	0	0	0	0	149,000
Lake	355,600	40,000	0	0	0	0	395,600
Lassen	592,200	80,900	377,600	0	0	0	1,050,700
Los Angeles	0	28,200	0	0	469,800	0	498,000
Madera	368,100	9,700	0	0	0	0	377,800
Marin	0	0	0	0	199,800	0	199,800
Mariposa	426,900	16,200	0	500	0	0	443,600
Mendocino	1,838,700	21,700	0	0	0	0	1,860,400
Merced	393,900	0	0	0	0	0	393,900
Modoc	371,500	187,500	73,100	0	0	0	632,100
Mono	2,500	92,200	161,100	0	0	0	255,800
Monterey	1,250,600	38,000	0	0	0	0	1,288,600
Napa	360,400	0	0	0	0	0	360,400
Nevada	299,400	84,400	0	0	0	0	383,800
Orange	0	2,500	0	0	104,100	0	106,600
Placer	275,100	85,100	0	0	0	0	360,200
Plumas	96,600	342,100	100	0	0	0	438,800
Riverside	555,400	26,100	48,500	0	2,600	0	632,600
Sacramento	113,500	0	0	0	0	0	113,500
San Benito	729,000	0	0	0	0	0	729,000
San Bernardino	311,100	38,500	0	0	0	0	349,600
San Diego	1,088,100	79,600	0	0	0	0	1,167,700
San Francisco	0	0	0	0	0	0	0
San Joaquin	150,200	0	0	0	0	0	150,200
San Luis Obispo	1,406,500	40,200	81,500	0	1,700	0	1,529,900

Attachment A

Table 3. (continued) State Responsibility Area, Acres Protected by State and Other Agencies (2020) *

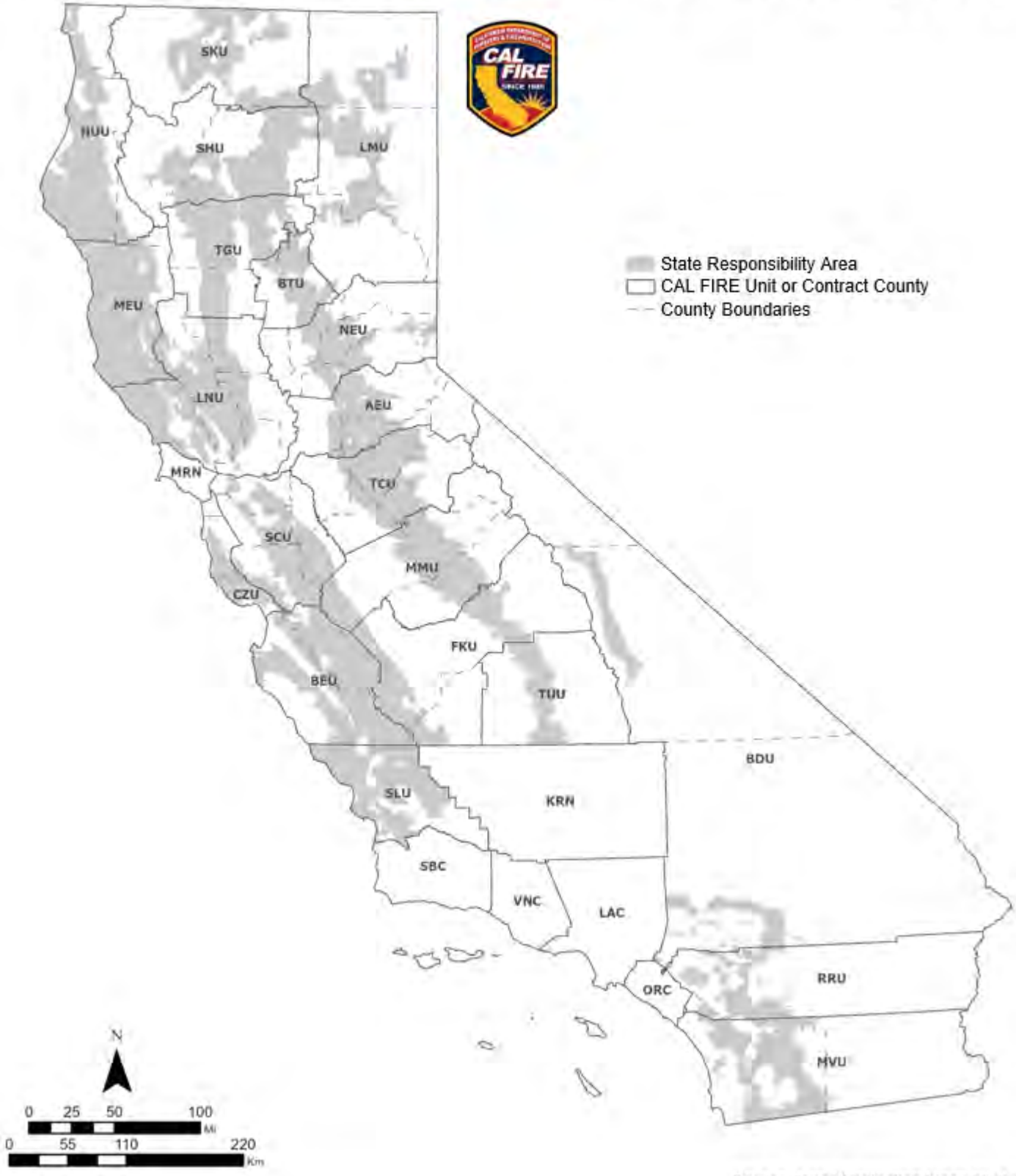
COUNTY	CAL FIRE	USFS	BLM	NPS	CC	Other FED	TOTAL
San Mateo	176,100	0	0	0	0	0	176,100
Santa Barbara	0	65,800	0	55,200	667,700	1,200	789,900
Santa Clara	554,700	0	0	0	0	0	554,700
Santa Cruz	228,600	0	0	0	0	0	228,600
Shasta	1,142,700	219,000	0	2,500	0	0	1,364,200
Sierra	0	155,500	2,300	0	0	0	157,800
Siskiyou	1,012,000	352,400	0	0	0	0	1,364,400
Solano	86,900	0	0	0	0	0	86,900
Sonoma	794,000	0	0	0	0	0	794,000
Stanislaus	448,000	0	0	0	0	0	448,000
Sutter	0	0	0	0	0	0	0
Tehama	1,148,900	136,800	0	0	0	0	1,285,700
Trinity	259,200	228,900	0	400	0	0	488,500
Tulare	573,300	11,700	11,300	2,500	0	300	599,100
Tuolumne	299,000	58,700	0	1,500	0	0	359,200
Ventura	0	48,300	0	0	305,100	0	353,400
Yolo	179,300	0	0	0	0	0	179,300
Yuba	184,300	30,000	0	0	0	0	214,300
TOTAL	**23,702,200**	**2,912,000**	**924,800**	**63,800**	**3,393,400**	**1,500**	**30,997,700**

CAL FIRE - California Department of Forestry and Fire Protection
USFS - United States Forest Service
BLM - Bureau of Land Management
NPS - National Park Service
CC - Contract County
Other FED - Other Federal Fire Protection Agency

*Acres rounded to nearest hundred
Source: SRA20_1, DirectProtectionAreas 20_2
Map and data prepared by CAL FIRE Fire and Resource Assessment Program (FRAP)

Attachment A

CAL FIRE DIRECT PROTECTION AREA (DPA)



Source: DirectProtectionAreas20_2

Attachment A

Table 4. CAL FIRE Direct Protection Area, Acres by Jurisdiction (2020) *

COUNTY	STATE	FEDERAL	CDFLWC	TOTAL ACRES
Alameda	245,900	200	0	246,100
Alpine	0	0	0	0
Amador	279,600	13,800	0	293,400
Butte	500,700	60,300	900	561,900
Calaveras	524,400	98,900	0	623,300
Colusa	241,500	44,300	0	285,800
Contra Costa	193,200	100	0	193,300
Del Norte	172,300	15,900	0	188,200
El Dorado	404,900	66,300	0	471,200
Fresno	774,800	197,000	0	971,800
Glenn	290,100	12,300	0	302,400
Humboldt	1,542,100	126,400	500	1,669,000
Imperial	1,800	13,900	0	15,700
Inyo	308,100	146,000	0	454,100
Kern	0	0	0	0
Kings	149,000	1,700	0	150,700
Lake	355,600	126,700	0	482,300
Lassen	592,100	372,000	0	964,100
Los Angeles	0	0	0	0
Madera	368,100	44,400	0	412,500
Marin	0	0	0	0
Mariposa	426,900	88,900	0	515,800
Mendocino	1,838,400	156,800	0	1,995,200
Merced	393,800	33,400	0	427,200
Modoc	371,500	144,700	0	516,200
Mono	2,400	3,800	0	6,200
Monterey	1,250,000	39,700	0	1,289,700
Napa	360,400	63,100	0	423,500
Nevada	299,400	37,800	7,900	345,100
Orange	0	0	3,000	3,000
Placer	275,100	61,700	1,600	338,400
Plumas	96,600	21,700	0	118,300
Riverside	555,400	170,700	12,100	738,200
Sacramento	113,500	100	0	113,600
San Benito	728,800	82,800	0	811,600
San Bernardino	311,000	181,900	18,400	511,300
San Diego	1,087,900	317,600	0	1,405,500
San Francisco	0	0	0	0
San Joaquin	150,100	300	0	150,400
San Luis Obispo	1,405,900	47,700	0	1,453,600
San Mateo	176,100	100	0	176,200
Santa Barbara	0	0	0	0
Santa Clara	554,100	1,500	0	555,600

Attachment A

Table 4. (continued) CAL FIRE Direct Protection Area, Acres by Jurisdiction (2020) *

COUNTY	STATE	FEDERAL	CDFLWC	TOTAL ACRES
Santa Cruz	228,600	5,900	0	234,500
Shasta	1,142,700	275,800	0	1,418,500
Sierra	0	0	0	0
Siskiyou	1,011,900	248,700	0	1,260,600
Solano	86,900	2,100	1,400	90,400
Sonoma	793,700	23,700	0	817,400
Stanislaus	448,000	1,800	0	449,800
Sutter	0	0	0	0
Tehama	1,148,900	81,200	0	1,230,100
Trinity	259,200	85,700	0	344,900
Tulare	573,000	48,100	0	621,100
Tuolumne	299,000	87,500	0	386,500
Ventura	0	0	0	0
Yolo	179,300	29,400	0	208,700
Yuba	184,200	6,800	0	191,000
TOTAL	**23,696,900**	**3,691,200**	**45,800**	**27,433,900**

STATE - State of California
FEDERAL - Federal Lands
CDFLWC - CAL FIRE Local Wildland Contract

*Acres rounded to nearest hundred
Source: DirectProtectionAreas20_2, SRA20_1
Map and data prepared by CAL FIRE Fire and Resource Assessment Program (FRAP)

Table 5. Large Fires 300 Acres and Greater - State and Contract Counties Direct Protection Area

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident #	County	Fire Name	Start	Cont.	DPA	Total	Type	Cause	Dest.	Dam.	Fire	Civil
NEU-11799	PLACER	AMORUSO	06/01/20	06/01/20	CAL FIRE	670	G	EQUIPMENT USE				
LNU-8419	SOLANO	QUAIL	06/06/20	06/13/20	CAL FIRE	1,837	T	FIREARMS	5	12		
SLU-7149	SAN LUIS OBISPO	SODA	06/10/20	06/10/20	CAL FIRE	1,680	G	VEHICLE				
VNC-45530	VENTURA	ELIZABETH	06/10/20	06/12/20	CC	300	B	UNDETERMINED				
VNC-45754	VENTURA	LIME	06/10/20	06/16/20	CC	803	B, G	UNDETERMINED				
AEU-16543	SACRAMENTO	GRANT	06/12/20	06/19/20	CAL FIRE	5,042	G	EQUIPMENT USE		1		
SBC-12322	SANTA BARBARA	DRUM	06/14/20	06/17/20	CC	696	B, G	ELECTRICAL POWER				
FKU-8094	FRESNO	EAGLE	06/15/20	06/13/20	CAL FIRE	300	G	UNDETERMINED				
SLU-7409	SAN LUIS OBISPO	AVILA	06/15/20	06/20/20	CAL FIRE	445	B, G	UNDER INVESTIGATION		1		
BEU-2847	SAN BENITO	BITTER	06/16/20	06/20/20	CAL FIRE	813	B, G	VEHICLE				
TCU-6494	CALAVERAS	WALKER	06/16/20	06/21/20	CAL FIRE	1,455	B, G	EQUIPMENT USE	2	2		
BEU-2986	MONTEREY	RICO	06/22/20	06/23/20	CAL FIRE	348	G	ELECTRICAL POWER				
TUU-298	TULARE	GRADE	06/22/20	06/25/20	CAL FIRE	1,050	G	UNDER INVESTIGATION				
MMU-13431	MERCED	PASS	06/28/20	06/30/20	CAL FIRE	2,192	B, G	ELECTRICAL POWER				
KRN-27271	KERN	BENA	07/01/20	07/05/20	CC	4,000	B, G	EQUIPMENT USE				
MMU-13801	MADERA	BONADELLE	07/02/20	07/03/20	CAL FIRE	500	G	EQUIPMENT USE				
SCU-4669	SANTA CLARA	PARK	07/04/20	07/08/20	CAL FIRE	353	B, G	PLAYING WITH FIRE				
SLU-8435	SAN LUIS OBISPO	LAKE	07/04/20	07/05/20	CAL FIRE	583	G	VEHICLE	1			
LAC-197926	LOS ANGELES	SOLEDAD	07/05/20	07/06/20	CC	1,525	B, G	MISCELLANEOUS				
SCU-4686	SANTA CLARA	CREWS	07/05/20	07/20/20	CAL FIRE	5,513	B, G	ELECTRICAL POWER	4			
FKU-10219	FRESNO	MINERAL	07/13/20	07/26/20	CAL FIRE	29,667	B, G	STRUCTURE	7			
BEU-3441	SAN BENITO	COYOTE	07/15/20	07/18/20	CAL FIRE	1,485	B, G	UNDER INVESTIGATION	1			
LMU-3874	LASSEN	HOG	07/18/20	08/28/20	CAL FIRE	9,564	T	UNDER INVESTIGATION	2			
SKU-5356	SISKIYOU	BADGER	07/18/20	07/28/20	CAL FIRE	557	B, G, T	VEHICLE				
SHU-7049	SHASTA	PLATINA	07/19/20	07/27/20	CAL FIRE	333	B, G	DEBRIS BURNING				

The information on this list is gathered from the ICS 209 incident reports and Damage Inspection (DINS) database, then verified in the California Incident Data and Statistics (CalStats) database and includes information on fire activity within the Direct Protection Areas of CAL FIRE and Contract Counties.

Table 5. (continued) Large Fires 300 Acres and Greater - State and Contract Counties Direct Protection Area

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident #	County	Fire Name	Start	Cont.	DPA	Total	Type	Cause	Dest.	Dam.	Fire	Civil
LMU-3917	LASSEN	GOLD	07/20/20	09/29/20	CAL FIRE	22,614	B, T	UNDETERMINED	13	5		
FKU-10922	FRESNO	WILD	07/25/20	07/25/20	CAL FIRE	1,040	G	ARSON				
LAC-222638	LOS ANGELES	RIDGE	07/27/20	07/27/20	CC	321	B, G, T	UNDETERMINED				
MMU-16043	MERCED	COTTONWOOD	07/27/20	07/29/20	CAL FIRE	788	G	VEHICLE				
SLU-9669	SAN LUIS OBISPO	BRANCH	07/28/20	08/03/20	CAL FIRE	3,222	G	VEHICLE	8			
AEU-22430	SACRAMENTO	CLAY	07/29/20	07/29/20	CAL FIRE	741	G	SMOKING				
FKU-11181	FRESNO	LINCOLN	07/29/20	07/29/20	CAL FIRE	640	G	ARSON				
RRU-96640*	RIVERSIDE	APPLE	07/31/20	11/18/20	CAL FIRE	33,424	B, G	VEHICLE	13	6		
SLU-9866	SAN LUIS OBISPO	POND	08/01/20	08/09/20	CAL FIRE	2,005	B, G	STRUCTURE	4	1		
LNU-12277	COLUSA	SITES	08/02/20	08/06/20	CAL FIRE	560	B, T	UNDER INVESTIGATION	1	1		
SLU-10018	SAN LUIS OBISPO	PASS	08/04/20	08/05/20	CAL FIRE	322	G	VEHICLE				
AEU-24350	SACRAMENTO	MEISS	08/13/20	08/15/20	CAL FIRE	512	G	FIREARMS				
FKU-12279	FRESNO	HILLS	08/15/20	09/27/20	CAL FIRE	2,121	B, G	LIGHTNING			1	
SLU-10533	SAN LUIS OBISPO	WHALE	08/15/20	08/18/20	CAL FIRE	320	G	LIGHTNING				
BEU-4024	MONTEREY	RIVER	08/16/20	09/04/20	CAL FIRE	48,088	B, G	LIGHTNING	30	13		
CZU-5205*	SAN MATEO, SANTA CRUZ	CZU AUGUST LIGHTNING COMPLEX	08/16/20	09/22/20	CAL FIRE	86,509	B, T	LIGHTNING	1,490	140		1
SCU-5740*	CONTRA COSTA, SANTA CLARA, ALAMEDA, SAN JOAQUIN, STANISLAUS	SCU LIGHTNING COMPLEX	08/16/20	09/15/20	CAL FIRE	396,625	B, G	LIGHTNING	225	26		
BTU-9979*	BUTTE, TEHAMA, GLENN	BUTTE TEHAMA GLENN COMPLEX	08/17/20	09/16/20	CAL FIRE	19,609	T	LIGHTNING				
LNU-13407*	NAPA, LAKE, SONOMA, SOLANO	LNU LIGHTNING COMPLEX	08/17/20	09/22/20	CAL FIRE	363,220	B, G, T	LIGHTNING	1,491	232		5
MEU-10843*	TRINITY, TEHAMA, GLENN, LAKE, MENDOCINO	AUGUST COMPLEX WEST ZONE	08/17/20	10/15/20	CAL FIRE	143,181	B, G, T	LIGHTNING	55	6		
NEU-19231	NEVADA	JONES	08/17/20	09/06/20	CAL FIRE	705	B, T	LIGHTNING	18	3		
VNC-30441 LAC-246170	VENTURA, LOS ANGELES	HOLSER	08/17/20	08/22/20	CC	2,189	B, G	EQUIPMENT USE				
BEU-4081	MONTEREY	CARMEL	08/18/20	09/06/20	CAL FIRE	6,901	B, G	VEHICLE	73	7		

The information on this list is gathered from the ICS 209 incident reports and Damage Inspection (DINS) database, then verified in the California Incident Data and Statistics (CalStats) database and includes information on fire activity within the Direct Protection Areas of CAL FIRE and Contract Counties.

Table 5. (continued) Large Fires 300 Acres and Greater - State and Contract Counties Direct Protection Area

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident #	**County**	**Fire Name**	**Start**	**Cont.**	**DPA**	**Total**	**Type**	**Cause**	**Dest.**	**Dam.**	**Fire**	**Civil**
MEU-9786	MENDOCINO	CREEK	08/18/20	08/26/20	CAL FIRE	820	B, G	VEHICLE	3			
TCU-9353	CALAVERAS	SALT	08/18/20	08/24/20	CAL FIRE	1,783	B, G	EQUIPMENT USE				
TCU-9457	TUOLUMNE	MOC	08/20/20	08/31/20	CAL FIRE	2,857	B, G	EQUIPMENT USE	2	1		
MMU-19014	MADERA	HENSLEY #2	08/30/20	08/30/20	CAL FIRE	400	G	ARSON				
BDU-12925	SAN BERNARDINO	EL DORADO	09/05/20	11/16/20	CAL FIRE	22,744	B, G, T	PYROTECHNICS	14	2	1	
MEU-10700	MENDOCINO	OAK	09/07/20	09/25/20	CAL FIRE	1,100	G, T	STRUCTURE	56	1		
NEU-21423	YUBA	WILLOW	09/09/20	09/09/20	CAL FIRE	1,311	B, G, T	ARSON	11	5		
RRU-119353	RIVERSIDE	SNOW	09/17/20	09/24/20	CAL FIRE	6,254	B, G, T	VEHICLE				
LNU-15947*	NAPA, SONOMA	GLASS	09/27/20	10/20/20	CAL FIRE	67,484	B, G, T	UNDETERMINED	1,528	282		
SHU-9978*	SHASTA	ZOGG	09/27/20	10/14/20	CAL FIRE	56,338	B, G	ELECTRICAL POWER	204	27		4
RRU-124873	RIVERSIDE	CANDY	09/29/20	09/30/20	CAL FIRE	454	G	ARSON				
ORC-121364	ORANGE	SILVERADO	10/26/20	11/07/20	CC	12,466	B, G	UNDER INVESTIGATION	5	11		
ORC-121612	ORANGE	BLUE RIDGE	10/26/20	11/07/20	CC	13,694	B, G	UNDETERMINED	1	12		
ORC-136890	ORANGE	BOND	12/02/20	12/11/20	CC	6,686	B, G	STRUCTURE	31	21		
RRU-160421	RIVERSIDE	SANDERSON	12/13/20	12/13/20	CAL FIRE	1,954	G	CAMPFIRE				
SUBTOTAL						**1,403,713**			**5,298**	**818**	**2**	**10**

The information on this list is gathered from the ICS 209 incident reports and Damage Inspection (DINS) database, then verified in the California Incident Data and Statistics (CalStats) database and includes information on fire activity within the Direct Protection Areas of CAL FIRE and Contract Counties.

*Some of the complex incidents in this list are comprised of more than one CALFIRS report to account for multiple ignitions, jurisdictions, or counties. These reports combined amount to the total acres and other loss figures of the incident.

Table 6. Large Fires 300 Acres and Greater - Other Agencies Direct Protection Areas

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident #	County	Fire Name	Start	Cont.	DPA	Total	Type	Cause	Dest.	Dam.	Fire	Civil
KCF	KINGS	INTERSTATE 5	05/03/20	05/03/20	LOCAL	2,060	G	UNDETERMINED				
BOB-6492	SAN LUIS OBISPO	RANGE	05/27/20	05/28/20	MIL	5,000	G	UNDETERMINED				
CNP-1216	SANTA BARBARA	SCORPION	05/31/20	06/05/20	NPS	1,395	B, G	UNDETERMINED				
MCP-1474	SAN DIEGO	INDIA	06/09/20	06/16/20	MIL	1,100	B, G	UNDETERMINED				
SNF-593	FRESNO	HOG	06/14/20	06/15/20	USFS	533	B, G	UNDETERMINED				
MNP-9202	SAN BERNARDINO	IVANPAH	06/22/20	06/26/20	NPS	1,088	B, G	UNDETERMINED				
NOD-3218	LASSEN	R-2	06/23/20	06/25/20	BLM	563	B, G	UNDETERMINED				
ANF-2440	LOS ANGELES	ROWHER	07/01/20	07/09/20	USFS	616	B, G	PLAYING WITH FIRE				
BEA	YUBA	VALLEY	07/15/20	07/15/20	MIL	500	G	UNDETERMINED				
MDF-487	SISKIYOU, MODOC	JULY COMPLEX	07/22/20	08/22/20	USFS	83,261	B, G, T	LIGHTNING	15			
YNP-54	MARIPOSA	BLUEJAY	07/24/20	11/19/20	NPS	6,922	T	LIGHTNING				
PNF-976	LASSEN	ADAMS	07/26/20	07/31/20	USFS	918	B, G, T	LIGHTNING				
SRF-656	HUMBOLDT	RED SALMON COMPLEX	07/28/20	11/16/20	USFS	144,698	B, G, T	LIGHTNING				
LNF-4290	TEHAMA	STUMP	08/01/20	08/13/20	USFS	684	T	LIGHTNING				
BEA	YUBA	BEALE	08/02/20	08/03/20	MIL	600	G	UNDETERMINED				
CCD-30547	LASSEN, WASHOE (NV)	NORTH	08/02/20	08/08/20	BLM	6,882	B, G	UNDETERMINED		1		
CND-2309	KERN	STAGECOACH	08/03/20	08/14/20	BLM	7,760	B, T	EQUIPMENT USE	31	4	1	
SNF-1160	FRESNO	TRIMMER	08/03/20	09/01/20	USFS	594	B, T	UNDETERMINED				
YNP-75	TUOLUMNE	WOLF	08/11/20	11/19/20	NPS	2,057	T	LIGHTNING				
ANF-3273	LOS ANGELES	LAKE	08/12/20	09/30/20	USFS	31,089	B, G, T	UNDETERMINED	34	6		
ANF-3289	LOS ANGELES	RANCH 2	08/13/20	09/03/20	USFS	4,237	B, G	ARSON				
TNF-1600	SIERRA	LOYALTON	08/14/20	08/30/20	USFS	47,029	G, T	LIGHTNING	35			

Table 6. (continued) Large Fires 300 Acres and Greater - Other Agencies Direct Protection Areas

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident #	County	Fire Name	Start	Cont.	DPA	Total	Type	Cause	Dest.	Dam.	Fire	Civil
MNP-12356	SAN BERNARDINO	DOME	08/15/20	08/22/20	NPS	43,273	B, G	LIGHTNING	6			
INF-2140	MONO	BEACH	08/16/20	08/28/20	USFS	3,780	B, T	LIGHTNING				
KNP-80	TULARE	RATTLESNAKE	08/16/20	12/31/20	NPS	8,419	B, T	LIGHTNING				
MNF-753	TRINITY, TEHAMA, GLENN, LAKE, MENDOCINO	AUGUST COMPLEX	08/17/20	11/15/20	USFS	889,467	B, T	LIGHTNING	34	4	1	
NOD-4682	LASSEN	R-5	08/17/20	08/19/20	BLM	471	B, G	UNDETERMINED				
PNF-1299	PLUMAS	SHEEP	08/17/20	09/09/20	USFS	29,570	B, G, T	LIGHTNING	26	2		
PNF-1308*	PLUMAS, BUTTE	NORTH COMPLEX	08/17/20	11/30/20	USFS	318,935	B, G, T	LIGHTNING	2,352	119		16
LPF-2428	MONTEREY	DOLAN	08/18/20	12/31/20	USFS	124,924	B, G, T	UNDETERMINED	19	4		
NOD-4727	LASSEN	W-5 COLD SPRINGS	08/18/20	09/13/20	BLM	84,817	B, T	LIGHTNING	1			
RNP-12009	MARIN	WOODWARD	08/18/20	10/01/20	NPS	4,929	B, G, T	LIGHTNING				
SQF-2622	TULARE	SQF COMPLEX	08/19/20	01/07/21	USFS	175,019	G, T	LIGHTNING	232	12		
KNP-91	TULARE	MORAINE	08/21/20	12/31/20	NPS	1,316	B, T	LIGHTNING				
HTF-30684	MONO	SLINK	08/29/20	10/15/20	USFS	26,759	B, G, T	LIGHTNING	2			
SHF-1376	TRINITY	HOBO	09/01/20	09/10/20	USFS	413	B, G, T	UNDETERMINED				
SNF-1392*	FRESNO, MADERA	CREEK	09/04/20	12/31/20	USFS	379,895	T	UNDETERMINED	858	71		
CNF-2833	SAN DIEGO	VALLEY	09/05/20	09/24/20	USFS	16,390	B, G	UNDETERMINED	64	11		
ANF-3687	LOS ANGELES	BOBCAT	09/06/20	11/30/20	USFS	115,997	B, T	UNDETERMINED	169	47		
ENF-27219	EL DORADO	FORK	09/08/20	11/08/20	USFS	1,673	T	UNDETERMINED				
KNF-7035	SISKIYOU	SLATER	09/08/20	11/15/20	USFS	157,270	B, T	UNDETERMINED	353	24		2
SNF-1402	FRESNO	BULLFROG	09/08/20	11/15/20	USFS	1,185	B, G, T	UNDETERMINED				
KNF-7084	SISKIYOU	DEVIL	09/09/20	11/15/50	USFS	8,857	T	UNDETERMINED				
KNF-7241	SISKIYOU	FOX	09/14/20	09/30/20	USFS	2,188	B, T	HUMAN				

Table 6. (continued) Large Fires 300 Acres and Greater - Other Agencies Direct Protection Areas

			Date		Origin	Acres Burned	Veg.		Structures		Fatalities	
Incident#	County	Fire Name	Start	Cont.	DPA	Total	Type	Cause	Dest.	Dam.	Fire	Civil
LPF3161	MONTEREY	COLEMAN	10/18/20	11/15/20	USFS	574	B, G	UNDETERMINED				
NOD-6431	LASSEN	LAURA 2	11/17/20	11/23/20	BLM	2,800	B, G	UNDETERMINED	42	7		
OVD-30860	MONO	MOUNTAIN VIEW	11/17/20	11/30/20	BLM	20,385	B, G	UNDETERMINED	97			1
COR-12597	RIVERSIDE	AIRPORT	12/01/20	12/17/20	LOCAL	1,087	B, G	UNDETERMINED				
MVU-20846	SAN DIEGO	CREEK 5	12/23/20	12/28/20	MIL	4,276	B, G	UNDETERMINED				
SUBTOTAL						**2,774,255**			**4,370**	**312**	**2**	**19**
STATE, CONTRACT COUNTIES, AND OTHER AGENCIES DPA TOTAL						**4,117,968**			**9,668**	**1,130**	**4**	**29**

The information on this list is not a complete or final list of other agency large fires. This information is gathered from the ICS 209 incident reports. Federal agencies are not obligated to provide reports to CAL FIRE on fire activity within their jurisdiction. CAL FIRE assisted on these fires with either equipment or resources.

Origin DPA = The agency on whose Direct Protection Area (DPA) the fires started.
Acres Burned = Acres burned in CAL FIRE area, other agencies and total area burned.
Structures Destroyed = Residence, commercial property, outbuilding or other structure that is declared unusable.
Structures Damaged = Residence, commercial property, outbuilding or other structure that its usefulness or value is impaired.
Fatalities = Death of civilian or fire service personnel assigned to the incident.

T = Timber
B = Brush
W = Woodland
G = Grass
A = Agricultural Products

LOCAL = Local Fire Departments
CC = Contract Counties
MIL = Military Land

BLM = Bureau of Land Management
BIA = Bureau of Indian Affairs
FWS = Fish and Wildlife Service
NPS = National Park Service
USFS = United States Forest Service

*Some of the complex incidents in this list are comprised of more than one CALFIRS report to account for multiple ignitions, jurisdictions, or counties. These reports combined amount to the total acres and other loss figures of the incident.

Table 7. Number of Fires and Acres Burned by Cause and by Size in Contract Counties

Number of Fires by Cause

Contract Counties	Total	Arson	Campfire	Debris Burning	Electrical Power	Equip. Use	Ltng.	Misc.	P-W-F	Railroad	Smoking	Undet.	Vehicle
Kern	146	4	0	5	10	25	4	21	0	0	0	76	1
Los Angeles	140	11	8	9	4	21	1	31	12	0	7	35	1
Marin	3	0	0	0	0	0	0	3	0	0	0	0	0
Orange	45	0	1	4	2	5	1	15	0	0	4	11	2
Santa Barbara	73	3	0	5	3	4	0	57	0	0	1	0	0
Ventura	59	0	0	0	0	3	2	38	0	0	0	15	1
TOTAL	466	18	9	23	19	58	8	165	12	0	12	137	5

Number of Acres Burned by Cause

Contract Counties	Total	Arson	Campfire	Debris Burning	Electrical Power	Equip. Use	Ltng.	Misc.	P-W-F	Railroad	Smoking	Undet.	Vehicle
Kern	13,617	12	0	36	34	12,043	25	481	0	0	0	895	91
Los Angeles	3,781	614	11	134	3	411	1	1,657	195	0	5	749	1
Marin	0	0	0	0	0	0	0	0	0	0	0	0	0
Orange	32,894	0	0	1	10	9	0	6,686	0	0	8	26,173	7
Santa Barbara	1,151	21	0	6	701	22	0	400	0	0	1	0	0
Ventura	3,319	0	0	0	0	1,965	7	188	0	0	0	1,159	0
TOTAL	54,762	647	11	177	748	14,450	33	9,412	195	0	14	28,976	99

Data provided by the Contract Counties and collected from the California Incident Data and Statistics (CalStats) database.

Table 7. (continued) Number of Fires and Acres Burned by Cause and by Size in Contract Counties

Number of Fires by Size

Contract Counties	Total	A< .25 acres or <	B .26-9.99 acres	C 10-99 acres	D 100-299 acres	E 300-999 acres	F 1000-4999 acres	G 5000 acres >
Kern	146	53	63	24	4	0	1	1
Los Angeles	140	41	84	7	5	2	1	0
Marin	3	3	0	0	0	0	0	0
Orange	45	33	7	2	0	0	0	3
Santa Barbara	73	2	62	7	1	1	0	0
Ventura	59	40	13	2	1	2	1	0
TOTAL	466	172	229	42	11	5	3	4

Data provided by the Contract Counties and collected from the California Incident Data and Statistics (CalStats) database.

Table 8. Number of Fires by Cause, by Unit

	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
NORTHERN REGION													
Amador-El Dorado	302	19	10	102	24	31	3	26	5	0	9	42	31
Butte	157	15	4	28	6	23	29	12	2	1	2	21	14
Humboldt-Del Norte	63	9	5	3	8	5	7	7	0	0	0	9	10
Lassen-Modoc	104	15	15	18	7	9	2	5	1	0	2	18	12
Mendocino	109	5	6	14	1	8	56	3	1	0	0	12	3
Nevada-Yuba-Placer	318	31	15	39	47	37	29	29	6	0	1	38	46
San Mateo-Santa Cruz	137	22	4	35	7	10	14	15	0	0	2	13	15
Santa Clara	304	12	8	89	33	33	12	34	6	2	1	52	22
Shasta-Trinity	196	28	3	4	24	17	19	15	6	0	3	23	54
Siskiyou	217	40	9	56	19	20	11	11	3	0	10	13	25
Sonoma-Lake-Napa	101	0	3	9	10	7	33	4	0	1	1	23	10
Tehama-Glenn	112	6	0	23	11	22	20	10	3	0	0	9	8
TOTAL	2,120	202	82	420	197	222	235	171	33	4	31	273	250
SOUTHERN REGION													
Fresno-Kings	117	11	2	8	8	5	2	18	4	1	2	42	14
Madera-Mariposa	125	5	1	6	26	20	2	11	4	1	0	27	22
Riverside	89	13	2	8	21	13	2	5	2	0	0	17	6
San Benito-Monterey	184	20	2	53	22	15	3	15	4	0	2	15	33
San Bernardino	180	11	2	19	8	28	1	20	7	0	0	57	27
San Diego	230	25	5	7	12	25	1	41	17	0	10	61	26
San Luis Obispo	145	2	8	7	19	18	7	16	5	0	1	31	31
Tulare	248	20	5	49	19	26	10	26	2	0	1	64	26
Tuolumne-Calaveras	63	11	1	2	3	9	1	3	2	0	0	17	14
TOTAL	1,381	118	28	159	138	159	29	155	47	2	16	331	199
STATE TOTAL	3,501	320	110	579	335	381	264	326	80	6	47	604	449

Table 9. Number of Fires by Cause, by County

COUNTY	Total	Arson	Campfire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
Alameda	61	8	0	1	10	5	4	6	1	0	1	7	18
Alpine	0	0	0	0	0	0	0	0	0	0	0	0	0
Amador	73	8	1	24	8	7	0	7	0	0	2	7	9
Butte	153	15	4	28	6	23	25	12	2	1	2	21	14
Calaveras	119	7	2	24	10	14	5	18	1	0	0	23	15
Colusa	12	0	1	2	0	0	2	2	0	0	0	2	3
Contra Costa	52	9	2	0	10	7	5	3	0	0	0	6	10
Del Norte	13	5	4	3	0	0	0	0	0	0	0	1	0
El Dorado	197	9	9	76	13	17	1	16	5	0	6	28	17
Fresno	76	12	2	8	18	13	1	5	2	0	0	10	5
Glenn	16	0	0	1	0	2	11	1	0	0	0	0	1
Humboldt	91	10	11	15	7	9	2	5	1	0	2	17	12
Imperial	1	0	0	0	0	0	0	0	0	0	0	1	0
Inyo	17	2	0	2	2	0	0	1	0	0	0	8	2
Kings	13	1	0	0	3	0	1	0	0	0	0	7	1
Lake	80	10	2	8	8	9	11	6	3	0	1	11	11
Lassen	76	0	3	5	0	6	49	2	1	0	0	8	2
Madera	78	10	2	22	11	6	0	9	2	0	0	6	10
Mariposa	73	6	0	31	9	7	2	4	2	0	2	4	6
Mendocino	137	22	4	35	7	10	14	15	0	0	2	13	15
Merced	33	4	0	0	2	2	1	2	0	0	0	5	17
Modoc	26	5	0	7	1	1	7	1	0	0	0	3	1
Mono	0	0	0	0	0	0	0	0	0	0	0	0	0
Monterey	98	5	1	6	20	18	2	6	2	1	0	21	16
Napa	61	7	2	9	13	9	9	2	1	0	0	1	8
Nevada	115	2	2	49	15	8	8	10	2	0	0	13	6
Placer	115	7	2	27	12	13	1	13	3	2	1	26	8

Table 9. (continued) Number of Fires by Cause, by County

COUNTY	Total	Arson	Campfire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
Plumas	9	0	3	2	0	1	2	0	0	0	0	1	0
Riverside	230	25	5	7	12	25	1	41	17	0	10	61	26
Sacramento	25	0	0	1	3	6	2	3	0	0	1	5	4
San Benito	27	0	0	0	6	2	0	5	2	0	0	6	6
San Bernardino	100	9	2	6	6	5	2	17	4	1	2	34	12
San Diego	179	11	2	19	8	28	1	20	7	0	0	56	27
San Francisco	0	0	0	0	0	0	0	0	0	0	0	0	0
San Joaquin	33	4	1	2	0	5	7	0	0	0	1	8	5
San Luis Obispo	145	2	8	7	19	18	7	16	5	0	1	31	31
San Mateo	18	2	0	0	3	2	2	1	0	0	0	3	5
Santa Clara	59	8	1	2	4	4	4	6	5	0	1	7	17
Santa Cruz	45	7	5	3	5	3	5	6	0	0	0	6	5
Shasta	181	29	8	47	16	18	6	11	2	0	8	13	23
Sierra	0	0	0	0	0	0	0	0	0	0	0	0	0
Siskiyou	101	0	3	9	10	7	33	4	0	1	1	23	10
Solano	21	3	0	3	3	3	1	1	0	0	0	2	5
Sonoma	129	11	10	13	22	14	5	13	2	0	0	22	17
Stanislaus	33	4	0	1	1	2	2	2	0	0	0	14	7
Sutter	0	0	0	0	0	0	0	0	0	0	0	0	0
Tehama	98	6	0	22	11	20	11	9	3	0	0	9	7
Trinity	36	11	1	9	3	2	5	0	1	0	2	0	2
Tulare	63	11	1	2	3	9	1	3	2	0	0	17	14
Tuolumne	94	10	2	24	8	7	2	6	1	0	1	24	9
Yolo	15	0	0	4	1	2	1	5	0	0	0	0	2
Yuba	74	3	4	13	6	12	3	11	1	0	0	13	8
STATE TOTAL	3,501	320	110	579	335	381	264	326	80	6	47	604	449

Contract County statistics can be found in Table 7.

Table 10. Number of Fires and Acres Burned by Cause — Detailed

CAL FIRE Wildland Fire Cause	Incident Count	% of Total Incident Count	Incident Count Acres Burned => 10	Acres Burned	% of Total Acres Burned
ARSON	**320**	**9%**	**24**	**44,609**	**3%**
HOT START	**120**		**8**	**1,049**	
IGNITABLE LIQUID	**2**		**1**	**21**	
INCENDIARY DEVICE	**26**		**0**	**24**	
OTHER	**28**		**2**	**228**	
UNDETERMINED	**144**		**13**	**43,287**	
CAMPFIRE	**110**	**3%**	**3**	**421**	**0%**
NO PERMIT	**43**		**1**	**228**	
OTHER	18		1	201	
PROPER CLEARANCE	7		0	1	
TOOLS PRESENT	1		0	1	
UNDETERMINED	17		0	25	
PERMIT	**3**		**0**	**0**	
OTHER	1		0	0	
PROPER CLEARANCE	1		0	0	
UNDETERMINED	1		0	0	
UNDETERMINED	**64**		**2**	**193**	
DEBRIS BURNING	**579**	**17%**	**21**	**1,471**	**0%**
COMMERCIAL USE	**37**		**1**	**61**	
NO PERMIT/PROPER CLEARANCES	14		0	14	
NO PERMIT/TOOLS PRESENT	4		1	18	
PERMIT/PROPER CLEARANCES	7		0	7	
PERMIT/TOOLS PRESENT	4		0	16	
UNDETERMINED	8		0	6	
OTHER	**40**		**3**	**321**	
RESIDENTIAL USE	**460**		**15**	**1,011**	
NO PERMIT/PROPER CLEARANCES	157		5	277	
NO PERMIT/TOOLS PRESENT	65		1	58	
PERMIT/PROPER CLEARANCES	68		2	98	
PERMIT/TOOLS PRESENT	90		2	100	
UNDETERMINED	80		5	478	
UNDETERMINED	**42**		**2**	**78**	
ELECTRICAL POWER	**335**	**10%**	**31**	**59,334**	**4%**
ANIMALS	**27**		**7**	**437**	
HARDWARE	**52**		**2**	**71**	
LINE SLAP	**33**		**2**	**2,235**	
LINES DOWN	**107**		**11**	**909**	
OTHER	**47**		**4**	**214**	
UNDETERMINED	**26**		**0**	**55**	
VEGETATION CONTACT	**43**		**5**	**55,413**	

Table 10. (continued) Number of Fires and Acres Burned by Cause — Detailed

CAL FIRE Wildland Fire Cause	Incident Count	% of Total Incident Count	Incident Count Acres Burned => 10	Acres Burned	% of Total Acres Burned
EQUIPMENT USE	**381**	**11%**	**38**	**12,968**	**1%**
COMMERCIAL USE	**88**		**10**	**5,385**	
MOBILE EQUIPMENT/CHAFF	2		0	2	
MOBILE EQUIPMENT/HOT EXHAUST	4		1	20	
MOBILE EQUIPMENT/MECHANICAL	10		1	45	
MOBILE EQUIPMENT/ROCK STRIKE	25		3	140	
OTHER	7		1	21	
PORTABLE EQUIPMENT/CHAFF	1		0	0	
PORTABLE EQUIPMENT/HOT EXHAUST	4		0	1	
PORTABLE EQUIPMENT/MECHANICAL	1		0	1	
PORTABLE EQUIPMENT/ROCK STRIKE	8		1	13	
PORTABLE EQUIPMENT/WELDING/GRINDING	13		3	5,127	
UNDETERMINED	13		0	15	
NON-COMMERCIAL USE	**242**		**25**	**7,439**	
MOBILE EQUIPMENT/CHAFF	10		1	121	
MOBILE EQUIPMENT/HOT EXHAUST	10		1	40	
MOBILE EQUIPMENT/MECHANICAL	20		2	60	
MOBILE EQUIPMENT/ROCK STRIKE	70		7	634	
OTHER	16		2	45	
PORTABLE EQUIPMENT/CHAFF	2		0	5	
PORTABLE EQUIPMENT/HOT EXHAUST	13		1	35	
PORTABLE EQUIPMENT/MECHANICAL	17		1	31	
PORTABLE EQUIPMENT/ROCK STRIKE	17		1	45	
PORTABLE EQUIPMENT/WELDING/GRINDING	49		5	3,345	
UNDETERMINED	18		4	3,078	
OTHER	**22**		**2**	**115**	
UNDETERMINED	**29**		**1**	**27**	
LIGHTNING	**264**	**8%**	**65**	**1,159,009**	**79%**
MISCELLANEOUS	**326**	**9%**	**32**	**39,523**	**3%**
EXPLOSIVE DEVICE	**1**		**1**	**512**	
EXPOSURE (STRUCTURE)	**3**		**1**	**1,710**	
FIREWORKS	**56**		**5**	**182**	
DANGEROUS	31		4	138	
SAFE AND SANE	2		0	0	
UNDETERMINED	23		1	44	
GLASS REFRACTION	**2**		**0**	**1**	
OTHER	**200**		**14**	**34,616**	

Table 10. (continued) Number of Fires and Acres Burned by Cause — Detailed

CAL FIRE Wildland Fire Cause	Incident Count	% of Total Incident Count	Incident Count Acres Burned => 10	Acres Burned	% of Total Acres Burned
SHOOTING	**31**		**10**	**2,427**	
AMMUNITION/COPPER JACKET	5		1	128	
AMMUNITION/LEAD	2		1	109	
AMMUNITION/STEEL CORE	1		0	2	
OTHER	1		0	2	
TARGET/EXPLODING	2		0	2	
TARGET/METAL	8		1	39	
TARGET/OTHER	2		1	15	
TARGET/ROCK	3		2	1,859	
UNDETERMINED	7		4	271	
SPONTANEOUS COMBUSTION	**33**		**1**	**75**	
PLAYING WITH FIRE	**80**	**2%**	**3**	**111**	**0%**
10-13 YEARS OLD	**7**		**0**	**2**	
14+ YEARS OLD	**15**		**1**	**27**	
5-9 YEARS OLD	**11**		**0**	**5**	
UNDETERMINED	**47**		**2**	**77**	
RAILROAD	**6**	**0%**	**0**	**2**	**0%**
MECHANICAL	**2**		**0**	**1**	
UNDETERMINED	**4**		**0**	**1**	
SMOKING	**47**	**1%**	**2**	**818**	**0%**
OTHER	**4**		**0**	**1**	
SMOKING MATERIAL	**30**		**1**	**758**	
SMOKING PARAPHERNALIA	**4**		**0**	**1**	
UNDETERMINED	**9**		**1**	**58**	
UNDETERMINED	**604**	**17%**	**52**	**112,949**	**8%**
VEHICLE	**449**	**13%**	**51**	**27,668**	**2%**
CHAFF	**10**		**0**	**21**	
EXHAUST	**97**		**10**	**9,693**	
EXPOSURE (VEHICLE)	**3**		**2**	**802**	
MECHANICAL	**81**		**11**	**6,415**	
OTHER	**51**		**6**	**1,582**	
TRAFFIC COLLISION	**46**		**5**	**484**	
UNDETERMINED	**161**		**17**	**8,671**	
TOTAL WILDLAND FIRE INCIDENTS	**3,501**	**100%**	**322**	**1,458,881**	**100%**

Table 11. Number of Fires by Size, by Unit

		A	B	C	D	E	F	G
	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
NORTHERN REGION								
Amador-El Dorado	302	177	112	10	0	2	0	1
Butte	157	53	81	12	6	2	0	3
Humboldt-Del Norte	63	38	21	1	1	0	0	2
Lassen-Modoc	104	62	39	2	1	0	0	0
Mendocino	109	38	59	10	0	0	0	2
Nevada-Yuba-Placer	318	126	157	17	4	1	4	9
San Mateo-Santa Cruz	137	49	78	5	2	1	1	1
Santa Clara	304	138	156	7	1	1	1	0
Shasta-Trinity	196	44	111	27	6	2	2	4
Siskiyou	217	77	126	8	3	1	0	2
Sonoma-Lake-Napa	101	60	35	5	0	1	0	0
Tehama-Glenn	112	30	64	10	3	1	1	3
TOTAL	2,120	892	1,039	114	27	12	9	27
SOUTHERN REGION								
Fresno-Kings	117	55	54	4	2	0	0	2
Madera-Mariposa	125	44	62	11	3	2	1	2
Riverside	89	20	56	10	0	0	1	2
San Benito-Monterey	184	59	102	11	7	2	2	1
San Bernardino	180	82	92	5	1	0	0	0
San Diego	230	64	144	17	2	1	0	2
San Luis Obispo	145	51	75	8	4	4	3	0
Tulare	248	91	141	13	0	0	3	0
Tuolumne-Calaveras	63	17	39	3	2	0	1	1
TOTAL	1,381	483	765	82	21	9	11	10
STATE TOTAL	3,501	1,375	1,804	196	48	21	20	37

Table 12. Number of Fires by Size, by County

		A	B	C	D	E	F	G
COUNTY	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
Alameda	61	8	38	8	4	1	1	1
Alpine	0	0	0	0	0	0	0	0
Amador	73	47	25	1	0	0	0	0
Butte	153	53	80	11	5	2	0	2
Calaveras	119	41	69	7	0	0	2	0
Colusa	12	5	2	2	1	1	1	0
Contra Costa	52	6	33	11	0	1	1	0
Del Norte	13	10	3	0	0	0	0	0
El Dorado	197	119	73	5	0	0	0	0
Fresno	76	18	47	8	0	0	1	2
Glenn	16	2	7	3	1	1	0	2
Humboldt	91	52	36	2	1	0	0	0
Imperial	1	1	0	0	0	0	0	0
Inyo	17	10	7	0	0	0	0	0
Kings	13	2	9	2	0	0	0	0
Lake	80	39	35	4	0	0	1	1
Lassen	76	30	40	4	0	0	0	2
Madera	78	32	37	3	4	1	0	1
Mariposa	73	22	45	4	2	0	0	0
Mendocino	137	49	78	5	2	1	1	1
Merced	33	5	20	4	1	1	2	0
Modoc	26	5	15	6	0	0	0	0
Mono	0	0	0	0	0	0	0	0
Monterey	98	38	46	8	3	1	0	2
Napa	61	20	34	3	0	0	0	4
Nevada	115	50	64	0	0	1	0	0
Placer	115	62	50	3	0	0	0	0

Table 12. (continued) Number of Fires by Size, by County

		A	B	C	D	E	F	G
SOUTHERN REGION	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
Plumas	9	3	4	0	1	0	0	1
Riverside	230	64	144	17	2	1	0	2
Sacramento	25	6	13	3	0	2	0	1
San Benito	27	6	16	3	0	1	1	0
San Bernardino	100	45	47	4	2	0	0	2
San Diego	179	81	92	5	1	0	0	0
San Francisco	0	0	0	0	0	0	0	0
San Joaquin	33	18	8	5	1	0	0	1
San Luis Obispo	145	51	75	8	4	4	3	0
San Mateo	18	10	7	0	0	0	0	1
Santa Clara	59	24	30	4	0	0	0	1
Santa Cruz	45	28	14	1	1	0	0	1
Shasta	181	62	108	7	2	1	0	1
Sierra	0	0	0	0	0	0	0	0
Siskiyou	101	60	35	5	0	1	0	0
Solano	21	3	13	2	1	0	1	1
Sonoma	129	56	65	3	2	0	1	2
Stanislaus	33	5	20	6	1	0	0	1
Sutter	0	0	0	0	0	0	0	0
Tehama	98	28	58	8	2	0	1	1
Trinity	36	15	18	1	1	0	0	1
Tulare	63	17	39	3	2	0	1	1
Tuolumne	94	38	55	0	0	0	1	0
Yolo	15	3	8	3	0	0	0	1
Yuba	74	26	42	4	1	0	1	0
STATE TOTAL	3,501	1,375	1,804	196	48	21	20	37

Contract County statistics can be found in Table 7.

Table 13. Number of Acres Burned by Cause, by Unit

	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
NORTHERN REGION													
Amador-El Dorado	6,788	3	1	136	99	5,105	8	582	1	0	790	35	28
Butte	207,320	25	4	23	8	50	206,925	3	2	1	0	208	71
Humboldt-Del Norte	84,994	28	6	1	3	0	84,943	2	0	0	0	6	5
Lassen-Modoc	188	7	8	33	4	116	2	5	1	0	1	6	5
Mendocino	13,860	5	3	97	5	43	84	2	0	0	0	13,594	27
Nevada-Yuba-Placer	379,767	41,284	4	51	217	218	269,749	1,881	6	0	0	65,885	472
San Mateo-Santa Cruz	32,201	16	171	70	3	167	29,932	1,118	0	0	2	8	714
Santa Clara	2,469	1,414	2	64	24	68	713	62	3	1	1	97	20
Shasta-Trinity	394,496	307	2	3	419	68	392,896	226	14	0	1	23	537
Siskiyou	100,006	293	3	399	53,902	32	45,002	18	11	0	6	299	41
Sonoma-Lake-Napa	382	0	0	21	9	6	20	1	0	0	1	112	212
Tehama-Glenn	70,769	5	0	342	1,377	107	68,694	38	4	0	0	174	28
TOTAL	1,293,240	43,387	204	1,240	56,070	5,980	1,098,968	3,938	42	2	802	80,447	2,160
SOUTHERN REGION													
Fresno-Kings	7,715	13	1	12	15	4	0	3,505	2	0	2	28	4,133
Madera-Mariposa	55,140	114	195	1	622	326	44,530	8	8	0	0	1,603	7,733
Riverside	54,556	37	0	7	109	125	2,150	29,671	4	0	0	22,451	2
San Benito-Monterey	14,457	727	0	103	2,363	108	3,983	198	4	0	7	5,912	1,052
San Bernardino	386	7	0	6	3	14	0	8	3	0	0	322	23
San Diego	7,658	274	8	2	14	51	4	169	35	0	6	292	6,803
San Luis Obispo	8,576	1	10	53	74	186	407	1,783	0	0	0	538	5,524
Tulare	6,692	28	2	47	62	6,166	6	16	1	0	1	174	189
Tuolumne-Calaveras	10,461	21	1	0	2	6	8,961	227	12	0	0	1,182	49
TOTAL	165,641	1,222	217	231	3,264	6,986	60,041	35,585	69	0	16	32,502	25,508
STATE TOTAL	1,458,881	44,609	421	1,471	59,334	12,966	1,159,009	39,523	111	2	818	112,949	27,668

Table 14. Number of Acres Burned by Cause, County

COUNTY	Total	Arson	Campfire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Railroad	Smoking	Undet.	Vehicle
Alameda	25,141	14	0	1	364	16	24,271	140	2	0	1	8	324
Alpine	0	0	0	0	0	0	0	0	0	0	0	0	0
Amador	87	1	0	13	9	3	0	3	0	0	47	2	9
Butte	173,004	25	4	23	8	50	172,609	3	2	1	0	208	71
Calaveras	3,546	20	1	28	49	3,255	4	13	0	0	0	79	97
Colusa	878	0	0	19	0	0	134	22	0	0	0	564	139
Contra Costa	3,490	48	2	0	42	42	3,277	38	0	0	0	10	31
Del Norte	4	1	2	1	0	0	0	0	0	0	0	0	0
El Dorado	183	2	1	27	21	47	0	45	1	0	2	19	18
Fresno	54,468	36	0	7	65	125	2,121	29,671	4	0	0	22,438	1
Glenn	34,428	0	0	12	0	7	34,393	8	0	0	0	0	8
Humboldt	183	6	6	31	4	116	2	5	1	0	1	6	5
Imperial	0	0	0	0	0	0	0	0	0	0	0	0	0
Inyo	7	2	0	0	0	0	0	1	0	0	0	4	0
Kings	88	0	0	0	44	0	29	0	0	0	0	13	2
Lake	18,595	8	0	2	4	10	18,480	2	3	0	0	39	47
Lassen	13,679	0	2	2	0	41	32	2	0	0	0	13,591	9
Madera	6,914	615	0	46	16	12	0	177	2	0	0	5,906	140
Mariposa	542	8	0	58	155	91	192	6	2	0	7	2	21
Mendocino	32,201	16	171	70	3	167	29,932	1,118	0	0	2	8	714
Merced	7,001	104	0	0	2,192	5	3,791	15	0	0	0	4	890
Modoc	177	5	0	94	5	1	52	0	0	0	0	2	18
Mono	0	0	0	0	0	0	0	0	0	0	0	0	0
Monterey	52,762	114	195	2	571	323	44,530	2	1	0	0	115	6,909
Napa	213,211	41,268	0	5	27	28	132,466	5	1	0	0	39,343	68
Nevada	779	0	0	39	7	7	710	6	1	0	0	6	3
Placer	121	2	0	16	10	48	0	28	1	1	1	11	3

Table 14. (continued) Number of Acres Burned by Cause, by County

COUNTY	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
Plumas	34,286	0	1	1	0	1	34,282	0	0	0	0	1	0
Riverside	7,658	274	8	2	14	51	4	169	35	0	6	292	6,803
Sacramento	6,426	0	0	6	69	5,053	8	534	0	0	741	14	1
San Benito	2,378	0	0	0	51	3	0	5	7	0	0	1,488	824
San Bernardino	7,708	11	1	12	15	4	0	3,504	2	0	2	24	4,133
San Diego	386	7	0	6	3	14	0	8	3	0	0	322	23
San Francisco	0	0	0	0	0	0	0	0	0	0	0	0	0
San Joaquin	24,598	33	0	91	0	47	24,353	0	0	0	0	2	72
San Luis Obispo	8,576	1	10	53	74	186	407	1,783	0	0	0	538	5,524
San Mateo	22,698	5	0	0	1	0	22,685	0	0	0	0	5	2
Santa Clara	165,309	10	0	0	13	9	165,203	48	12	0	0	3	11
Santa Cruz	62,296	23	7	1	2	0	62,259	1	0	0	0	1	2
Shasta	54,878	189	3	381	53,898	31	5	18	10	0	4	299	40
Sierra	0	0	0	0	0	0	0	0	0	0	0	0	0
Siskiyou	382	0	0	21	9	6	20	1	0	0	1	112	212
Solano	22,648	2	0	2	9	6	20,574	1,837	0	0	0	121	97
Sonoma	82,478	7	4	12	171	169	56,270	8	2	0	0	25,818	17
Stanislaus	176,261	205	0	1	0	2	175,793	1	0	0	0	76	183
Sutter	0	0	0	0	0	0	0	0	0	0	0	0	0
Tehama	36,374	5	0	330	1,377	99	34,335	30	4	0	0	174	20
Trinity	45,129	104	0	18	4	2	44,997	0	1	0	2	0	1
Tulare	10,461	21	1	0	2	6	8,961	227	12	0	0	1,182	49
Tuolumne	2,935	5	1	18	13	2,865	1	2	1	0	1	19	9
Yolo	41,956	0	0	10	5	4	41,825	8	0	0	0	0	104
Yuba	1,571	1,412	1	10	8	14	2	29	1	0	0	80	14
STATE TOTAL	1,458,881	44,609	421	1,471	59,334	12,966	1,159,009	39,523	111	2	818	112,949	27,668

Contract County statistics can be found in Table 7.

Table 15. Number of Acres Burned by Vegetation Type, by Unit

	Total	Brush	Grass	Timber	Woodland	Other
NORTHERN REGION						
Amador-El Dorado	6,788	41	6,677	16	54	0
Butte	207,320	47	336	206,935	2	0
Humboldt-Del Norte	84,994	6	29	84,959	0	0
Lassen-Modoc	188	0	141	45	2	0
Mendocino	13,860	25	7,108	6,658	69	0
Nevada-Yuba-Placer	379,767	370,700	3,542	5,516	9	0
San Mateo-Santa Cruz	32,201	4	1,559	30,637	1	0
Santa Clara	2,469	1,331	378	749	11	0
Shasta-Trinity	394,496	39	394,438	9	10	0
Siskiyou	100,006	45	54,897	45,030	34	0
Sonoma-Lake-Napa	382	249	47	59	27	0
Tehama-Glenn	70,769	34,692	2,715	33,359	3	0
TOTAL	1,293,240	407,179	471,867	413,972	222	0
SOUTHERN REGION						
Fresno-Kings	7,715	20	7,691	2	2	0
Madera-Mariposa	55,140	4	55,132	3	1	0
Riverside	54,556	2	2,491	52,037	26	0
San Benito-Monterey	14,457	8	8,636	5,811	2	0
San Bernardino	386	276	108	2	0	0
San Diego	7,658	4,490	3,167	1	0	0
San Luis Obispo	8,576	2,107	6,467	2	0	0
Tulare	6,692	10	6,645	18	19	0
Tuolumne-Calaveras	10,461	0	1,499	8,962	0	0
TOTAL	165,641	6,917	91,836	66,838	50	0
STATE TOTAL	1,458,881	414,096	563,703	480,810	272	0

Table 16. Number of Acres Burned by Vegetation Type, by County

COUNTY	Total	Brush	Grass	Timber	Woodland	Other
Alameda	25,141	0	25,135	6	0	0
Alpine	0	0	0	0	0	0
Amador	87	1	32	3	51	0
Butte	173,004	46	337	172,619	2	0
Calaveras	3,546	6	3,511	11	18	0
Colusa	878	152	726	0	0	0
Contra Costa	3,490	25	3,464	1	0	0
Del Norte	4	0	2	2	0	0
El Dorado	183	19	148	12	4	0
Fresno	54,468	2	2,403	52,037	26	0
Glenn	34,428	0	1,071	33,354	3	0
Humboldt	183	0	138	43	2	0
Imperial	0	0	0	0	0	0
Inyo	7	4	3	0	0	0
Kings	88	0	88	0	0	0
Lake	18,595	15,366	96	3,133	0	0
Lassen	13,679	4	7,023	6,614	38	0
Madera	6,914	2	1,112	5,799	1	0
Mariposa	542	5	523	14	0	0
Mendocino	32,201	4	1,559	30,637	1	0
Merced	7,001	0	7,001	0	0	0
Modoc	177	21	83	43	30	0
Mono	0	0	0	0	0	0
Monterey	52,762	4	52,754	3	1	0
Napa	213,211	213,067	133	8	3	0
Nevada	779	5	39	725	10	0
Placer	121	4	105	10	2	0

Table 16. (continued) Number of Acres Burned by Vegetation Type, by County

COUNTY	Total	Brush	Grass	Timber	Woodland	Other
Plumas	34,286	0	1	34,283	2	0
Riverside	7,658	4,490	3,167	1	0	0
Sacramento	6,426	21	6,405	0	0	0
San Benito	2,378	0	2,377	1	0	0
San Bernardino	7,708	16	7,688	2	2	0
San Diego	386	276	108	2	0	0
San Francisco	0	0	0	0	0	0
San Joaquin	24,598	0	24,598	0	0	0
San Luis Obispo	8,576	2,107	6,467	2	0	0
San Mateo	22,698	5	4	22,689	0	0
Santa Clara	165,309	14	165,283	2	10	0
Santa Cruz	62,296	1	26	62,269	0	0
Shasta	54,878	44	54,791	24	19	0
Sierra	0	0	0	0	0	0
Siskiyou	382	249	47	60	26	0
Solano	22,648	20,575	2,073	0	0	0
Sonoma	82,478	79,715	384	2,373	6	0
Stanislaus	176,261	1	176,260	0	0	0
Sutter	0	0	0	0	0	0
Tehama	36,374	34,692	1,644	38	0	0
Trinity	45,129	1	108	45,006	14	0
Tulare	10,461	0	1,499	8,962	0	0
Tuolumne	2,935	4	2,924	6	1	0
Yolo	41,956	41,825	129	2	0	0
Yuba	1,571	1,323	234	14	0	0
STATE TOTAL	1,458,881	414,096	563,703	480,810	272	0

Contract County statistics can be found in Table 7.

Table 17. Dollar Damage by Cause, by Unit

	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
NORTHERN REGION													
Amador-El Dorado	$3,644,362	$0	$3,000	$1,010,406	$58,100	$1,511,500	$0	$856,002	$0	$0	$0	$6,402	$198,952
Butte	$38,209,457	$3,002	$500	$0	$0	$81,054	$38,000,000	$2,300	$1	$0	$0	$109,100	$13,500
Humboldt-Del Norte	$5,000,200	$0	$0	$0	$0	$200	$5,000,000	$0	$0	$0	$0	$0	$0
Lassen-Modoc	$944,850	$0	$1,000	$305,500	$20,100	$595,850	$0	$21,300	$0	$0	$0	$0	$1,100
Mendocino	$1,505,832	$0	$2,000	$110	$0	$2,000	$1,210	$0	$0	$0	$0	$1,500,512	$0
Nevada-Yuba-Placer	$2,748,063,917	$300,010,000	$2,100	$501	$640,260	$229,100	$738,070,000	$3,474,205	$1,000	$0	$5,000	$1,705,281,250	$350,501
San Mateo-Santa Cruz	$246,704	$55,000	$3,000	$100	$10,000	$18,000	$604	$140,000	$0	$0	$0	$20,000	$0
Santa Clara	$2,989,562	$2,510,000	$1,000	$74,252	$34,400	$219,710	$0	$63,400	$200	$0	$0	$9,700	$76,900
Shasta-Trinity	$543,977,107	$3,325	$0	$0	$58,150	$18,550	$543,585,200	$101,650	$0	$0	$0	$2,002	$208,230
Siskiyou	$117,483,850	$323,100	$0	$30,000	$50,390,650	$612,800	$66,000,000	$600	$0	$0	$23,000	$94,000	$9,700
Sonoma-Lake-Napa	$686,650	$0	$50	$2,500	$354,500	$5,300	$0	$300,000	$0	$0	$500	$10,300	$13,500
Tehama-Glenn	$6,745,456	$1,150	$0	$67,000	$28,700	$403,972	$6,206,200	$5,350	$1,010	$0	$0	$26,950	$5,124
TOTAL	$3,469,497,947	$302,905,577	$12,650	$1,490,369	$51,594,860	$3,698,036	$1,396,863,214	$4,964,807	$2,211	$0	$28,500	$1,707,060,216	$877,507
SOUTHERN REGION													
Fresno-Kings	$90,131,914	$6,002	$0	$0	$1,000	$2,500	$0	$90,031,700	$0	$0	$0	$4,212	$86,500
Madera-Mariposa	$379,795	$1,830	$0	$0	$77,850	$1,705	$0	$200	$20,000	$0	$0	$252,400	$25,810
Riverside	$380,024,372	$520	$8,000	$56,000	$6,292	$15,100	$263,630	$300	$0	$0	$0	$379,673,930	$600
San Benito-Monterey	$35,606,255	$1,152,250	$0	$357,230	$215,960	$52,350	$4,000	$5,000	$0	$0	$0	$33,793,950	$25,515
San Bernardino	$1,049,225	$1,000	$0	$2,600	$12,750	$4,800	$0	$4,125	$250	$0	$0	$758,200	$265,500
San Diego	$8,066,503	$50,702	$3,000	$0	$62,000	$19,500	$0	$25,601	$500	$0	$100	$7,000	$7,898,100
San Luis Obispo	$577,022	$0	$50	$3,000	$8,120	$62,000	$12,000	$37,300	$1,050	$0	$0	$12,652	$440,850
Tulare	$1,043,373	$12,100	$100	$157,013	$22,450	$481,595	$400	$153,390	$0	$0	$0	$143,071	$73,254
Tuolumne-Calaveras	$278,541,759	$98	$0	$0	$0	$350	$278,400,000	$100	$260	$0	$0	$93,000	$47,951
TOTAL	$795,420,218	$1,224,502	$11,150	$575,843	$406,422	$639,900	$278,680,030	$90,257,716	$22,060	$0	$100	$414,738,415	$8,864,080
STATE TOTAL	$4,264,918,165	$304,130,079	$23,800	$2,066,212	$52,001,282	$4,337,936	$1,675,543,244	$95,222,523	$24,271	$0	$28,600	$2,121,798,631	$9,741,587

*Definition of what Dollar Damage entails can be found in the Glossary.

Table 18. Dollar Damage by Cause, by County

COUNTY	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
Alameda	$101,020,955	$2,625	$0	$0	$1,300	$500	$100,819,200	$100,000	$0	$0	$0	$0	$97,330
Alpine	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Amador	$19,300	$0	$0	$200	$100	$0	$0	$11,000	$0	$0	$0	$0	$8,000
Butte	$8,209,457	$3,002	$500	$0	$0	$81,054	$8,000,000	$2,300	$1	$0	$0	$109,100	$13,500
Calaveras	$834,351	$11,300	$100	$156,683	$14,950	$397,475	$0	$150,720	$0	$0	$0	$30,771	$72,352
Colusa	$140,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$40,000	$100,500
Contra Costa	$99,700	$700	$0	$0	$850	$15,000	$46,000	$1,650	$0	$0	$0	$0	$35,500
Del Norte	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
El Dorado	$1,090,562	$0	$3,000	$10,206	$44,500	$11,500	$0	$825,002	$0	$0	$0	$5,402	$190,952
Fresno	$380,024,372	$520	$8,000	$56,000	$6,292	$15,100	$263,630	$300	$0	$0	$0	$379,673,930	$600
Glenn	$4,244,900	$0	$0	$22,400	$0	$14,500	$4,204,400	$3,000	$0	$0	$0	$0	$600
Humboldt	$944,850	$0	$1,000	$305,500	$20,100	$595,850	$0	$21,300	$0	$0	$0	$0	$1,100
Imperial	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Inyo	$4	$2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2	$0
Kings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lake	$82,183,550	$10,000	$100	$0	$5,000	$5,500	$81,000,000	$1,000,200	$1,000	$0	$5,000	$750	$156,000
Lassen	$1,503,732	$0	$0	$10	$0	$2,000	$1,210	$0	$0	$0	$0	$1,500,512	$0
Madera	$34,923,990	$700,000	$0	$356,230	$2,060	$50,000	$0	$4,800	$0	$0	$0	$33,790,700	$20,200
Mariposa	$670,500	$452,050	$0	$1,000	$203,800	$2,150	$4,000	$0	$0	$0	$0	$3,000	$4,500
Mendocino	$246,704	$55,000	$3,000	$100	$10,000	$18,000	$604	$140,000	$0	$0	$0	$20,000	$0
Merced	$11,765	$200	$0	$0	$10,100	$200	$0	$200	$0	$0	$0	$250	$815
Modoc	$100	$0	$0	$100	$0	$0	$0	$0	$0	$0	$0	$0	$0
Mono	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Monterey	$70,490	$1,830	$0	$0	$54,850	$1,700	$0	$100	$0	$0	$0	$2,000	$10,010
Napa	$1,129,079,102	$300,000,000	$0	$1	$12,000	$200,100	$3,550,000	$0	$0	$0	$0	$825,300,000	$17,001
Nevada	$152,362	$0	$0	$73,452	$100	$1,510	$0	$60,000	$0	$0	$0	$7,700	$9,600
Placer	$311,400	$10,000	$0	$800	$20,300	$209,600	$0	$3,200	$200	$0	$0	$2,000	$65,300

*Definition of what Dollar Damage entails can be found in the Glossary.

COUNTY	Total	Arson	Camp-fire	Debris Burning	Elec. Power	Equip. Use	Ltng.	Misc.	P-W-F	Rail-road	Smoking	Undet.	Vehicle
Plumas	$30,002,000	$0	$2,000	$0	$0	$0	$30,000,000	$0	$0	$0	$0	$0	$0
Riverside	$8,066,503	$50,702	$3,000	$0	$62,000	$19,500	$0	$25,601	$500	$0	$100	$7,000	$7,898,100
Sacramento	$1,533,500	$0	$0	$0	$13,500	$1,500,000	$0	$20,000	$0	$0	$0	$0	$0
San Benito	$309,305	$0	$0	$0	$23,000	$5	$0	$100	$20,000	$0	$0	$250,400	$15,800
San Bernardino	$90,131,910	$6,000	$0	$0	$1,000	$2,500	$0	$90,031,700	$0	$0	$0	$4,210	$86,500
San Diego	$1,049,225	$1,000	$0	$2,600	$12,750	$4,800	$0	$4,125	$250	$0	$0	$758,200	$265,500
San Francisco	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
San Joaquin	$70,131,020	$0	$0	$1,000,000	$0	$9,020	$69,120,400	$0	$0	$0	$0	$1,200	$400
San Luis Obispo	$577,022	$0	$50	$3,000	$8,120	$62,000	$12,000	$37,300	$1,050	$0	$0	$12,652	$440,850
San Mateo	$3,000,100	$0	$0	$0	$0	$100	$3,000,000	$0	$0	$0	$0	$0	$0
Santa Clara	$304,571,052	$0	$0	$0	$56,000	$3,050	$304,480,000	$0	$0	$0	$0	$2,002	$30,000
Santa Cruz	$2,000,100	$0	$0	$0	$0	$100	$2,000,000	$0	$0	$0	$0	$0	$0
Shasta	$50,761,750	$103,000	$0	$19,000	$50,382,650	$132,800	$0	$600	$0	$0	$20,500	$94,000	$9,200
Sierra	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Siskiyou	$686,650	$0	$50	$2,500	$354,500	$5,300	$0	$300,000	$0	$0	$500	$10,300	$13,500
Solano	$224,590,500	$0	$0	$0	$0	$3,000	$222,300,000	$2,250,000	$0	$0	$0	$500	$37,000
Sonoma	$1,302,549,765	$0	$2,000	$500	$123,260	$500	$422,220,000	$224,005	$0	$0	$0	$879,940,000	$39,500
Stanislaus	$69,175,400	$700	$0	$0	$400	$100	$69,120,000	$100	$0	$0	$0	$9,100	$45,000
Sutter	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tehama	$2,500,556	$1,150	$0	$44,600	$28,700	$389,472	$2,001,800	$2,350	$1,010	$0	$0	$26,950	$4,524
Trinity	$66,722,100	$220,100	$0	$11,000	$8,000	$480,000	$66,000,000	$0	$0	$0	$2,500	$0	$500
Tulare	$278,541,759	$98	$0	$0	$0	$350	$278,400,000	$100	$260	$0	$0	$93,000	$47,951
Tuolumne	$189,002	$100	$0	$330	$7,100	$75,000	$0	$2,570	$0	$0	$0	$103,000	$902
Yolo	$9,520,500	$0	$0	$0	$500,000	$20,000	$9,000,000	$0	$0	$0	$0	$0	$500
Yuba	$2,525,800	$2,500,000	$1,000	$0	$14,000	$8,600	$0	$200	$0	$0	$0	$0	$2,000
STATE TOTAL	$4,264,918,165	$304,130,079	$23,800	$2,066,212	$52,001,282	$4,337,936	$1,675,543,244	$95,222,523	$24,271	$0	$28,600	$2,121,798,631	$9,741,587

Contract County statistics can be found in Table 7.

*Definition of what Dollar Damage entails can be found in the Glossary.

Table 19. Dollar Damage by Size, by Unit

		A	B	C	D	E	F	G
	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
NORTHERN REGION								
Amador-El Dorado	$3,644,362	$64,756	$825,106	$1,234,500	$0	$20,000	$0	$1,500,000
Butte	$38,209,457	$11,652	$80,805	$117,000	$0	$0	$0	$38,000,000
Humboldt-Del Norte	$5,000,200	$200	$0	$0	$0	$0	$0	$5,000,000
Lassen-Modoc	$944,850	$74,950	$869,400	$500	$0	$0	$0	$0
Mendocino	$1,505,832	$0	$3,222	$2,610	$0	$0	$0	$1,500,000
Nevada-Yuba-Placer	$2,748,063,917	$1,654,360	$891,557	$18,000	$0	$40,000	$2,550,000	$2,742,910,000
San Mateo-Santa Cruz	$246,704	$2,000	$224,704	$20,000	$0	$0	$0	$0
Santa Clara	$2,989,562	$130,802	$155,760	$203,000	$0	$0	$2,500,000	$0
Shasta-Trinity	$543,977,107	$7,602	$304,025	$80,280	$0	$6,000	$59,200	$543,520,000
Siskiyou	$117,483,850	$233,300	$1,211,550	$9,000	$20,000	$10,000	$0	$116,000,000
Sonoma-Lake-Napa	$686,650	$23,550	$663,100	$0	$0	$0	$0	$0
Tehama-Glenn	$6,745,456	$2,850	$464,232	$73,624	$59,350	$145,400	$0	$6,000,000
TOTAL	$3,469,497,947	$2,206,022	$5,693,461	$1,758,514	$79,350	$221,400	$5,109,200	$3,454,430,000
SOUTHERN REGION								
Fresno-Kings	$90,131,914	$16,510	$93,204	$1,000	$21,200	$0	$0	$90,000,000
Madera-Mariposa	$379,795	$12,215	$30,700	$24,530	$52,750	$9,600	$250,000	$0
Riverside	$380,024,372	$16,020	$61,492	$10,730	$0	$0	$263,630	$379,672,500
San Benito-Monterey	$35,606,255	$7,400	$1,012,355	$555,200	$381,300	$100,000	$10,000	$33,540,000
San Bernardino	$1,049,225	$795,025	$254,200	$0	$0	$0	$0	$0
San Diego	$8,066,503	$17,000	$88,903	$27,600	$8,000	$50,000	$0	$7,875,000
San Luis Obispo	$577,022	$6,850	$62,070	$65,600	$10,002	$500	$432,000	$0
Tulare	$1,043,373	$219,883	$227,490	$204,000	$0	$0	$392,000	$0
Tuolumne-Calaveras	$278,541,759	$14,600	$29,709	$7,450	$10,000	$0	$80,000	$278,400,000
TOTAL	$795,420,218	$1,105,503	$1,860,123	$896,110	$483,252	$160,100	$1,427,630	$789,487,500
STATE TOTAL	$4,264,918,165	$3,311,525	$7,553,584	$2,654,624	$562,602	$381,500	$6,536,830	$4,243,917,500

*Definition of what Dollar Damage entails can be found in the Glossary.

Table 20. Dollar Damage by Size, by County

		A	B	C	D	E	F	G
COUNTY	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
Alameda	$101,020,955	$2,500	$185,625	$13,630	$0	$0	$19,200	$100,800,000
Alpine	$0	$0	$0	$0	$0	$0	$0	$0
Amador	$19,300	$2,100	$17,200	$0	$0	$0	$0	$0
Butte	$8,209,457	$11,652	$80,805	$117,000	$0	$0	$0	$8,000,000
Calaveras	$834,351	$210,743	$44,608	$187,000	$0	$0	$392,000	$0
Colusa	$140,500	$100,500	$0	$0	$0	$40,000	$0	$0
Contra Costa	$99,700	$5,100	$31,950	$16,650	$0	$6,000	$40,000	$0
Del Norte	$0	$0	$0	$0	$0	$0	$0	$0
El Dorado	$1,090,562	$61,656	$807,906	$221,000	$0	$0	$0	$0
Fresno	$380,024,372	$16,020	$61,492	$10,730	$0	$0	$263,630	$379,672,500
Glenn	$4,244,900	$100	$19,400	$24,400	$55,600	$145,400	$0	$4,000,000
Humboldt	$944,850	$74,950	$869,400	$500	$0	$0	$0	$0
Imperial	$0	$0	$0	$0	$0	$0	$0	$0
Inyo	$4	$0	$4	$0	$0	$0	$0	$0
Kings	$0	$0	$0	$0	$0	$0	$0	$0
Lake	$82,183,550	$1,146,800	$36,750	$0	$0	$0	$0	$81,000,000
Lassen	$1,503,732	$0	$1,222	$2,510	$0	$0	$0	$1,500,000
Madera	$34,923,990	$5,800	$553,390	$350,000	$374,800	$100,000	$0	$33,540,000
Mariposa	$670,500	$1,400	$457,850	$204,750	$6,500	$0	$0	$0
Mendocino	$246,704	$2,000	$224,704	$20,000	$0	$0	$0	$0
Merced	$11,765	$200	$1,115	$450	$0	$0	$10,000	$0
Modoc	$100	$0	$0	$100	$0	$0	$0	$0
Mono	$0	$0	$0	$0	$0	$0	$0	$0
Monterey	$70,490	$11,910	$3,300	$2,530	$52,750	$0	$0	$0
Napa	$1,129,079,102	$218,000	$11,102	$0	$0	$0	$0	$1,128,850,000
Nevada	$152,362	$65,702	$86,660	$0	$0	$0	$0	$0
Placer	$311,400	$63,900	$44,500	$203,000	$0	$0	$0	$0

*Definition of what Dollar Damage entails can be found in the Glossary.

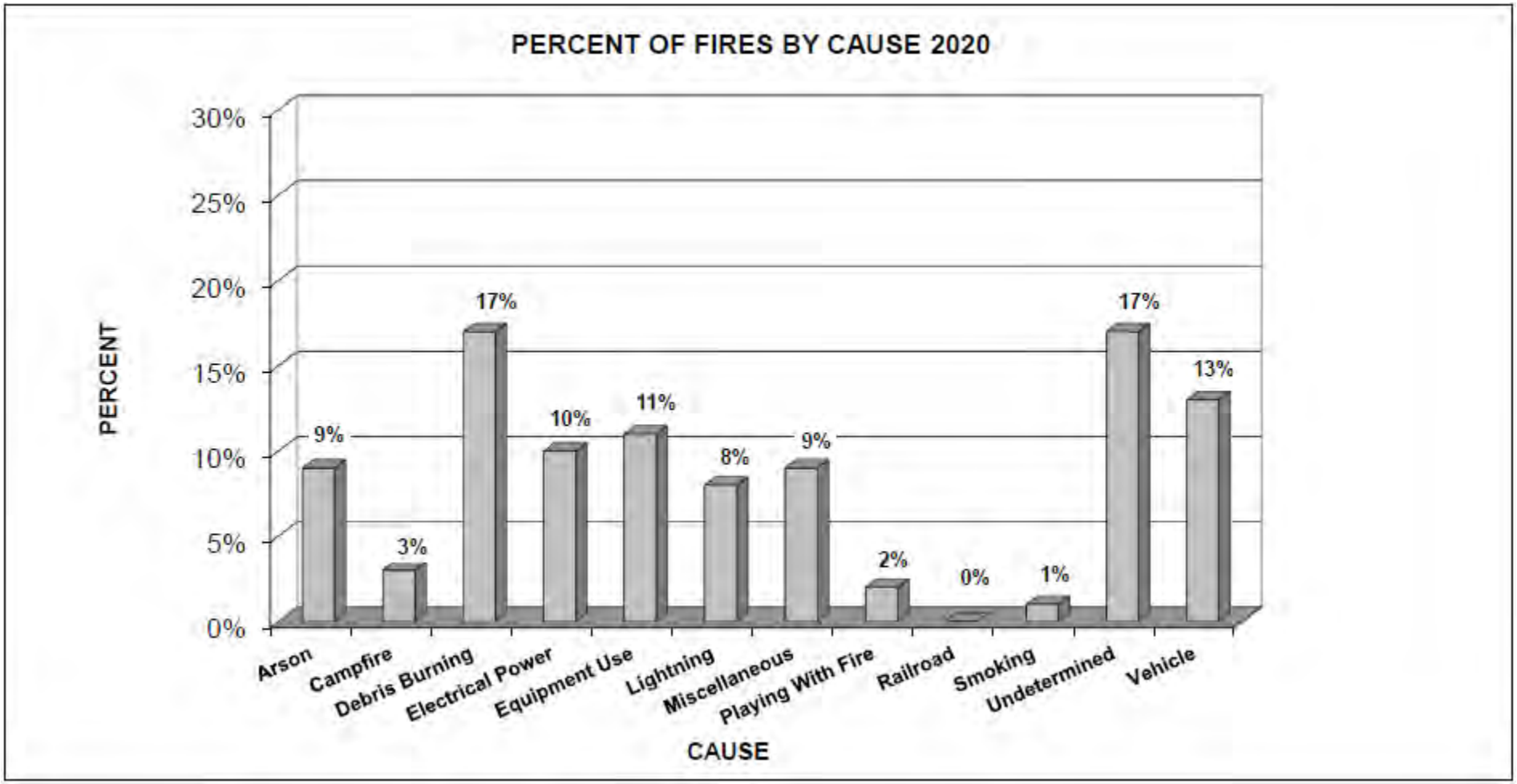
Table 20. (continued) Dollar Damage by Size, by County

		A	B	C	D	E	F	G
COUNTY	Total	.25 acres or <	.26-9.99 acres	10-99 acres	100-299 acres	300-999 acres	1000-4999 acres	5000 acres >
Plumas	$30,002,000	$0	$2,000	$0	$0	$0	$0	$30,000,000
Riverside	$8,066,503	$17,000	$88,903	$27,600	$8,000	$50,000	$0	$7,875,000
Sacramento	$1,533,500	$0	$0	$13,500	$0	$20,000	$0	$1,500,000
San Benito	$309,305	$305	$27,400	$22,000	$0	$9,600	$250,000	$0
San Bernardino	$90,131,910	$16,510	$93,200	$1,000	$21,200	$0	$0	$90,000,000
San Diego	$1,049,225	$795,025	$254,200	$0	$0	$0	$0	$0
San Francisco	$0	$0	$0	$0	$0	$0	$0	$0
San Joaquin	$70,131,020	$1,120	$900	$1,009,000	$0	$0	$0	$69,120,000
San Luis Obispo	$577,022	$6,850	$62,070	$65,600	$10,002	$500	$432,000	$0
San Mateo	$3,000,100	$100	$0	$0	$0	$0	$0	$3,000,000
Santa Clara	$304,571,052	$2	$41,050	$50,000	$0	$0	$0	$304,480,000
Santa Cruz	$2,000,100	$100	$0	$0	$0	$0	$0	$2,000,000
Shasta	$50,761,750	$30,200	$693,050	$8,500	$20,000	$10,000	$0	$50,000,000
Sierra	$0	$0	$0	$0	$0	$0	$0	$0
Siskiyou	$686,650	$23,550	$663,100	$0	$0	$0	$0	$0
Solano	$224,590,500	$0	$40,000	$500	$0	$0	$2,250,000	$222,300,000
Sonoma	$1,302,549,765	$189,060	$283,705	$17,000	$0	$0	$300,000	$1,301,760,000
Stanislaus	$69,175,400	$50	$47,350	$8,000	$0	$0	$0	$69,120,000
Sutter	$0	$0	$0	$0	$0	$0	$0	$0
Tehama	$2,500,556	$2,750	$444,832	$49,224	$3,750	$0	$0	$2,000,000
Trinity	$66,722,100	$203,100	$518,500	$500	$0	$0	$0	$66,000,000
Tulare	$278,541,759	$14,600	$29,709	$7,450	$10,000	$0	$80,000	$278,400,000
Tuolumne	$189,002	$8,970	$180,032	$0	$0	$0	$0	$0
Yolo	$9,520,500	$0	$520,000	$500	$0	$0	$0	$9,000,000
Yuba	$2,525,800	$1,200	$24,600	$0	$0	$0	$2,500,000	$0
STATE TOTAL	$4,264,918,165	$3,311,525	$7,553,584	$2,654,624	$562,602	$381,500	$6,536,830	$4,243,917,500

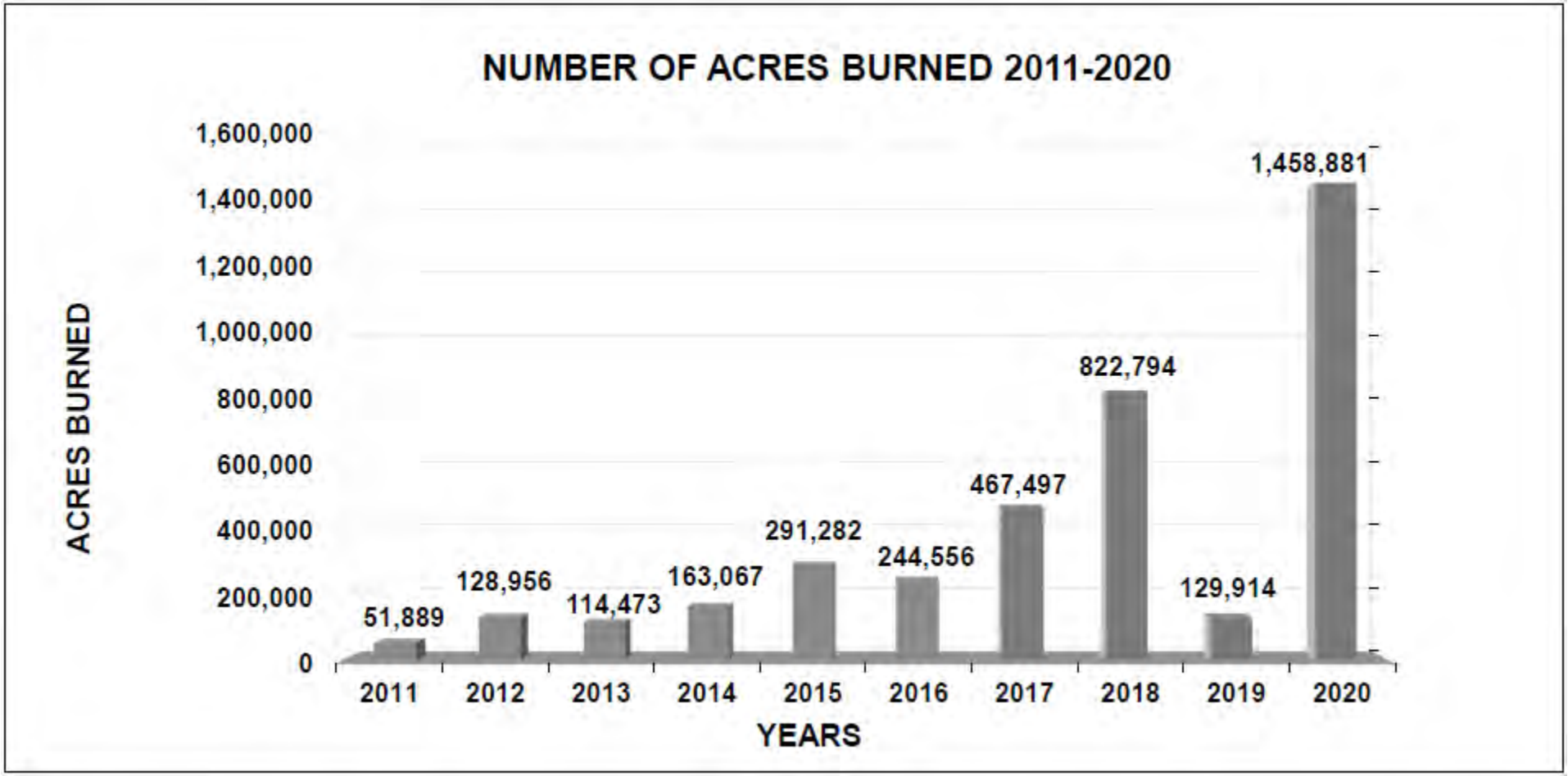
Contract County statistics can be found in Table 7.

*Definition of what Dollar Damage entails can be found in the Glossary.

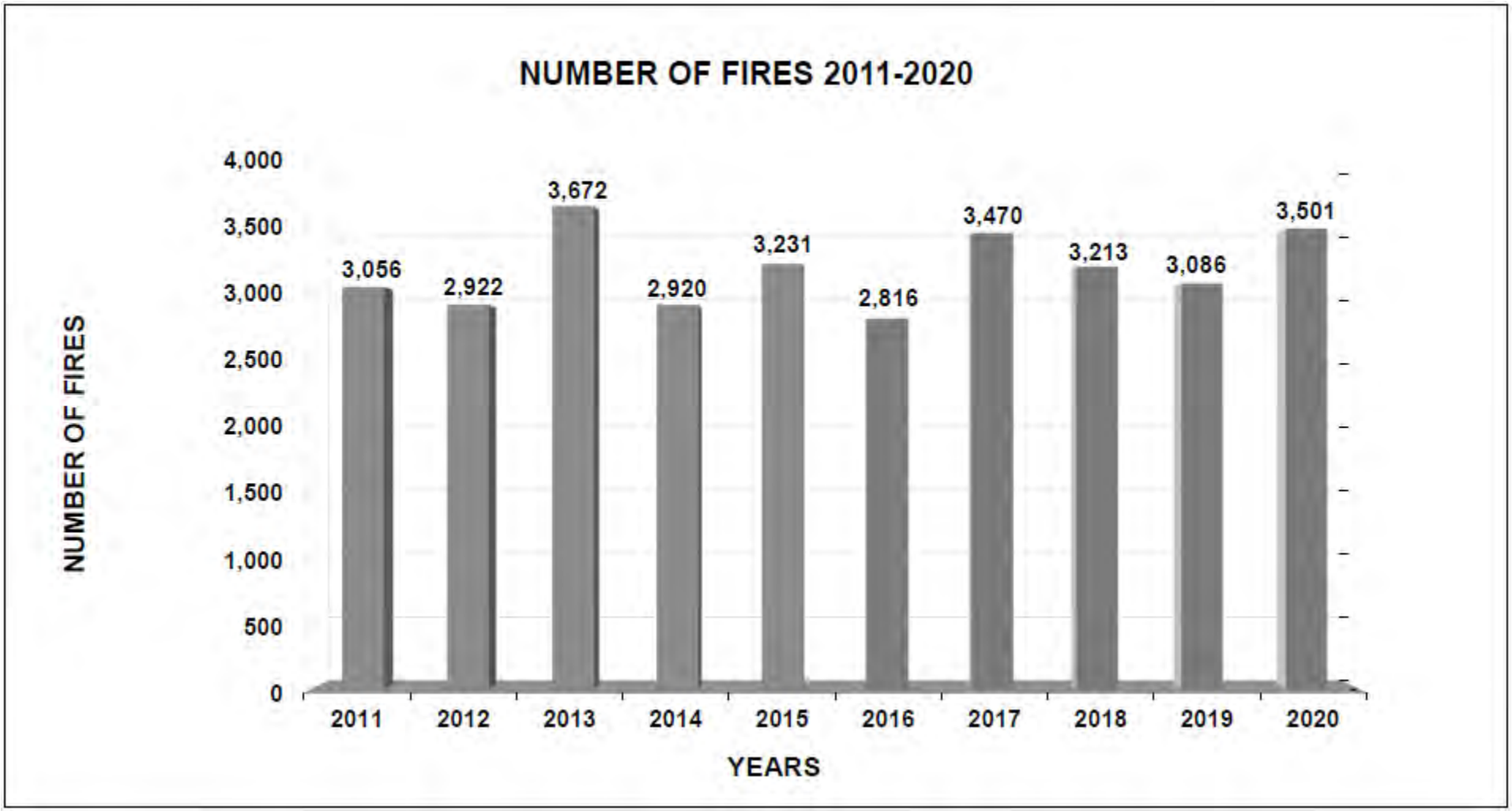
Graphic Figure 1. Percent of Fires by Cause



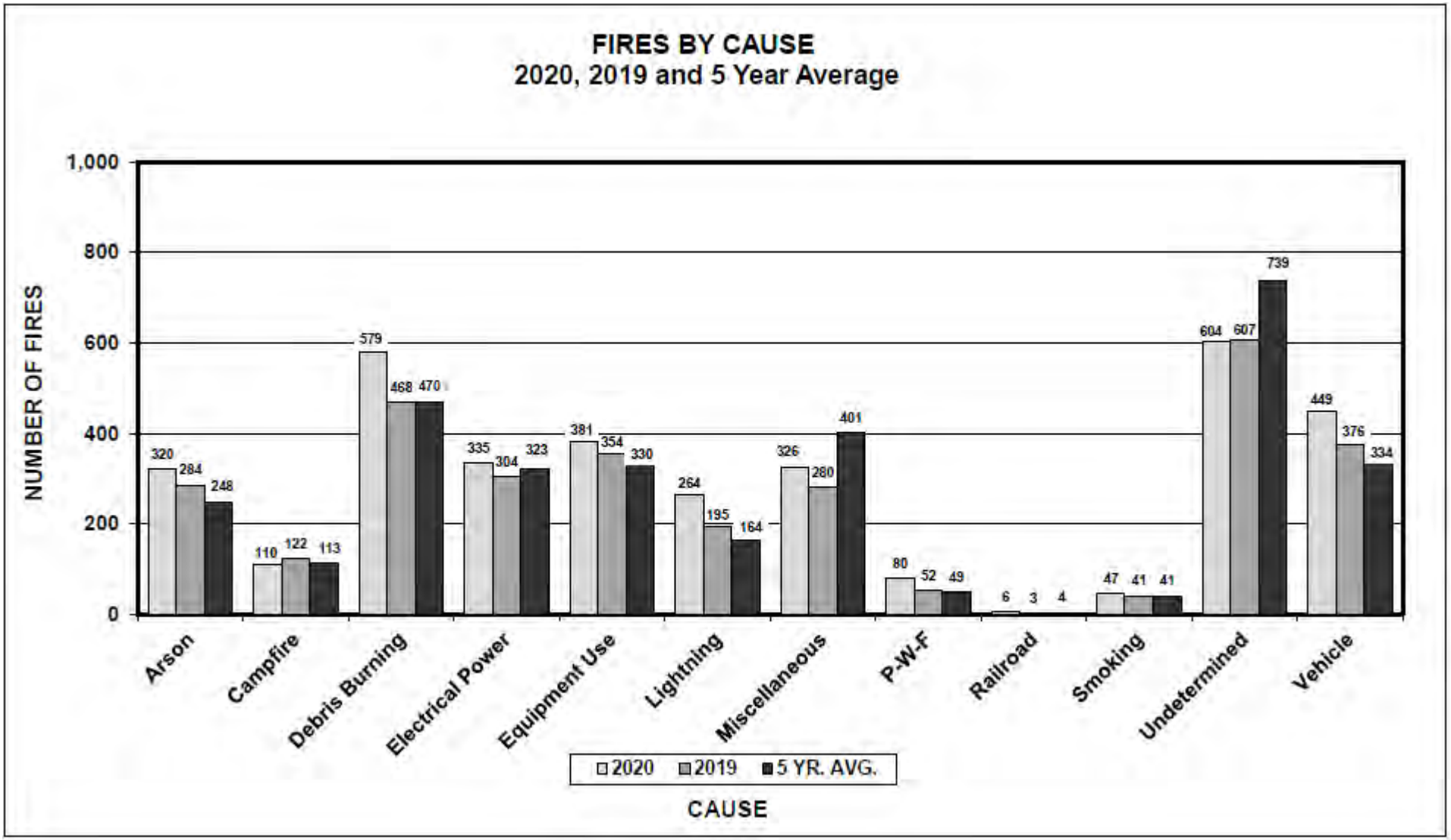
Graphic Figure 2. Number of Acres Burned — 2011-2020



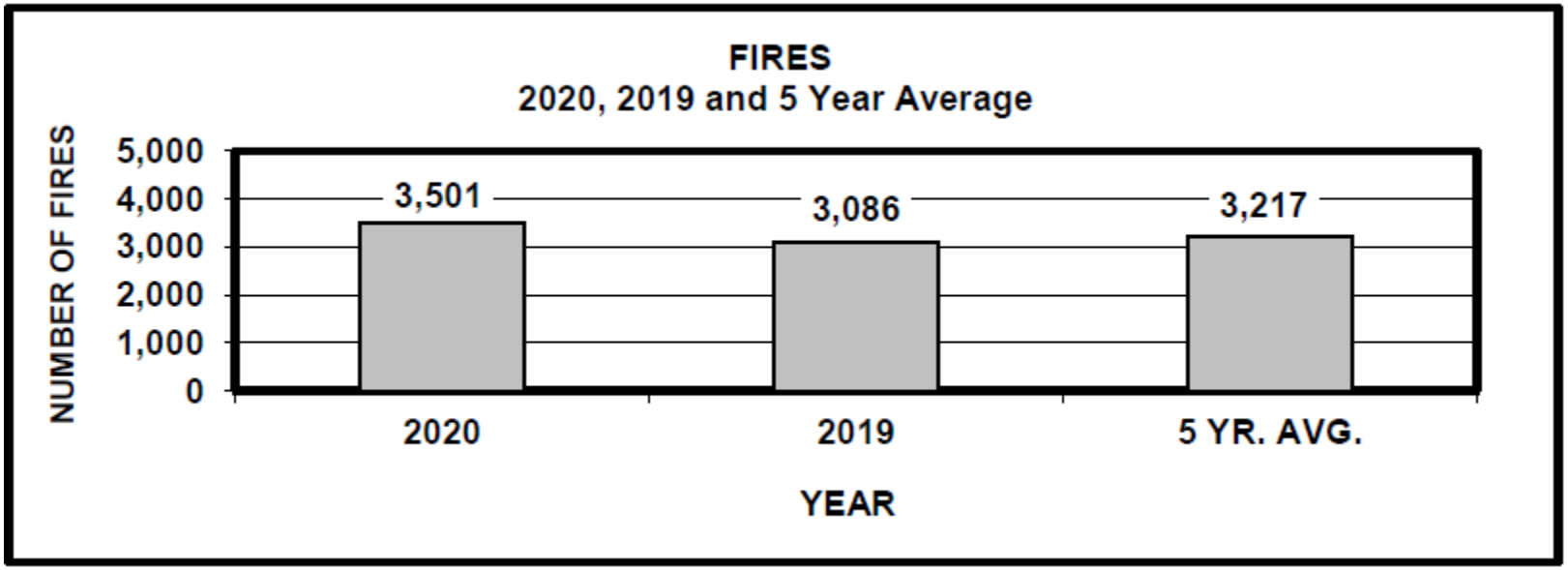
Graphic Figure 3. Number of Fires — 2011-2020

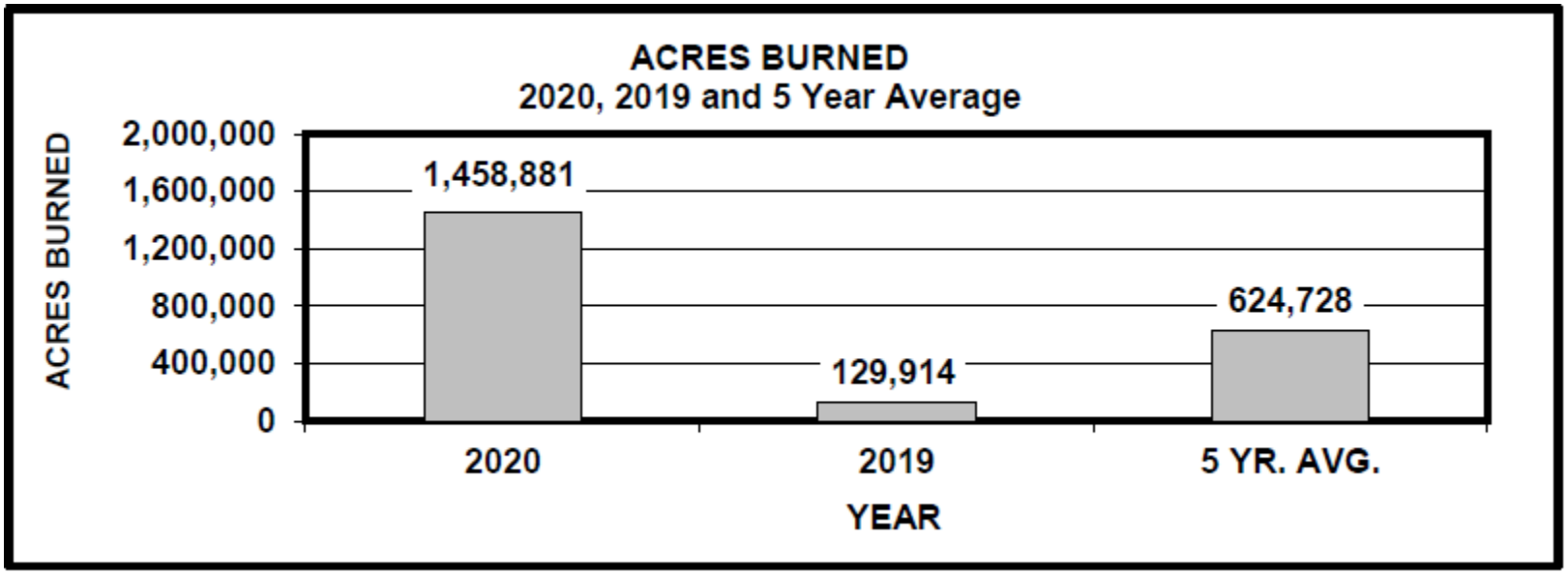


Graphic Figure 4. Number of Fires by Cause — 2020, 2019, and 5 Year Average

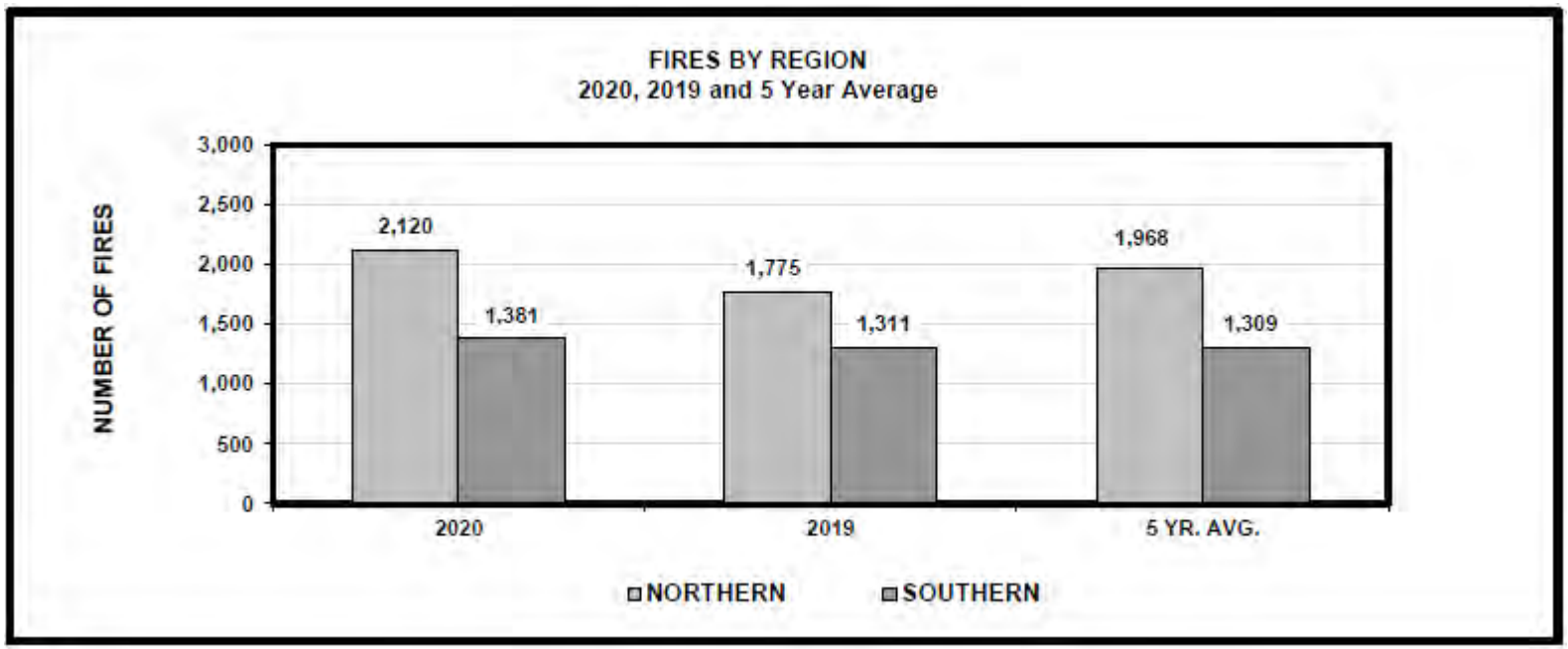


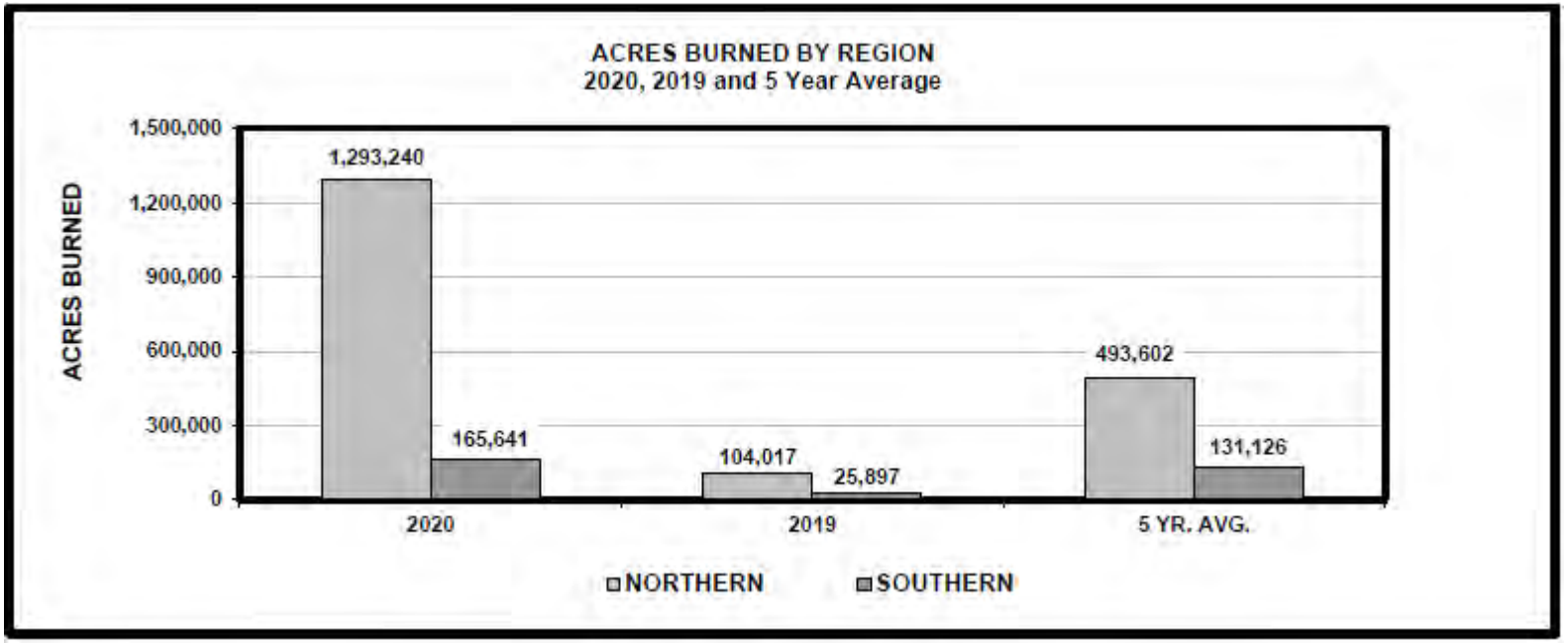
Graphic Figure 5. Fires and Acres — 2020, 2019, and 5 Year Average





Graphic Figure 6. Fires and Acres by Region — 2020, 2019, and 5 Year Average





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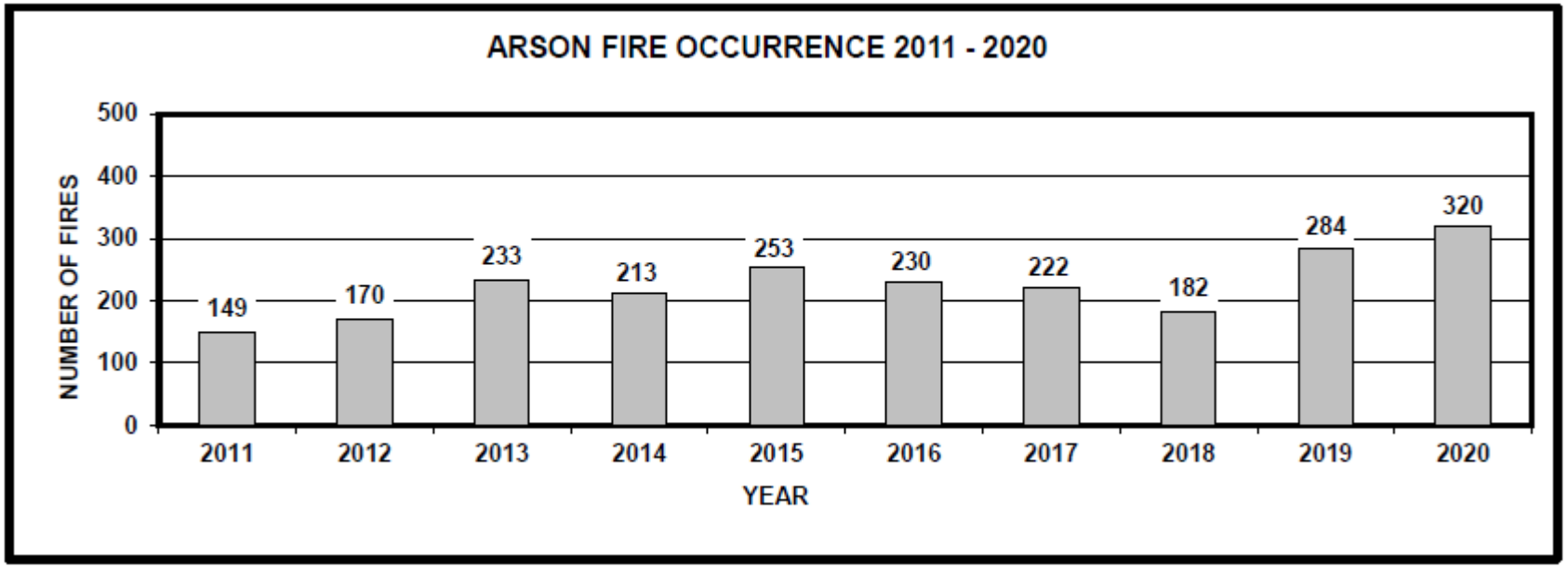

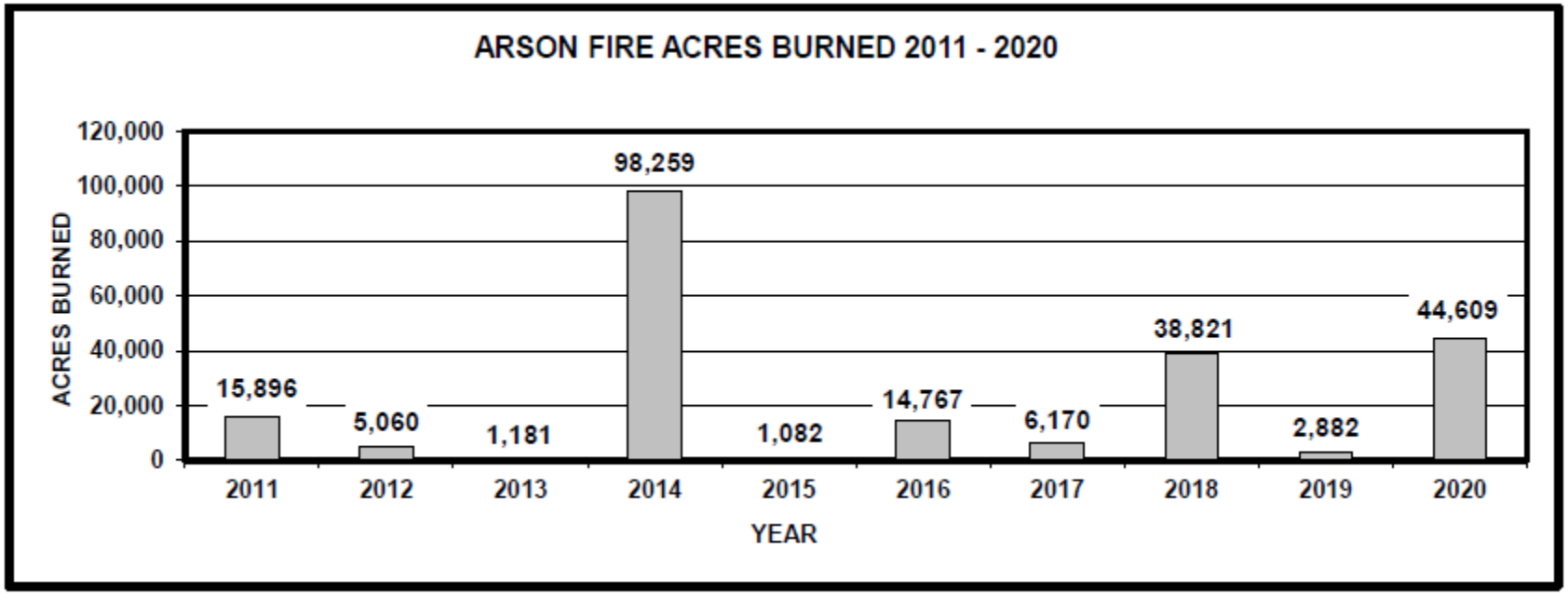

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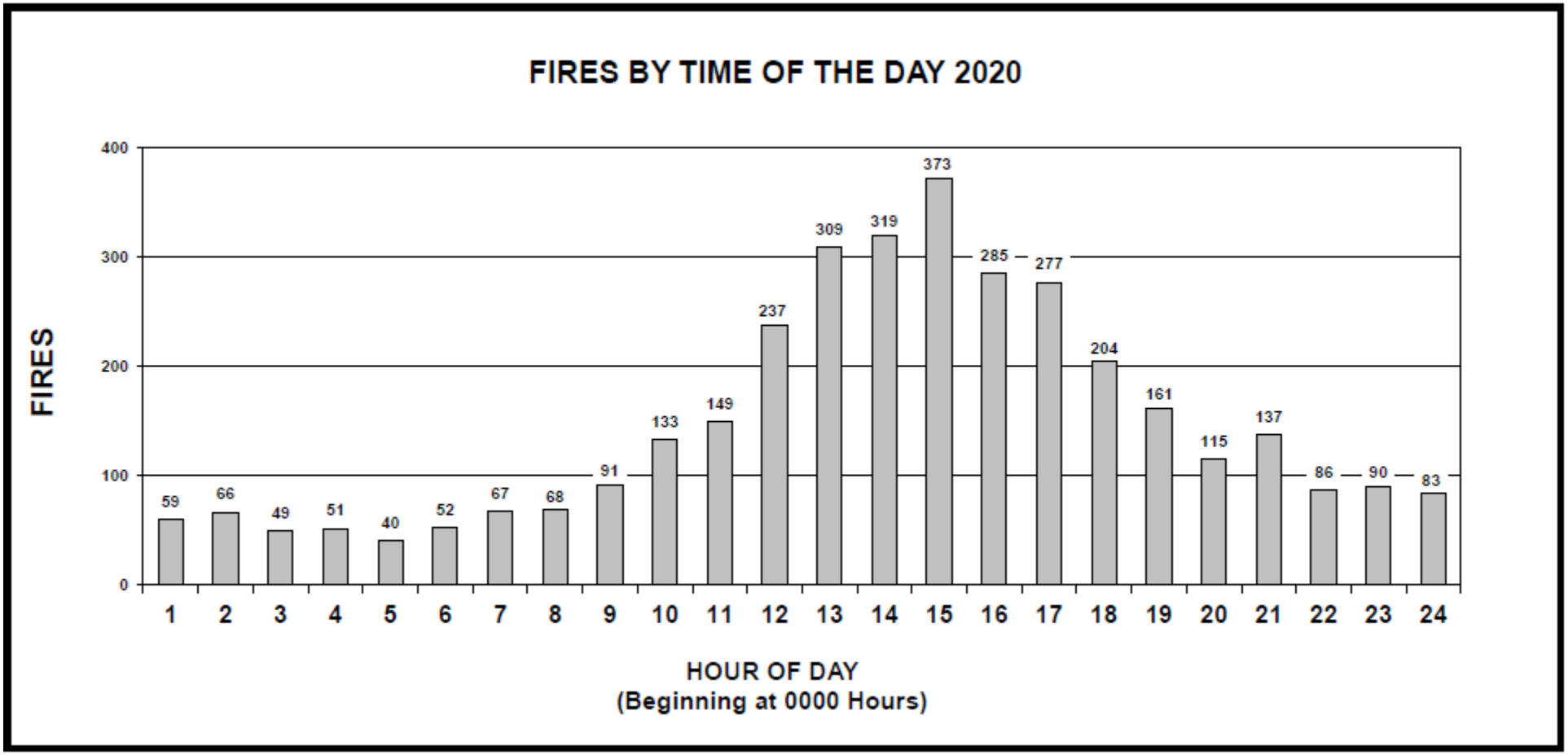

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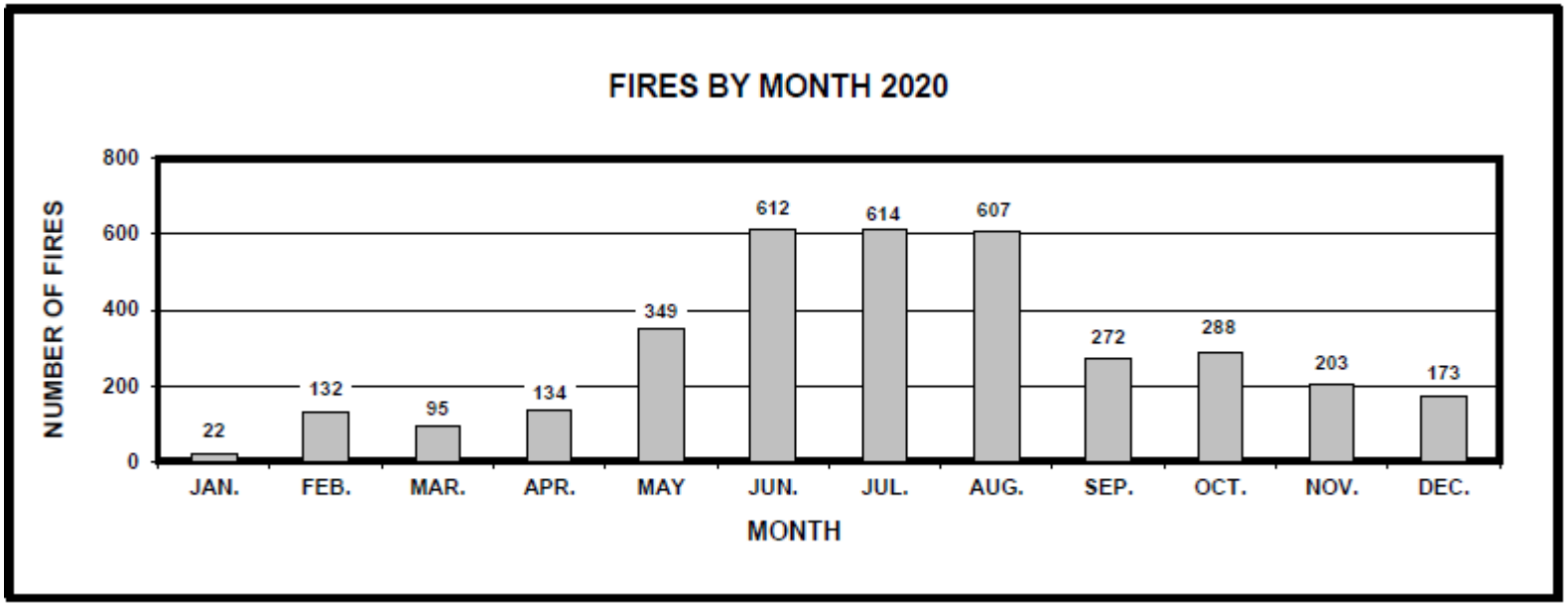

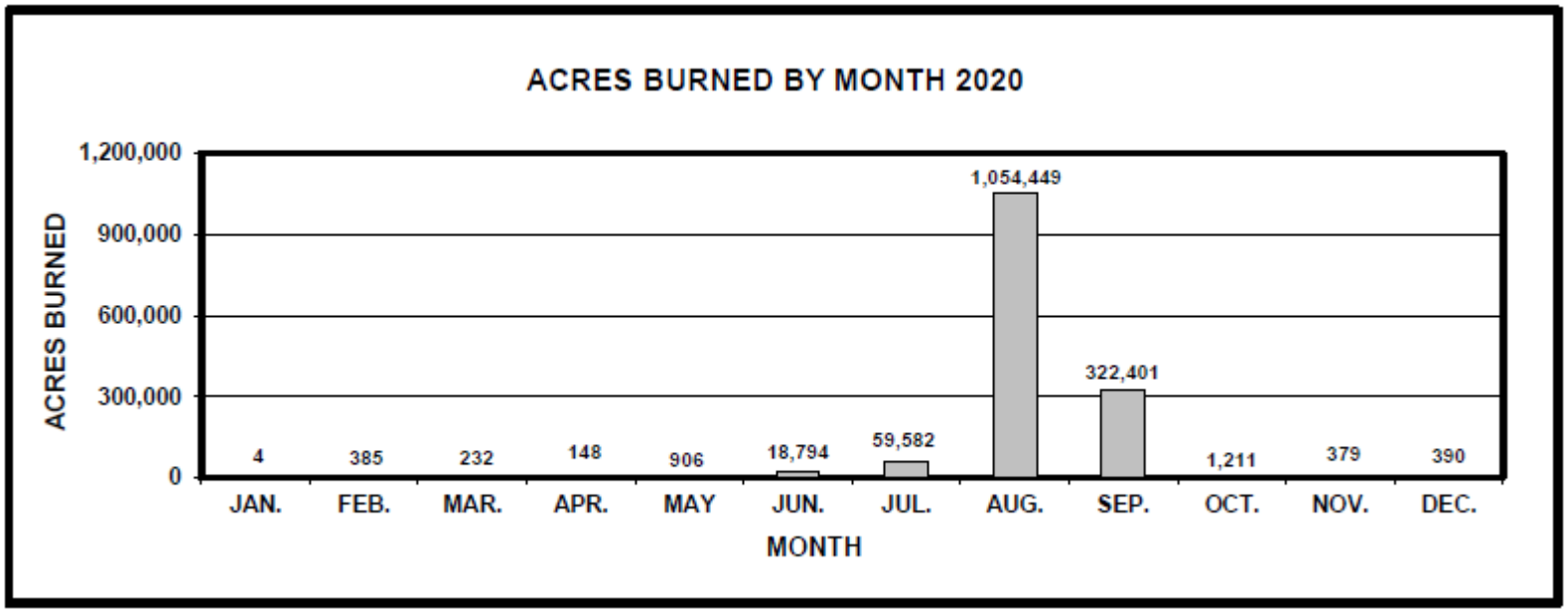

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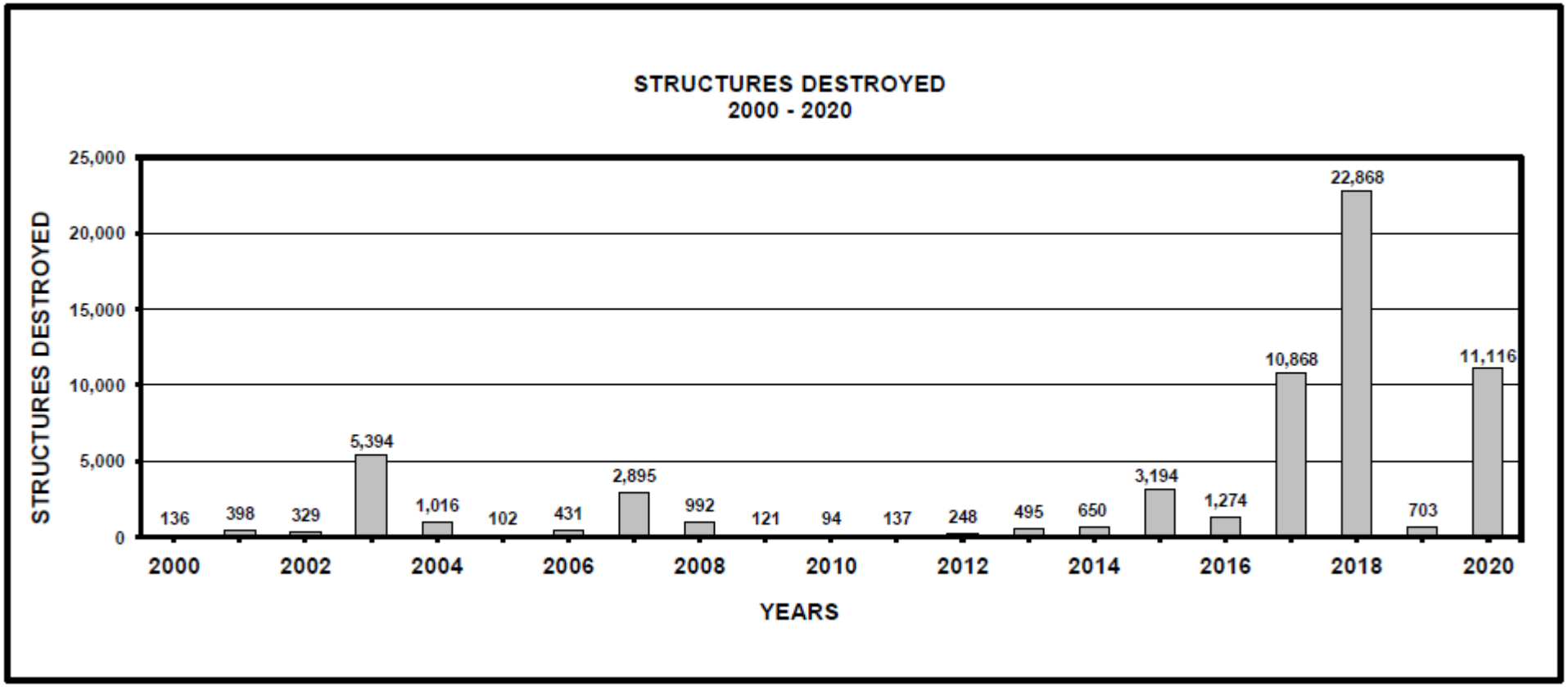

The information on this list includes data on fire activity within the Direct Protection Areas of CAL FIRE and Contract Counties. This information is gathered from the ICS 209 incident reports, the CAL FIRE Incident Reporting System (CALFIRS), and CAL FIRE Damage Inspection (DINS) reports.

Structures Destroyed = Residence, commercial property, outbuilding or other structure that is declared lost.

2003 includes the Cedar Fire, which destroyed 2,820 structures.
2015 includes the Valley Fire, which destroyed 1,958 structures, and the Butte Fire, which destroyed 965 structures.
2016 includes the Erskine, Bluecut, Sand, and Clayton fires, which destroyed a combined total of 1,023 structures.
2017 includes the Thomas Fire, which destroyed 1,060 structures, as well as the Mendocino Lake Complex, Central LNU Complex, Southern LNU Complex and NEU Wind Complex incidents, which destroyed a combined total of 8,886 structures. These complex incidents were comprised of the Redwood Valley, Sulphur, Tubbs, Nuns, Pocket, Atlas, Cascade, La Porte, McCourtney, and Lobo fires.
2018 includes the Carr, Camp, and Woolsey fires, which destroyed 1,614 structures, 18,804 structures, and 1,185 structures, respectively.
2020 includes the group of incidents known as the “2020 Fire Siege,” which destroyed a combined total of over 9,000 structures.

GLOSSARY

ARSON – To unlawfully and intentionally damage, or attempt to damage, any real or personal property by fire or incendiary device.

CAMPFIRE – Outside fire used for cooking, warmth, lighting, ceremonial or aesthetic purposes.

CONTRACT COUNTIES – PRC §4133 and Section 55607 of the Government Code permit the CAL FIRE Director to contract with counties for protection of State Responsibility Area (SRA). In California, CAL FIRE contracts with six counties to provide fire-protection and prevention services in SRA. The counties of Kern, Los Angeles, Marin, Orange, Santa Barbara and Ventura are Contract Counties.

DEBRIS BURNING – Outside fire for vegetation, waste, or trash disposal.

DIRECT PROTECTION AREA (DPA) – The area for which a particular fire protection organization has the primary responsibility by law or contract for attacking an uncontrolled fire and directing the suppression activities.

DOLLAR DAMAGE – Estimates of the total property and contents dollar loss in terms of replacement in like kind and quantity. This estimation of the dollar loss includes property and contents damaged by fire, smoke, water, and overhaul. This does not include suppression costs or indirect loss, such as business interruption.

ELECTRICAL POWER – Fire ignited by electrical power distribution or transmission.

EQUIPMENT USE – Fire ignited by the use or failure of mechanical or electrical equipment. Does not include fire ignited by powerlines.

FOREST FIRE – A fire burning uncontrolled on land covered entirely or in part by timber, brush, grass, grain or other flammable vegetation.

LIGHTNING – Fire ignited by lightning discharge.

LOCAL GOVERNMENT – A fire department, especially of a municipal government, whose purpose is preventing and extinguishing fires.

LOCAL GOVERNMENT CONTRACT – PRC §4142 allows CAL FIRE to contract with local governments to provide fire protection and emergency services through the administration of 146 cooperative fire protection agreements in 35 of the State's 58 counties, 25 cities, 31 fire districts and 34 other special districts and service areas.

MISCELLANEOUS – Fire ignited by events or activities that are not classified as arson, campfire, debris burning, equipment use, lightning, playing with fire, powerline, railroad, smoking, vehicle, or undetermined.

OUTBUILDING – A building that is separate from a main building and located on the same property.

PLAYING WITH FIRE (P-W-F) – Fire ignited unintentionally by children while playing or experimenting with fire or fire-causing devices.

RAILROAD – Fire ignited by rail transport vehicles or fire ignited on or near railroad right-of-way.

SMOKING – Fires ignited by smoking tobacco or other smoking material; includes matches, lighters, or other heat sources used in smoking.

STATE RESPONSIBILITY AREA (SRA) – Areas of the State in which the financial responsibility of preventing and suppressing fires has been determined by the State Board of Forestry and Fire Protection, to be primarily the responsibility of the State, PRC §4102.

STRUCTURE – An assembly of materials forming a construction for occupancy or use to serve a specific purpose, includes enclosed building, fixed portable building or mobile home.

UNCONTROLLED FIRE – Any fire which threatens to destroy life, property, or resources and either: (1) is unattended by any person; (2) is attended by persons unable to prevent its unrestricted spread; and (3) is burning with such velocity or intensity that it could not be readily controlled with ordinary tools available to persons at the fire scene.

UNDETERMINED – A fire that has been investigated and has insufficient information to classify further, a fire that is under investigation, or a fire that has not yet been investigated.

VEHICLE – Fire ignited by mobile property which include: Passenger automobile, bus, school bus, off road recreational, motor home, travel trailer, camping trailer, mobile home or office designed to be towed, motorcycle or scooter.

WILDFIRE – Any uncontrolled fire spreading through vegetative fuels that threatens to destroy life, property, or resources, PRC §4103 and 4104.

WILDLAND-URBAN INTERFACE – A geographical area identified by the State as a “Fire Hazard Severity Zone” in accordance with the PRC §4201 through 4204 and Government Code §51175 through 51189, or other areas designed to be at a significant risk from wildfires.

APPEAL EXHIBIT F

Top 20 Largest California Wildfires

	FIRE NAME (CAUSE)	DATE	COUNTY	ACRES	STRUCTURES	DEATHS
1	**AUGUST COMPLEX** *(Lightning)*	August 2020	Mendocino, Humboldt, Trinity, Tehama, Glenn, Lake, & Colusa	**1,032,648**	935	1
2	**DIXIE** *(Powerlines)*	July 2021	Butte, Plumas, Lassen, Shasta & Tehama	**963,309**	1,311	1
3	**MENDOCINO COMPLEX** *(Human Related)*	July 2018	Colusa, Lake, Mendocino & Glenn	**459,123**	280	1
4	**SCU LIGHTNING COMPLEX** *(Lightning)*	August 2020	Stanislaus, Santa Clara, Alameda, Contra Costa, & San Joaquin	**396,625**	225	0
5	**CREEK** *(Undetermined)*	September 2020	Fresno & Madera	**379,895**	858	0
6	**LNU LIGHTNING COMPLEX** *(Lightning/Arson)*	August 2020	Napa, Solano, Sonoma, Yolo, Lake, & Colusa	**363,220**	1,491	6
7	**NORTH COMPLEX** *(Lightning)*	August 2020	Butte, Plumas & Yuba	**318,935**	2,352	15
8	**THOMAS** *(Powerlines)*	December 2017	Ventura & Santa Barbara	**281,893**	1,060	2
9	**CEDAR** *(Human Related)*	October 2003	San Diego	**273,246**	2,820	15
10	**RUSH** (*Lightning*)	August 2012	Lassen	**271,911 CA / 43,666 NV**	0	0
11	**RIM** *(Human Related)*	August 2013	Tuolumne	**257,314**	112	0
12	**ZACA** *(Human Related)*	July 2007	Santa Barbara	**240,207**	1	0
13	**CARR** *(Human Related)*	July 2018	Shasta County & Trinity	**229,651**	1,614	8
14	**MONUMENT** (*Lightning*)	July 2021	Trinity	**223,124**	28	0
15	**CALDOR** *(Human Releated)*	August 2021	Alpine, Amador, & El Dorado	**221,835**	1,005	1
16	**MATILIJA** *(Undetermined)*	September 1932	Ventura	**220,000**	0	0
17	**RIVER COMPLEX** *(Lightning)*	July 2021	Siskiyou & Trinity	**199,359**	122	0
18	**WITCH** (*Powerlines*)	October 2007	San Diego	**197,990**	1,650	2
19	**KLAMATH THEATER COMPLEX** *(Lightning)*	June 2008	Siskiyou	**192,038**	0	2
20	**MARBLE CONE** *(Lightning)*	July 1977	Monterey	**177,866**	0	0

There is no doubt that there were fires with significant acreage burned in years prior to 1932, but those records are less reliable, and this list is meant to give an overview of the large fires in more recent times.
This list does not include fire jurisdiction. These are the Top 20 regardless of whether they were state, federal, or local responsibility.
*Numbers not final.

10/24/2022

APPEAL EXHIBIT G

VOL. 47, NO.2

MARCH 2020

FREMONTIA

JOURNAL OF THE CALIFORNIA NATIVE PLANT SOCIETY

CALIFORNIA FIRES: Challenges and Proposed Solutions

CALIFORNIA NATIVE PLANT SOCIETY

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California Native Plant Society
ISSN 0092-1793 (print)
ISSN 2572-6870 (online)

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Photograph by Aaron Sims/CNPS

FREMONTIA

VOL. 47, NO. 2, MARCH 2020

FROM THE EDITORS

Perhaps you are one of thousands of California residents who have recently become intimately acquainted with Public Safety Power Shutoffs. Even those of us who haven't found ourselves in the path of recent wildfires have had to navigate dramatic interruptions to our daily lives, including smoke-filled air and increases in the cost of fire insurance (if we can still get it). It is becoming abundantly clear that living in California means living with wildfire.

Of course, fire has always been integral to California's diverse ecosystems. Many people choose to live here because of the state's natural beauty. But proximity to that natural beauty comes with the responsibility to respect and understand the forces that created it, including fire.

Over the past 20 years, a dramatic increase in large, deadly wildfires has transformed California's environmental politics, with unprecedented impacts on our communities. We're living through a time of remarkable change, and the need for solutions is urgent. Often missing in the midst of crisis, however, is a science-based, historical perspective which would help inform our search for effective responses to this "new normal."

The diversity of California's ecosystems means that we can't treat wildfire the same way throughout the state. Instead, we need rigorous science and regional expertise to inform how we deal with fire, from Sierra Nevada forests, to the chaparral of Southern California.

Providing such scientific expertise and local input is CNPS's role and the purpose of this special issue of *Fremontia*. In it, you'll find commentary from ecologists, foresters, sociologists, and others dedicated to understanding fire in California, as well as science-based recommendations for more fire-resilient homes, gardens, and communities.

Of course, even a special expanded issue of *Fremontia* is too small to contain all that must be said about fire in California. Native perspectives—and in particular, traditional practices developed by indigenous Californians over many centuries—are notably missing from this issue. For thousands of years, California's tribal communities have applied fire to steward landscapes and the critical resources they sustain. This tradition of caring for the land must be brought to the table as we seek more sustainable ways of living in this beautiful and diverse state. Generations of learning cannot be squeezed into a single article, and CNPS looks forward to devoting an upcoming issue to "Traditional Ecological Knowledge," encompassing (but not limited to) Native Californians' relationship with fire.

– Emily Underwood & David Loeb, *Guest Editors*

Cover: The 2017 Thomas Fire near Santa Barbara.
(Photograph by Stuart Palley / U.S. Forest Service)

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REESTABLISHING BALANCE BETWEEN PEOPLE, PLANTS, AND FIRE IN CALIFORNIA

Greg Suba

For millennia, fire has been a part of California. Our native flora evolved with fire and exists in part because of it. California's original people harnessed its forces to their advantage and continue to integrate fire successfully into their land management practices today. But over the last century, California's relationship with fire has changed.

While wildfire certainly brings great danger and tragedy to human communities, it remains fundamental to how California naturally functions. Nevertheless, most Californians have developed a misunderstanding of, and antagonism to, fire. This issue of *Fremontia* addresses how we got into our current wildfire situation, tracing the more than 100-year history of fire suppression in California. It describes how our penchant for harvesting the biggest trees has contributed to fire-starved, overgrown forests, and shows how an increasing population in chaparral and coastal sage scrub habitats is generating more problems with fire, suggesting that we must invest in more than vegetation management to develop resilience to wildfire.

The California Native Plant Society (CNPS) has long held a realistic view of the necessity of living with fire, communicated through policies, publications, and advocacy. We continue that dialog in this issue of *Fremontia*, which brings together a selection of research, personal stories, and expert opinion to explore our broken relationship with fire and what we can do to fix it.

Providing an historical perspective, Craig Thomas leads us along the path we've taken away from fire, describing the forest choices and actions that shape our current relationship with forest fire. Jon Keeley and Alexandra Syphard summarize research and data related to recent increases in wildfire extent, intensity, and damage. Caitlin

Above: The 2014 Happy Camp Complex Fire. *[Photograph courtesy of U.S. Forest Service]*

"The need for vigorous participation in the discourse underscores the fundamental importance of preserving a process whereby the public—all sides—can provide meaningful input that guides policy and action."

Cornwall and Jason Mills provide examples of how one post-fire community is learning from their tragedy to balance rebuilding with conservation, keeping resilience in mind.

Many voices, including those of CNPS members, have long advocated that—rather than focus almost exclusively on vegetation management—California's leaders should make a greater commitment to hardening homes against ember ignitions, maintaining defensible space, and favoring more fire-safe land use decisions. These are priorities reinforced by stories and findings presented by contributing authors in this issue.

[Photograph by Cecilio Ricardo / U.S. Forest Service]

Our members have advocated ardently and at length for appropriate vegetation management when and where it is needed. Rather than resist all vegetation management, CNPS has supported the thinning of some understory forest vegetation in order to restore greater forest structural heterogeneity, along with an increase in the pace and scale of prescribed and managed forest fire. At the same time, CNPS continues to dispel damaging misconceptions about the relationship between fire and chaparral and coastal sage scrub landscapes (see *Fremontia* Vol. 35, No. 4, Fall 2007 - Special Issue: Chaparral). In this issue, Rodd Kelsey makes the case for ecological thinning and increased burning in the Sierra Nevada's mixed conifer forests. Achieving this presents social, economic, and ecological challenges as well as opportunities. Jonathan Kusel describes the potential for community-based biomass energy and alternative wood products to provide solutions to these obstacles.

Our imperative to build a fire-resilient California faces unprecedented opposing forces: rapidly changing climate, fire-prone landscapes, having to unlearn a century of wildfire bias, and a growing population of fire-starting humans. We've built ourselves into a problem. Solving it responsibly must include keeping lives and property safe without forsaking the beauty and wildlife (plants and animals) we experience today, nor our ability to pass it on to those who follow us.

Under these conditions, especially within our forested lands, the no-action alternative is hardly an option. The pace and scale of intervention on natural lands has begun to increase, spurring a concurrent increase in the scales of environmental decision making and management actions. Finding a sustainable path through this uncharted territory requires an all-lands, all-voices approach. Success will require using the best science, continued research, letting go of "No" at times, and acknowledging we're going to make mistakes. Our ability to monitor our successes and failures effectively, to learn from them, and to improve on them will be all-important.

There will always be, and ought to be, tension around how much intervention is enough and how much is too much. Though frustrating at times, open debate is essential to successful natural lands management and conservation. The need for vigorous participation in the discourse underscores the fundamental importance of preserving a process whereby the public—all sides—can provide meaningful input that guides policy and action.

"The West is burning, but mostly not in the way it should be," as Craig Thomas sums it up. This winter we sat in his home in the Sierra foothills, where he has lived since the 1970s, and I listened to him recount the years of effort he and many others have dedicated to reestablishing fire as an ecological tool in the Sierra Nevada. Their journey is a saga about people living through something new, and working together to establish a path forward. I find myself invested in a central theme of their story, one which I hope readers will take away from this issue: Challenges are neither always bad nor insurmountable.

–Greg Suba is Conservation Biologist for Sierra Forest Legacy. He served as CNPS Conservation Program Director from 2009-2019.

NEXUS BETWEEN WILDFIRE, CLIMATE CHANGE, AND POPULATION GROWTH IN CALIFORNIA

Jon E. Keeley and Alexandra D. Syphard

Since the year 2000 California has experienced a remarkable upsurge in wildfires. Over five million hectares have burned in the last 20 years, which is double the area burned in the previous two decades. Much of this increase has been driven by large fires of more than 50,000 hectares that cause catastrophic losses of lives and property (Keeley and Syphard 2019). This increased fire activity has been correlated with an increase in average temperature over this same period, leading many observers to assert that global climate change must be playing a major role. Climate models forecast continued warming and thus some have suggested these catastrophic fires are the "new normal" or the "new *ab*normal," (Birnbaum 2018). In contrast, others have declared that these fires are the result of "forest mismanagement" (Cranley 2018) and this has stimulated renewed interest in fuel reduction (Office of Governor 2019). It's almost as though these opinions aren't even in reference to the same fires, and as described below, there is some validity to this assertion.

Sorting out the factors driving this rise in fire activity requires an appreciation for the diversity of landscapes and fire regimes in the state. After all, California has the largest latitudinal range of any western state, comparable to that from southern New Mexico to Wyoming, and the largest altitudinal range (containing both the lowest and highest points in the lower 48 states). California also is the most populous state in the union: One out of eight Americans live here. And most live within dense metropolitan areas juxtaposed with fire-prone wildlands, while a great many more live widely dispersed in rural settings.

A key to sorting out the factors behind increased fire activity is understanding that we are looking at two very different types of fires: fuel-dominated vs. wind-dominated fires. And each of these is controlled by different environmental and historical factors (Table 1). Understanding the differences between these two types of wildfires is helpful for navigating the confusing array of opinions expressed in the media as well as determining the appropriate management responses to reduce future fire impacts.

Above: Aerial retardant drop on a chaparral wildfire in coastal Southern California, taken July 5, 2008, in the foothills of the Los Padres National Forest. *[Photograph by Dan Lindsay]*

FUEL-DOMINATED FIRES

Many of the forest fires of the past two decades have grown out of control due to anomalous fuel loads resulting from 20th century management practices. In the early 1900s increasing state and federal interest in timber resources led to vigorous suppression of natural fires in forests that historically had burned at decadal frequency (McKelvey and Busse 1996) (Fig. 1). In the moderately productive mid-elevation conifer forests of the Sierra Nevada there is typically a vertical separation between dead branches and other litter on the ground and the living tree canopies above, and thus frequent lightning-ignited fires were commonly restricted to low intensity surface fires (Fig. 2). As a result such fires were relatively easy to extinguish and thus many forests in the western U.S. have experienced over a century of near total fire exclusion.

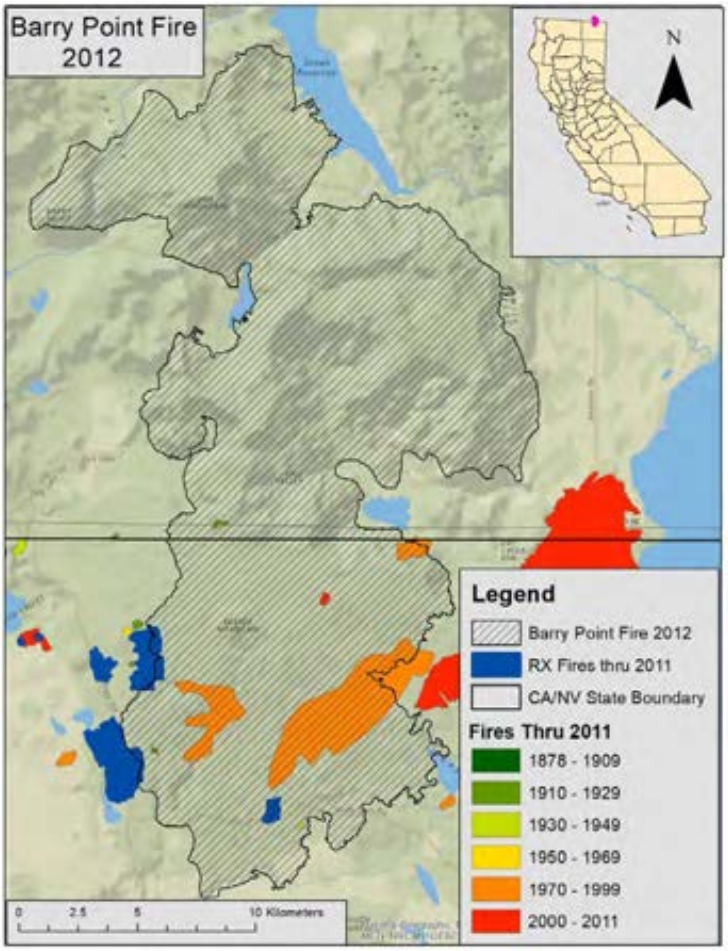
One consequence is that some of these forests have accumulated understory surface fuels that represent fuel loads an order of magnitude greater than historical levels (Keifer et al. 2006), made even worse by the massive ingrowth of new saplings that not only further increase the fuel load but also act as ladder fuels carrying fire from the surface to the canopy. A century without fire has made these forests susceptible to high-intensity crown fires, a fire pattern evident in many recent Sierra Nevada fires (Fig. 3). These types of fires are best described as fuel-dominated fires (Table 1).

To be sure, some fuel-dominated fires can produce their own extreme winds (e.g., the 2010 Station Fire in Los Angeles County or the 2018 Carr Fire in Shasta County), resulting from the high-intensity burning of heavy fuel loads. The extreme heat produces pyrocumulonimbus clouds and are often described as plume-driven fires that can collapse, producing extreme wind events (Clements et al. 2018). However, such winds are internally generated, a phenomenon that could be altered by undertaking fuel treatments prior to fire events.

Figure 1. Cross section of ponderosa pine, upper edge is the outer bark, pith is toward the bottom. Dates indicate previous fires and none since active fire suppression in the early 1900s *(Section from Bruce Kilgore, photograph by Jon Keeley, USGS)*

Figure 2. Low intensity surface fire typical of historical fires in many western forests *(Rim Fire burning in Yosemite National Park, photograph by Jon Keeley, USGS)*

Figure 3. Fire perimeter for the 2012 Barry Point Fire. Hatched area indicates no previous recorded fire from 1910 to 2012, roughly 90% of area burned in 2012. Legend indicates other historical fire dates *(Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, https://frap.fire.ca.gov/mapping/gis-data/; accessed Jan. 2020).*



WIND-DOMINATED FIRES

On the other hand, wind-dominated fires are those controlled by external weather events. This is an important distinction, as we have no ability to alter such weather-driven wind events. Our most catastrophic fires of the past few decades have been just such wind-dominated fires. They typically occur in the western portions of California and burn over non-forested landscapes of shrubs, grasses, and woodlands. These fires grow rapidly due to extreme wind events and, as a result, pose severe challenges to fire suppression efforts. Readers will be familiar with several of these recent "firestorms," including the 2017 Napa-Sonoma Wine Country fires and the 2018 Camp Fire driven by North winds in Northern California. (Historically this is the appropriate term; however, such winds are sometimes referred to as Diablo winds, a term spawned by a newspaper reporter who noted that the 1991 Oakland Hills Tunnel Fire was driven by winds coming from the direction of Mount Diablo; thus the term is less appropriate for wind-driven fires throughout the region.) Other such "firestorms" include the 2017 Thomas Fire and the 2018 Woolsey Fire driven by Santa Ana winds in Southern California. While these winds may occur in both the spring and autumn (Fig.5a) they are most problematic in the autumn, following the three to six months of drought typical of our Mediterranean climate (Fig. 5b), leaving natural vegetation at its lowest moisture level. It is these autumn Santa Ana wind and North wind fires that account for the most catastrophic fires in the state (Table 1).

Figure 4. Offshore dispersion of smoke from a) North Wind driven fires in northern California, 2017, and b) Santa Ana Wind driven fires in southern California, 2003.

TABLE 1. Selected fires representing fuel-dominated and wind-dominated fires.

Year	Fire	County	Mon. (days)*	Hectares	Cause	Lives	Structures
Fuel-Dominated Fires:							
2007	Marble C	Monterey	July -	71,980	Lightning	0	0
2012	Barry Point	Modoc	Aug -	37,630	Lightning	0	3
2012	Rush	Lassen	Aug -	110,080	Lightning	0	1
2013	Rim	Stanislaus	Aug -	104,220	Campfire	0	112
2014	King	El Dorado	Sept -	39,260	Arson	0	80
2015	Rough	Fresno	July -	61,360	Lightning	0	4
Wind-Dominated Fires:							
1889	Santiago	Orange	Sept (3)	125,000	Campfire	0	0
1970	Laguna	San Diego	Sept (3)	70,500	Powerline	5	382
2003	Cedar	San Diego	Oct (3)	109,500	Flares	15	2,820
2007	Witch	San Diego	Oct (2)	80,200	Powerline	2	1,265
2017	Tubbs	Sonoma	Oct (2)	14,900	Powerline	22	5,643
2017	Thomas	Ventura	Dec (10)	114,080	Powerline	2	1,063
2018	Camp	Butte	Nov (2)	62,060	Powerline	88	18,804
2018	Woolsey	Ventura	Nov (3)	39,335	Powerline	3	1,643
2019	Kincade	Sonoma	Nov (5)	31,470	Powerline	0	374

*Indicates days of Santa Ana or North winds *[Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, https://frap.fire.ca.gov/mapping/gis-data/; accessed Jan 2020].*

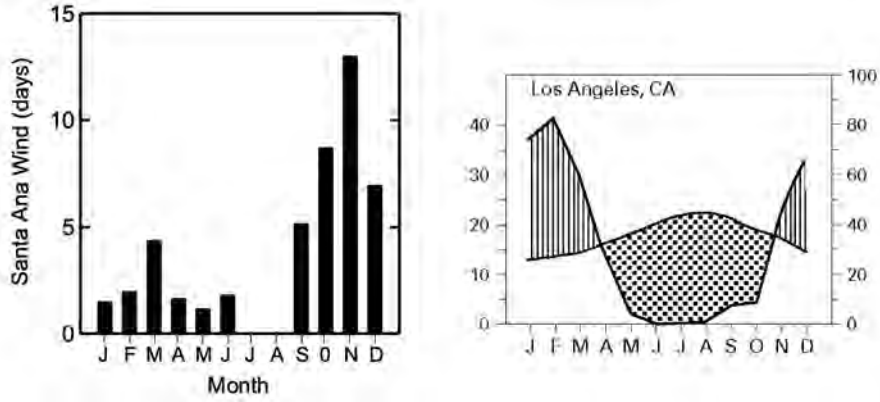


Figure 5. Days of Santa Ana winds (left) and (right) temperature and precipitation in Los Angeles illustrating typical Mediterranean climate of winter rains and summer droughts *(from Keeley et al. 2012).*

Historically these landscapes have not experienced the fire exclusion seen in many Sierra Nevada landscapes, despite being managed by the same fire suppression policy (Fig. 6). This is due to the fact that essentially all are caused by human ignitions, which are relatively common due to the high population density in the western portion of California (Keeley and Syphard 2018). As a consequence, there has not been any lack of fire and most large fire events burn across landscapes with an extensive fire history and no anomalous fuel accumulation. Indeed, some of these large fires—e.g., the Thomas Fire (Keeley and Syphard 2019)—have burned across areas where extensive prescription burning had occurred in recent years, pointing to the conclusion that prior fuel treatments are having limited effect on the spread of these fires. Even landscapes not experiencing high fire frequencies, such as the San Francisco Bay Area, are not outside their range of natural fire frequencies and so fuels have not accumulated due to fire suppression (Keeley 2005). To be sure, some communities in this region have dangerous fuels but these are often the result of urban plantings of *Acacia*, *Eucalyptus* and *Pinus* and not so much due to accumulation of wildland fuels from elimination of natural fires.

Every year there are many Santa Ana wind events but most years we don't see major wind-driven fires because they are entirely dependent on a human ignition happening during an extreme wind event. Indeed, only about five percent of the Santa Ana wind days are accompanied by a large fire event (Rolinski et al. 2019). Some have suggested that these Santa Ana winds are increasing in frequency, duration, and intensity, but records do not show a change in the character of these winds since the mid-1900s (Williams et al. 2019). Rolinksi et al. (2016) found that fires during extreme weather events are larger than ones in less extreme Santa Ana conditions, and some have interpreted this to mean that fires are becoming worse because Santa Ana winds are becoming more extreme. However, this study only considered Santa Ana winds after an ignition had occurred, thus ignition sources are critically important. It is important to recognize that Rolinksi's Santa Ana Wind Threat Index is not an indication of when an extreme fire will occur but only how bad the fire will be once ignited. What determines an extreme fire year is the untimely human ignition during an extreme wind event. This is illustrated by the fact that the frequency of these wind events is not correlated with area burned (Keeley and Syphard 2018) and our largest fire years occur in high-as well as low-Santa Ana wind intensity years

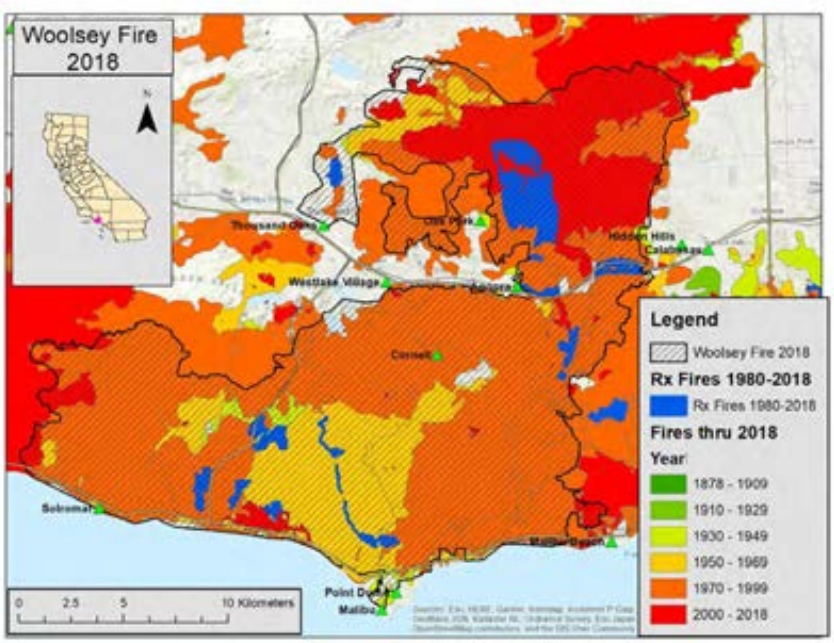


Figure 6. Fire history within the perimeter of the 2018 Woolsey Fire. Hatched area indicates less than 1% of the area unburned prior to 2018. Legend indicates other fire dates *(Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, https://frap.fire.ca.gov/mapping/gis-data/; accessed Jan. 2020).*

(Fig. 7). Ultimately it is all determined by an untimely human ignition event. Of course climate is peripherally related as it has been found that these fires are less likely to occur when relative humidity is high (Jin et al. 2014) and this most certainly is tied to decreased probability of such fires after early autumn precipitation (Keeley and Syphard 2017).

Indeed, Santa Ana wind events occur multiple times every year, yet during most such wind events there is no human ignition and thus no fire (Keeley and Syphard 2017). There is little evidence that the increase in the number of catastrophic fires is the result of increased intensity of Santa Ana wind events. For example Guzman-Morales et al. (2016) mapped the annual intensity of Santa Ana wind events (Fig. 7) yet when we overlaid extreme fire years of over 100,000 hectares burned in Southern California (Fig. 7), we find that such extreme fire years are associated with low as well as high intensity Santa Ana wind years; e.g., the catastrophic 2003 Cedar Fire (Table 1) occurred during a year with low-intensity Santa Ana winds.

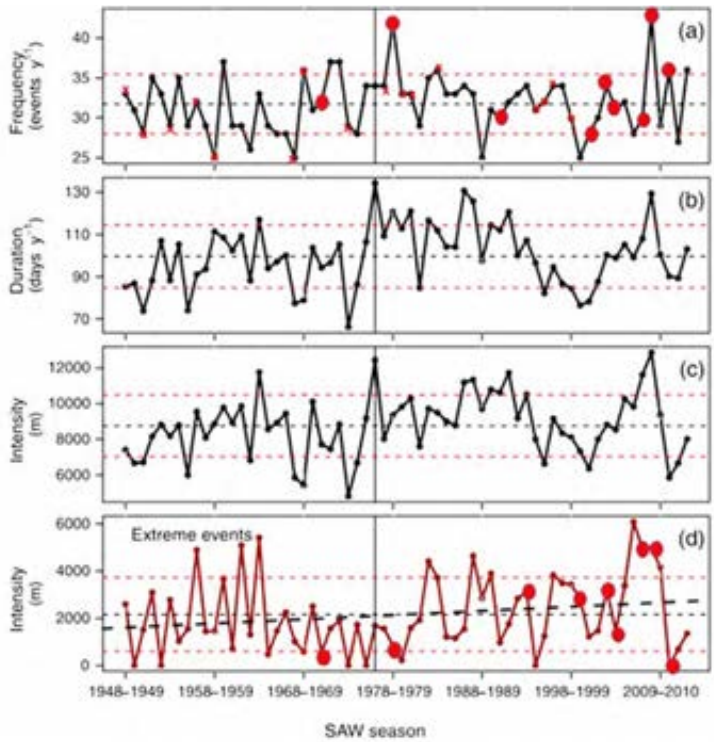


Figure 7. Pattern of Santa Ana wind (SAW) characteristics from Guzman-Morales et al. 2017 and with red dots indicating very high fire years exceeding a hundred thousand hectares burned *(from Keeley and Syphard 2017)*. Correlation analysis between frequency of Santa Ana wind events or the intensity of extreme Santa Ana wind events with area burned suggests there is no significant relationship in Southern California (R2=0.01 and R2=0.00, respectively).

CHANGING IGNITION SOURCES

Lightning is a common ignition source in forests of the Sierra Nevada and northeastern California and thus accounts for many fuel-dominated fires (Table 1). However, lightning is relatively uncommon in coastal regions (Keeley and Syphard 2018) and does not occur under the synoptic conditions that create extreme Santa Ana and North wind events. Thus, these wind-dominated fires are ~ 100 percent human-ignited fires (either from intentional causes, such as arson, or accidental causes, such as sparks from equipment).

In the last decade, the majority of these large fires—including some of the biggest fires in 2017, 2018, and 2019—have been ignited by powerline failures during extreme wind events. Indeed, since the year 2000, over half a million acres have burned due to powerline failures, which is five times more than in the prior two decades (Keeley unpublished data). The increased impact of powerline-ignited fires is not the result of increased frequency or intensity of extreme wind events. There are two likely explanations for this increase in powerline-ignited fires: 1) expansion of the electrical grid due to increased development, which provides more opportunities for powerline ignited fires, and/or 2) deteriorating powerline equipment resulting from age and inadequate maintenance (one California regulator contends that electrical grid equipment is being run to the point of failure (Penn et al. 2019)).

GLOBAL CLIMATE CHANGE

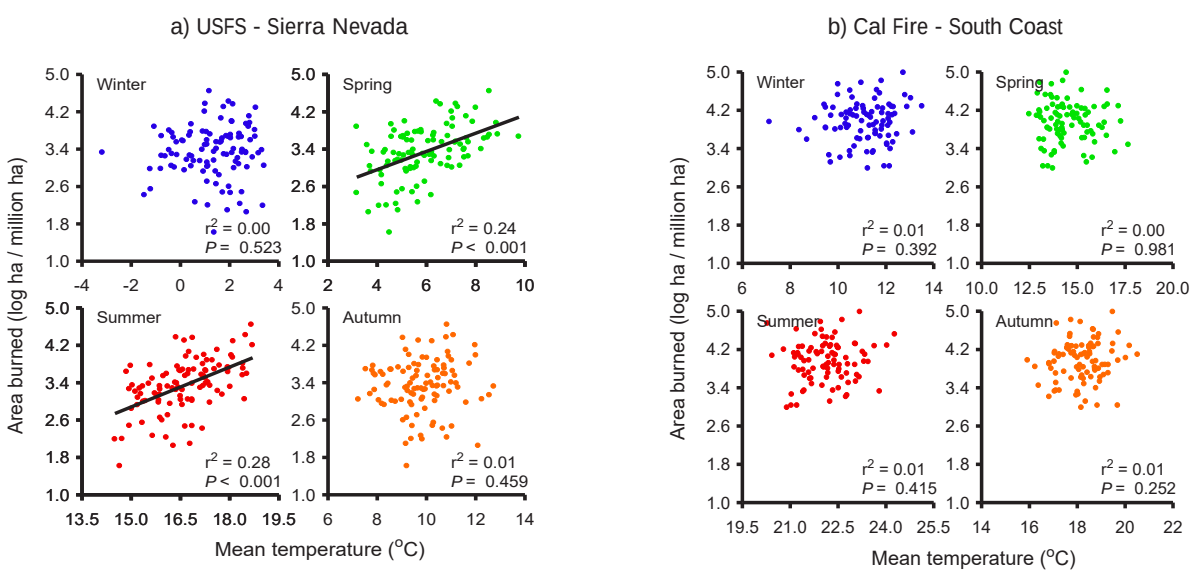
Some forecasts of future fire regimes based on different climate change simulations predict huge increases in California wildfires (Westerling 2018). These models need to be viewed in light of the fact that they are driven by untested assumptions. They don't adequately account for the complexity of fire-driven changes in vegetation (Syphard et al. 2018b), and they don't consider changes in fire–climate relationships over time, as well as changes in human-ignition patterns.

An alternative approach to future modeling is retrospective studies. Confucius stated, "If one wants to define the future, they must study the past" (Castro 2012). We recently conducted a study that took an empirical approach and asked how seasonal variation in temperature and precipitation has correlated with area burned, year to year, in the past. This investigation, which differs from those using algorithms of future fire–climate relationships, covered much of the last 100 years and separated out the effect of different seasonal temperatures (Keeley and Syphard 2017).

One interesting finding is that in no region of the state did winter temperature play a role in determining subsequent fire activity. This may be important since some climate models predict the greatest global warming to occur in the winter in the northern hemisphere. So perhaps this type of warming might not translate into changes in fire severity and frequency in California.

We can summarize our findings by contrasting U.S. Forest Service lands in the Sierra Nevada (Fig. 8a) with the lower elevation California Department of Forestry and Fire Protection (Cal Fire) responsibility lands in Southern California (Fig. 8b). In Sierra Nevada forests there is a significant relationship between higher spring and summer temperatures and area burned; indeed, in the last 50 years, the combination of these two climate variables (spring and summer temperature) could explain over 50 percent of the year-to-year variation in area burned (Keeley and Syphard 2017). This is consistent with claims that global warming has played a role in increased burning in western forests in recent decades (Abatzoglou and Williams 2016).

In contrast, on non-forested landscapes in Southern California we found little correlation between seasonal temperatures and area burned (Fig. 8b), a pattern consistent with other recent studies (Williams et al. 2019). We surmise that this is likely due to the fact that in Southern California it is hot and dry enough every year to support large fires. (Note that maximum summer temperatures in the Sierra Nevada, when fires are most extensive, are similar to the lowest temperatures observed in Southern California in the summer, Fig. 8a&b). The lack of a strong annual climate relationship with fires in Southern California is due to climate being overridden by other factors, such as extreme wind events, increasing human ignitions during severe wind events, and long-term drought. Interestingly, while there has been an effect in the last 50 years of prior year precipitation on fires in Southern California, this effect is well known in grasslands and savannas throughout the southwest and is tied to elevated grass fuel loads following high rainfall years (Keeley and Syphard 2017). We believe this relationship showed up for Southern California in the last half of the long-term record (Fig. 8b) because of the the well-documented increase in type conversion from shrublands to grasslands in the region (Syphard et al. 2018a).



Akaike IC regression models

Sierra Nevada (USFS)	r2	
1910 - 2013	0.39	Temp spr+Temp sum-Ppt spr
1910 – 1959	0.42	- Ppt spr - Ppt win
1960 - 2013	0.52	Temp spr + Temp sum

South Coast (Cal Fire)	r2	
1919 - 2013	0.00	
1919 - 1959	0.00	
1960 - 2013	0.25	Prior ppt-Ppt aut -Ppt sum

Figure 8. a) Annual area burned from 1910–2013 for USFS lands in the Sierra Nevada plotted against winter, spring, summer, autumn temperatures and multiple regression models using all temperature and precipitation data for these four seasons, and b) annual area burned from 1919 – 2013 on Cal Fire lands in Southern California and multiple regression analysis *(from Keeley and Syphard 2017).*

One climate factor not considered when investigating annual climates is the impact of long-term droughts; i.e., those that last for multiple years. Recently California experienced an intense drought that began in 2012 and lasted for three years in the Sierra Nevada and eight years in Southern California (Jacobsen and Pratt 2018). It was accompanied by an immense dieback of trees in the Sierra Nevada (Stephens et al. 2018) and of shrublands in Southern California (Keeley and Syphard 2019). This creation of massive dead fuel loads represents a legacy on the landscape that may persist through subsequent years of higher rainfall. If drought-induced dieback proves to have been a critical factor in making the 2017 and 2018 fire years so extreme, it raises doubts as to whether these fire years represent a new normal for California, since although droughts are expected to be more severe under climate change, there is no evidence that such extreme droughts will be a normal feature going forward.

What can we conclude about how climate change may impact these coastal wind-driven fires? Global warming may reduce grass growth leading to reduced fire frequency in these grass-dominated landscapes. On the other hand, higher temperatures have the potential for increasing the intensity of plant stress during droughts, perhaps elevating dieback of woody plants that would exacerbate fire spread and intensity; a study by Williams et al. (2015) concluded that the last severe drought in the Sierra Nevada increased the stress by ~10-15 percent. A further likely impact of global warming is that it will alter postfire recovery of shrublands by changing the competitive balance to favor alien grasses, increasing type conversion to highly flammable herbaceous fuels, and leading perhaps to increased fire frequency (Syphard et al. 2018a, 2019, Park et al. 2018).

In summary, there is good reason to conclude that global warming is affecting Sierra Nevada forest fires. In montane forests with fuel-dominated fires, summer temperatures—although fluctuating greatly from year to year—have been on an upward trajectory for many decades and it is reasonable to assume a causal relationship between increased fire activity and global warming. However, over this same period there has been a steady increase in understory fuels. This raises an interesting question: Would the strength of the observed climate impact (Fig. 8a) have been as strong in the absence of this anomalous fuel accumulation due to fire suppression? In contrast, in the coastal regions there is limited evidence that climate change is impacting wind-dominated fires (Fig. 8b). However, global warming has the potential for a number of indirect impacts on vegetation that may alter fire regimes.

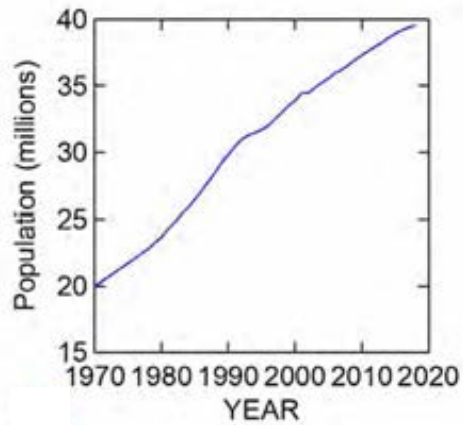


Figure 9. California population from Census Bureau *(www.census.gov; accessed June 2019)*

POPULATION GROWTH

Roger Kennedy, a former National Park Service director, was one of the first to bring attention to the role of population growth in raising the threat of wildfire (Kennedy 2006). It is true that since 2000 California has experienced a highly variable and subtle rise in temperature. However, less noticed is that there has also been a steep rise in population, adding about six million people (Fig. 9) over the last two decades. Since ~100 percent of the wind-dominated fires are ignited by humans or human infrastructure, there is likely a causal relationship between this population growth and the increased incidence of catastrophic wind-dominated wildfires.

Although local, state, and federal agencies have made significant progress in reducing the overall number of fires in the state over the last several decades (Keeley and Syphard 2018), there has been an increase in ignitions during extreme wind events. Thus, the real driver of wind-dominated fires is not the extreme wind events per se, but rather untimely human ignitions during such extreme wind events. And, of course, the addition of 300,000 more people every year in the state increases the probability of such an ignition event; moreover, urban sprawl into wildland areas increases the probability of losses of lives and property. An illustration of this is the 2017 Tubbs Fire that roared through sections of Santa Rosa, Sonoma County (Fig. 10b) causing the deaths of 22 people and destroying more than 5500 structures. Fifty years earlier the Hanly Fire had burned through much of the same landscape during a North wind event (Fig. 10a), yet no one died and only about

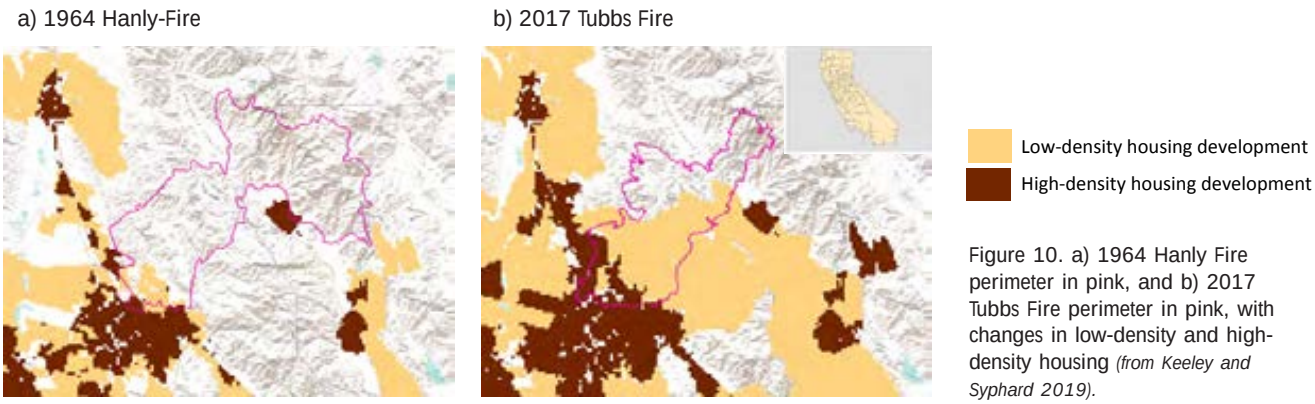


Figure 10. a) 1964 Hanly Fire perimeter in pink, and b) 2017 Tubbs Fire perimeter in pink, with changes in low-density and high-density housing *(from Keeley and Syphard 2019).*

100 structures were lost. Some researchers have discounted this comparison because the Hanly Fire burned over a longer period of time and therefore it is assumed it was not driven by severe winds. However, that fire burned for a longer duration because it was nearly three times the size of the Tubbs Fire and when it made its run toward Santa Rosa (overlapping with the perimeter of the much later Tubbs Fire) it was driven by extreme dry winds (*The Press Democrat*, September 26, 1964, front page), suggesting fire behavior similar to the 2017 Tubbs Fire. The difference in impact of these two fires is likely due to the fact that during this 50-year period Santa Rosa's population grew from 30,000 to 170,000 people and the urban footprint had expanded such that in 2017 development had expanded so that two-thirds of the area burned by the Tubbs Fire was low-density housing (Fig. 10b). This urban expansion was accompanied by expansion of the electric power grid, increasing the chances of a powerline failure during North wind events that drove both the Hanly and Tubbs fires.

MANAGEMENT CONSIDERATIONS

Fuel-dominated and wind-dominated fires exhibit important differences (Table 1) that inform how to manage these events. First, the fuel-dominated fires are largely forest fires in lightly populated regions such as the Sierra Nevada. In contrast, most wind-dominated fires occur in non-forested ecosystems in the western half of the state, though they may also occasionally occur in more interior sites, such as the 2018 Camp Fire that burned in Paradise. Wind-dominated fires occur in densely populated landscapes, and these fires are responsible for the greatest loss of lives and property.

MANAGEMENT CONSIDERATIONS—FUEL-DOMINATED FIRES

Montane forests have an anomalous accumulation of fuels due to more than a century of fire suppression and logging and therefore require concerted efforts at reducing the present fuel load (North et al. 2012). In the late 1960s, staff at Sequoia National Park began prescription (Rx) burning and soon after the other national parks in the Sierra Nevada followed suit (Keeley and Syphard 2019). Over time these parks greatly exceeded the area burned by adjacent forests. In recent years the USFS lands have accelerated the amount of Rx burning. However, all Sierra Nevada lands are a long way from burning at a rate sufficient to restore natural historical fire frequencies. There are many limitations, including funding, air quality restrictions, diversion of personnel from Rx burns due to wildfires, among others.

MANAGEMENT CONSIDERATIONS—WIND-DOMINATED FIRES: THE 5 P'S

The distinction between fuel-dominated and wind-dominated fires is similar to the dichotomy between katabatic and non-katabatic wind-driven fires made by Kolden and Abatzoglou (2018). They point out that in Southern California there are summer "fuel-dominated fires" and autumn "wind-dominated fires." While both types of fires occur in the region, it is the latter type that account for the vast amount of acreage burned, loss of lives and destruction of property. While management needs to be cognizant of both types of fire, it also needs to appreciate that summer fires are the least threatening fires and we should put our greatest effort toward autumn wind-dominated fires. Although all fires are a threat if fuels around homes have not been reduced, there are five points to consider with respect to the catastrophic wind-dominated fires:

1) *People:* On these landscapes, fire is more of a people problem than a fuel problem. More people translates into a greater probability of an ignition during a severe wind event, and more development in highly fire-prone landscapes inevitably results in greater losses of lives and homes.

2) *Prevention:* Rather than focusing on fuel treatments the scientific evidence clearly points to a need for a much greater emphasis on fire prevention. Although progress has been made in reducing the number of fires, the area burned has increased (Keeley and Syphard 2018). Powerline failures are a major cause of large fires and solutions to this increasing threat remain elusive. As widely reported in the media, three major utility companies in the state have implemented plans to monitor winds and shut down the power grid during extreme wind events. Such so-called Public Safety Power Shutoffs (PSPS) have the potential to decrease fire starts and limit damage (and, as a by-product, raise public awareness of fire threats). But there are many accompanying problems, as became evident during the recent Kincade Fire (Table 1) in October 2019, which was started by an electric failure, despite widespread power outages at the time. Such shutdowns impacted a multitude of vital services, including medical equipment, water pumps, traffic signals, communication equipment etc. One solution might be undergrounding the power lines in areas known to be corridors for extreme winds (Keeley et al. 2009). However, this would be much more expensive for the utilities to install and maintain. In addition, in areas where sensitive natural resources are present, overhead power lines may be less destructive. Nonetheless, San Diego Gas & Electric, which has led the way with responding to powerline-ignited wildfires, reports that 60 percent of its distribution lines are currently underground (Joe Vaccaro, Fire Mitigation & Climate Adaptation Manager, San Diego Gas & Electric Company, personal communication, 5 Dec 2019).

3) *Planning:* Community planning needs to devote similar attention and resources to fire as to other hazards. Since we have limited ability to control earthquakes and floods, some urban planners have utilized zoning restrictions to reduce impacts of these hazards. Yet, zoning restrictions are largely lacking when it comes to fire hazards, in large part because fires have been perceived as controllable. However it is increasingly obvious that this is not always the case and many communities are currently very vulnerable. Fire zoning (Kennedy 2006) needs to be given more consideration as well as urban planning that insures adequate ingress for fire fighters and egress for residents during extreme fire events. Perhaps replacing community planning with a more regional approach might contribute to these efforts.

4) *Protection:* High-intensity fires generally do not directly ignite homes when separated from vegetation by 30 meters (Cohen 2000). Home ignitions are usually the result of embers blown onto the structure, and this is particularly true under extreme wind conditions. Ember-cast firebrands often travel over a distance of half a mile or more. Embers ignite only under specific circumstances and this is most likely when they land on dead fuels (Zhou et al. 2019). Homeowners can diminish the probability of damage by addressing those factors that affect embers igniting their home, such as reducing plant litter on roofs and gutters, enclosing eves so that vent orientation is less susceptible to ember entry, closing open eves, placing fine-mesh screens on vents, and installing double-pane windows and appropriate siding (Syphard and Keeley 2019). Well-watered trees with significant foliage can provide protection from ember cast onto a home (Keeley and Syphard 2019). In fact, watered trees with green foliage may not be susceptible to ignitions by embers, but rather could serve to extinguish them and deprive them of dry fuels. While the notion of trees as "ember catchers" is appealing, it is a largely untested idea.

   Rooftop sprinklers may provide an added measure of protection and may be justified by the observation that trees adjacent to destroyed homes often survive because their foliage is moist, whereas combustible materials in homes represent dead fuels that are likely at equilibrium with ambient relative humidity of 10 percent or less. However, such sprinklers would need to address a number of issues. For example, metropolitan water lines and water supplies are sometimes compromised during fire events and thus there would need to be a stand-alone water tank. Also, shutting down the power grid is happening more often and thus solar or other alternative power would need to be available to pump water. In addition, there is the need for further research on how to engineer such a system in order to prevent the water spray from being dissipated to the atmosphere due to the high winds. Incorporating a system like this would likely be a significant expenditure that may not be possible for many home owners.

   Fuel treatment around homes is critical but needs to be focused on the "house out," i.e., putting the greatest effort into the area nearest the home and less as one moves further into the wildlands. Reducing fuels within 30 meters of the house is generally sufficient and further clearance beyond that is of doubtful value (Syphard et al. 2012).

5) *Prediction:* There is an urgent need for improved meteorological and fire behavior models that can provide real-time prediction of wind patterns and

fire spread during these extreme events, coupled with improvements in communication systems for providing that information to agencies and homeowners.

Acknowledgments

We thank Marti Witter and David Loeb for very constructive suggestions on this manuscript and Anne Pfaff for preparing the fire history maps. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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REFERENCES

Abatzoglou J. T., and A. P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences* 113: 11770-11775.

Birnbaum, E. 2018. California governor on wildfires: 'This is the new abnormal.' The Hill 11/11/18, https://thehill.com/homenews/state-watch/416167-california-governor-on-wildfires-this-is-the-new-abnormal.

Castro, J.A. 2012. What does 'Study the past if you define fhte future' mean? http://wiki.answers.com/Q/What_does_'Study_the_past_if_you_would_define_the_future'_mean

Clements, C.B., N.P. Lareau, D.E. Kingsmill, C.L. Bowers, C.P. Camacho, R.Bagley, and B. Davis. 2018. The rapid deployments to wildfires experiment (RaDFIRE): Observations from the fire zone. Bulletin of the American Meterological Society *https://doi.org/10.1175/BAMS-D-17-0230.1*.

Cranley, E. 2018. Trump continues to blame fires on forest mismanagement even while traveling to California. Business Insider 11/17/18, https://www.businessinsider.com/trump-continues-to-blame-wildfires-on-forest-mismanagement-2018-11.

Deser, C., A. Phillips, V. Bourdette, and H. Teng. 2012. Uncertainty in climate change projections: the role of internal variability. *Climate Dynamics* 38: 527-546.

Jacobsen, A. L., and R. B. Pratt. 2018. Extensive drought-associated plant mortality as an agent of type-conversion in chaparral shrublands. *New Phytologist* 219: 498-504.

Jin Y, J. T. Randerson, N. Faivre, S. Capps, A. Hall, and M. L. Goulden. 2014. Contrasting controls on wildland fires in Southern California during periods with and without Santa Ana winds. Journal of Geophysical Research, *Biogesciences* 119: doi:10.1002/2013/G002541.

Keeley, J. E., H. Safford, C. J. Fotheringham, J. Franklin, and M. Moritz. 2009. The 2007 southern California wildfires: Lessons in complexity. *Journal of Forestry* 107: 287-296.

Keeley, J. E., and A. D. Syphard. 2017. Different historical fire-climate relationships in California. *International Journal of Wildland Fire* 26: 253-268.

Keeley, J. E., and A. D. Syphard. 2018. Historical patterns of wildfire ignition sources in California ecosystems. *International Journal of Wildland Fire* 27: 781-799.

Keeley, J. E., and S. D. Syphard. 2019. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* 15: 24 doi.org/10.1186/s42408-019-0041-0.

Keifer, M. B. 2006. Long-term surface fuel accumulation in burned and unburned mixed-conifer forests of the Central and Southern Sierra Nevada, CA (USA). *Fire Ecology* 2: 53-72.

Kennedy, R. G. 2006. Wildfire and Americans. How to save lives, property, and your tax dollars. Hill and Wang, New York.

Kolden, C. A., and J. T. Abatzoglou. 2018. Spatial distribution of wildfires ignited under katabatic versus non-katabatic winds in Mediterranean Southern California USA. *Fire* 1:19, doi: 10.3390/fire1020019.

McKelvey, K.S. and K.K. Busse. 1996. Twentieth-century fire patterns on forest service lands. In Sierra Nevada Ecosystem Project: Final report to Congress, vol II, Centers for Water and Wildland Resources, University of California, Davis, pp1119-1138.

North, M., B. M. Collins, and S. Stephens. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110: 392-401.

Office of Governor 2019. Governor Newsom signs bills to enhance wildfire mitigation, preparedness and response effors. 10/2/2019, https://www.gov.ca.gov/2019/10/02/governor-newsom-signs-bills-to-enhance-wildfire-mitigation-preparedness-and-response-efforts/

Park, I. W., J. Hooper, J. M. Flegal, and G. D. Jenerette. 2018. Impacts of climate disturbance and topography on distribution of herbaceous cover in Southern California chaparral: insights from a remote-sensing method. *Diversity and Distributions* 24: 497-508.

Penn, I., P. Eavis, and J. Glanz. 2019. How PG&E ignore fire risks in favor of profits. New York Times 03/18/2019, https://www.nytimes.com/interactive/2019/03/18/business/pge-california-wildfires.html

Rolinski, T., S. B. Capps, R. G. Fovell, Y. Cao, B. J. D'Agostino, and S. Vanderburg. 2016. The Santa Ana wildfire threat index: Methodology and operational implementation. *Weather and Forecasting* 31: 1881-1897.

Rolinski, T., S. B. Capps, and W. Zhuang. 2019. Santa Ana Winds: A descriptive climatology. *Weather and Forecasting* 34: 257-275.

Stephens, S. L., B. M. Collins, C. J. Fettig, M. A. Finney, C. M. Hoffman, E. E. Knapp, M. P. North, H. Safford, and R. B. Wayman. 2018. Drought, tree mortality, and wildfire in forests adapted to frequent fire. *BioScience* 68: 77-88.

Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2018a. Chaparral landscape conversion in Southern California, pp. 311-334. In E. C. Underwood, H. D. Safford, J. E. Keeley, N. Molinari, and J. J. Hooper (eds), *Valuing Chaparral. Ecological, Socio-Economic, and Management Perspectives.* Springer, New York.

Syphard, A. D., T. Sheehan, H. Rustigian-Romsos, K. Ferschweller. 2018b. Mapping future fire probability under climate change: Does vegetation matter? *PLOS ONE* 10.1371/journal.pone.0201680.

Westerling, A. L. 2018. Wildfire simulations for California's fourth climate change assessment: projecting changes in extreme wildfire events with a warming climate. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CED-2018-014.

Williams, A. P., R. Seager, J. T. Abatzoglou, B. I. Cook, J. E. Smardon, and E. R. Cook. 2015. Contribution of anthropogenic warming to California drought during 2012-2014. *Geophysical Research Letters* 10.1002/2015GL064924.

Williams, A. P., J. T. Abatzoglou, A. Gershunov, J. Guzman-Morales, D. A. Bishop, J. K. Balch, and D. P. Lettenmaler. 2019. Observed impacts of anthropogenic climate change on wildfire in California. *Earth's Future* 7: 892-910.

WHY ARE SO MANY STRUCTURES BURNING IN CALIFORNIA?

Alexandra D. Syphard and Jon E. Keeley

California has earned a reputation for wildfires that inflict serious damage on human infrastructure, dating back to images of Richard Nixon hosing down the roof of his house in the 1961 Bel-Air fire, and of the famous "fireproof" home of grocery store entrepreneur Fred Roberts burning to the ground in 1982. In recent years, this notoriety has been transformed into public alarm, reflected in the apocalyptic headlines of recent newspaper articles suggesting the "end of California" (*New York Times*, 30 October 2019) and that "California is becoming unlivable" (*The Atlantic*, 30 October 2019). Now the phrase "the new normal" has worked its way into the lexicon, sustained by record-breaking structure loss numbers in 2017 and 2018 despite significantly lower structure losses in 2019.

It remains to be seen whether or not those two recent years were back-to-back, once in a century events, or if the trend has crossed some kind of tipping point, but data does show a long-term trend of significant increase in structures lost to wildfires since the beginning of the 20th century (Fig. 1). What was an average of ~500 homes lost per year in Southern California from about 1950–2000 (Cal Fire 2000) has recently climbed to ~2700 structures per year statewide from 2000–2018 (Syphard and Keeley 2019). California is not alone in the U.S., or in the world, in suffering increasing impacts from wildfires (e.g., Blanchi et al. 2012, Haynes 2015, Viegas 2018). Impacts so far in the recent Australian bushfire season have been record-breaking, with several thousand structures lost, more than 25 fatalities, and unthinkable losses to wildlife. The question that follows, then, is why?

Although trends vary from region to region, one clear reason for increasing wildfire-related losses is

Above: A home burned by the Thomas Fire in 2017.
[Photograph by Master Sgt. Brian Ferguson/U.S. Air Force]

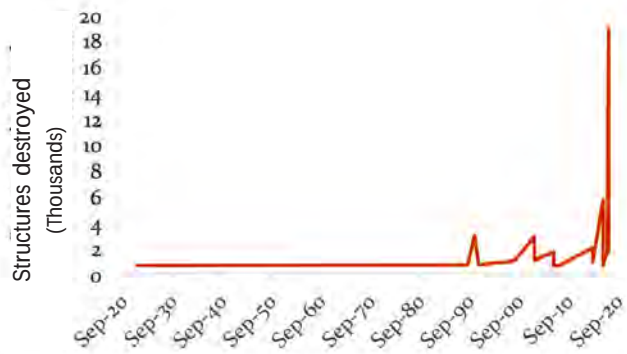

Figure 1. Annual number of structures destroyed in wildfires in California from 1920 to 2018. *[Source: California Department of Forestry & Fire Protection]*

the overall increase in wildfire activity. Although, counter to intuition, the number of wildfires has declined in the last several decades, area burned has either remained constant or increased, with substantially higher frequency of large wildfires (Keeley and Syphard 2018)(Discussed further in Keeley and Syphard, pg. 4 of this issue.) Perhaps an even stronger explanation for increased wildfire-related structure loss is the rapid development of the wildland–urban interface (WUI), which not only exposes more structures to wildland fire, but also increases the likelihood for more human-ignited fires (Radeloff et al. 2018). Despite these trends, however, not all fires result in structure loss, and not all structures are impacted by wildfires they are exposed to. Thus, it is essential to study the factors that are most strongly related to structure exposure and resilience to wildfire, which could then lead to better adaptation and coexistence with wildfire in this era of the "new normal."

In response to this need, a growing number of scientists are conducting empirical research studies to answer the question of why some structures are lost in wildfires and others aren't. Results so far show that the answer to that question is complicated. That is, structure loss results from the confluence of multiple interacting factors across different temporal and spatial scales, which all vary by ecosystem. Given this complexity, misunderstandings and disagreements have arisen over the cause and direction of trends in wildfire activity (Doerr and Santín 2016), fire risk and structure loss (Mccaffrey et al. 2019), and thus, the most effective approach for prioritizing fire management decisions (Moritz et al. 2014). In fact, management techniques appropriate for one region are commonly applied inappropriately to other regions (Noss et al. 2006).

One way that this conflict over priorities can be reduced is through better information and understanding of the similarities and differences that contribute to structure loss among wildfire ecoregions. As data accumulate about the range of conditions under which losses occur, it will be increasingly possible to sort out which risk management techniques are most appropriate for different regions. Wildfire structure losses in the last several decades have already provided a wealth of data for studies comparing factors associated with structures that survived or were destroyed. Most of this work has been done in California (Maranghides and Mell 2009, Syphard et al. 2012a, 2014, 2017, 2019c, Miner 2014, Alexandre et al. 2015, Kramer et al. 2019, Syphard and Keeley 2019) and Australia (Leonard 2009, Blanchi et al. 2010, 2012, Gibbons et al. 2012, 2018, Price and Bradstock 2013, Penman et al. 2019); but some work has also been done in other parts of the continental United States (Alexandre et al. 2016, Kramer et al. 2019).

Combined, the results of this research show clear roles for both local, house-level factors (e.g., structural characteristics of a particular house and property-level landscaping) and broader, landscape-level factors (e.g., housing pattern and location, topography, fuel, and fire characteristics) in explaining why some structures survive wildfires and others don't. This is consistent with the natural hazards literature that theoretically places vulnerability within the intersection of "exposure," that is, potential contact with a hazard; and "sensitivity," or the degree to which the hazard can cause harm (Birkmann 2006). Vulnerability to wildfire is a combination of exposure and sensitivity such that vulnerability results in loss when sensitive characteristics of structures are exposed to hazard events (e.g., the wildfire) (Cutter 1996, Schumann et al. 2019). Thus, exposure is the part of vulnerability related to characteristics of a location, and sensitivity is the risk of loss due to intrinsic physical or social characteristics.

EXPOSURE

Coincidence of fires and houses

A structure's wildfire hazard exposure ultimately lies at the spatial intersection of a wildfire event and the location of the property. The probability of structure loss thus depends on the relative likelihood that a fire ignition results in a fire within the geographical range of structures in the WUI. In turn, this depends on the location and timing of a fire ignition, which varies depending on cause and biophysical characteristics (Syphard and Keeley 2015) relative to other determinants of fire size, including topographic con-

Most homes don't burn from direct contact with flame. Here, a wind-driven fire carried embers over cement and ice plant to the house, reinforcing the importance of reducing the flammability of the home—focusing fire risk reduction from the "house outward." *[Photograph by Rick Halsey]*

ditions; fuel amount, moisture, and spatial continuity; and weather (Faivre et al. 2016). Large fires tend to be either primarily fuel-dominated or wind-dominated (Keeley and Syphard 2019), with most damage and economic loss occurring from wind-driven fire events (Jin et al. 2015, Keeley and Syphard this issue).

Large fire probability increases with the co-occurrence of human-caused ignitions and severe wind conditions (Abatzoglou et al. 2018). This means that, as population increases and development further encroaches into wildland vegetation, there is an increased risk that a human-caused ignition will coincide in place and time with hot, dry weather; flammable vegetation; and severe wind conditions. Data show that fires tend to be most frequent at low to intermediate housing and population densities (Syphard et al. 2009, Bistinas et al. 2013). Thus, the rapid increase in the spread of exurban development like that occuring now in California (Radeloff et al. 2018), has the potential to both increase the number of ignitions and decrease the overall distance between wildlands and housing.

As the distance between wildland vegetation and housing development decreases across a landscape, the overall exposure of houses to wildfire increases. This helps to explain research that shows the arrangement and location of housing development to be a top-ranked predictor of whether a structure survives or is destroyed by wildfire (e.g., Syphard et al. 2012b, Alexandre et al. 2016, Kramer et al. 2019). In terms of arrangement, data consistently shows that loss to wildfire is highest at relatively low housing density (Kramer et al. 2018, Syphard et al. 2019c) and at the interface between wildlands and development (Kramer et al. 2019), regardless of the geographic region in which a structure is located.

Other housing patterns, such as the way housing is dispersed, or the size of housing clusters, are also influential, although their relative importance in explaining structure loss varies from region to region (Alexandre et al. 2015, 2016). Topography is an additional exposure-related factor significantly related to structure loss, as fire tends to spread quickly upslope, meaning that houses on ridgetops are particularly vulnerable. An important caveat to the relationship between low structure density and structure loss is that, once a fire reaches a development, structure-to-structure spread is possible if adjacent houses are highly flammable and spaced within at least 50 meters of one another (Price and Bradstock (2013). In these circumstances, high housing density can be a significant risk factor (Maranghides and Mell 2009).

Fire patterns, altered fire regimes, and vegetation management

In addition to housing arrangement, housing location affects the potential exposure of a structure to wildfire because some areas are inherently more fire-prone than others (Syphard et al. 2012b). Certain parts of the landscape tend to burn repeatedly while others do not, and this reflects the wide variation in fire regimes across California (Syphard and Keeley in press). During the last century, fire regimes in California have been altered due to a range of factors including climate change, land use change, and legacies of fire management. However, the cause of fire regime changes, and their relative effects, have been nearly opposite in the northern and southern coastal parts of the state (Safford and Water 2014). As described in Keeley and Syphard (this issue), a history of successful fire exclusion in dry, mixed-conifer forests contributed to an alteration of what had been a low-intensity surface fire regime that typically burned back the understory plants without reaching into the canopy and burning

the large trees. The subsequent increase in the density of surface litter and the unchecked ingrowth of young trees that serve as ladder fuels now facilitate uncharacteristically severe crown fires. In contrast, in the native shrublands of southern and central coastal California, increased human-caused ignitions have resulted in unnaturally high fire frequency, with increases in wildfire further promoted by ongoing conversion of shrublands to more flammable invasive grasses (Fusco et al. 2019, Syphard et al. 2019b, 2019a).

These differences in the two fire regimes, and how they have been altered, have led to substantial controversy regarding wildfire exposure and the effects and effectiveness of vegetation management (Keeley et al. 2009, Halsey and Syphard 2015). In both northern and southern California, changes in fire regimes could lead to more dangerous or frequent wildfires, thereby increasing structure exposure to hazard. Mechanical treatments and prescribed fire in dry, mixed-conifer forests that reduce the understory and decrease small diameter tree density may help return these forests to a more resilient condition, and thereby potentially reduce exposure of structures to high fire hazard (Knapp et al. 2017).

On the other hand, in the non-forested landscapes that dominate the coastal central and southern parts of the state, vegetation management is primarily focused on reducing the extent of woody vegetation. That is, mechanical treatments are typically designed to remove and reduce the cover of native shrublands and increase the cover of herbaceous vegetation. Prescribed fire in this region *increases* the amount of uncharacteristically frequent fire, putting additional stress on native chaparral and shrublands. Therefore, in non-forested ecosystems vegetation management is inconsistent with ecological integrity and, in addition, has minimal efficacy in the wind-driven fires that result in the most structure loss (Keeley and Syphard this issue).

Access as a risk factor

While vegetation management may control fire behavior by slowing wildfire spread, wildfires during extreme wind conditions typically generate embers and burning debris that can fly kilometers ahead of the fire front. Therefore, fuels management in remote landscapes, even if it does alter fire behavior, has little possibility of preventing wind-driven fires from spreading and expanding if there are no firefighters present to control the fire. This is the likely explanation for why Penman et al. (2014) found that fire size and exposure of property to wildfire in Southern California are primarily controlled by fire weather and characteristics of the built environment, with fuel treatments or fuel load management having minimal influence. Fuel load is less likely to be limiting during wind-driven wildfires and reduction of fuel load in remote areas is unlikely to affect fire outcomes (Keeley et al. 2004, Schoennagel et al. 2004).

On the other hand, strategic placement of fuel breaks near communities may be more effective at reducing exposure because firefighters can use these for safe access to perform suppression activities (Syphard et al. 2011). In addition to strategically placed fuel breaks near communities, the road network surrounding a structure is also important for minimizing exposure from an access perspective. Wide roads and multiple access points can facilitate the transport of firefighting resources to properties within a community; in addition, a good road network provides faster and more efficient evacuation alternatives (Mangan 2000).

SENSITIVITY

Community sensitivity to wildfire, and the capacity to recover from wildfire losses, is related to the social and demographic characteristics of a region (Schumann et al. 2019). In terms of the physical nature of structure loss, however, the primary determinants of sensitivity include defensible space and home structure characteristics as well as firefighter accessibility.

Defensible space

There is certainly a degree of confusion regarding defensible space. A common sentiment is that the larger the defensible space, the better protected the home.

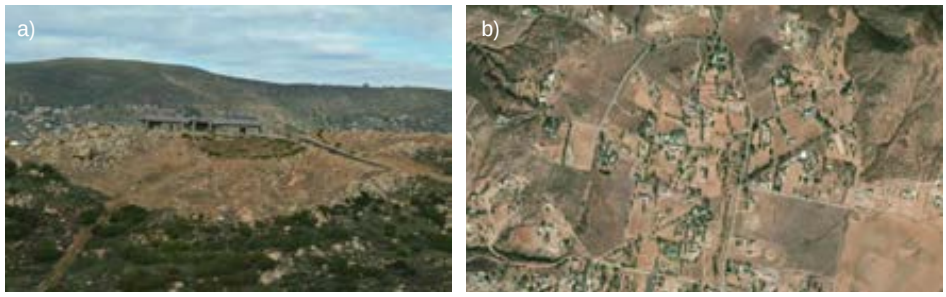

Figure 3. Local (a) and landscape-scale (b) examples of defensible space being performed beyond legal requirements or scientific evidence for protection. *[Images courtesy of Alexandra Syphard]*

Thus, clearance far in excess of legal requirements is increasingly being carried out (Fig. 3a), sometimes at a broad scale (Fig 3b). This is not necessarily helpful or effective. At the same time, many homeowners fail to create sufficient defensible space to improve structure survival.

What does the evidence show about the effectiveness of defensible space? The state of California requires homeowners in state-defined hazardous areas to provide 30 meters (100 feet) of defensible space around their home, which involves the maintenance of specific horizontal and vertical distances of spacing between patches of woody vegetation. Empirical studies in two Southern California areas found that defensible space of approximately 5-20 meters (16-66 feet) provided significant protection, with additional distance providing little or no significant benefit, even on steep slopes (Miner 2014, Syphard et al. 2014). Empirical research looking at structure loss in Australia also found that vegetation reduction and defensible space were most effective at close proximity to the structure (Gibbons et al. 2012, Penman et al. 2019), and that regular irrigation and proper spacing could be as just as effective as clearing woody vegetation (Gibbons et al. 2018).

The largest empirical study of home survival published to date, which included more than 40,000 structures subjected to wildfires over a five year period (Syphard and Keeley 2019), showed that defensible space distance explained little or none of the variance in structure survival. Instead, characteristics of the structure itself were far more significant (Fig. 4). These results should not be interpreted to mean defensible space is not important. But they do suggest that the most important component of defensible space may be the characteristics of vegetation closest to the house. For example, vegetation touching the structure and trees overhanging the roof were highly significant in the two empirical examples from Southern California.

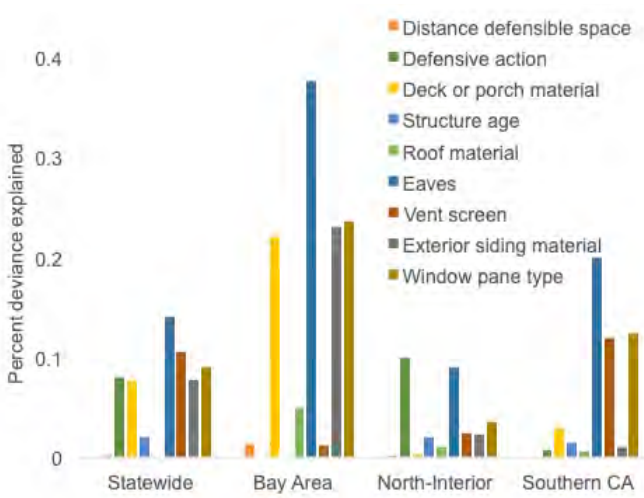

Figure 4. Relative importance (percent deviance explained) of defensible space distance and structural characteristics explaining structure loss to California wildfires from 2013–2018 for the entire state and broken into three broad regions. *[Figure modified from Syphard and Keeley 2019]*

Figure 5. Image of flammable debris on a roof that could ignite from wind-blown embers, reflecting how vegetation near or overhanging structures could increase the likelihood of structure loss.

Ember cast

It needs to be appreciated that, particularly during extreme wind-driven fires, most homes do not burn from direct flame contact, but rather from embers blown from the fire front, even from a kilometer or more away. Thus, the material that embers land on, be it vegetation or the structure itself, is key to whether the structure ignites or not. In some cases, the effect of overhanging trees or nearby vegetation is mostly related to the dead plant material or debris that is close to the structure (Fig.5). Likewise, many of the structural characteristics found to be most important in this recent study (Syphard and Keeley 2019) were related to the prevention of ember penetration, such as vent screens and eaves. Open eaves (Fig. 6a) are much more vulnerable to fires than closed eves (Fig. 6b). Open eaves have vents that are arranged perpendicular to the ground and thus in direct line of oncoming wind-driven ember cast. Closed eaves have vents facing down towards the ground and perhaps less prone to embers entering the vents.

Figure 6. Images of a) open eave design that may allow ember penetration into the structure more readily than b) closed eave design that has been significantly associated with structure survival in California wildfires. *[Photographs here and above courtesy of Alexandra Syphard and Jon Keeley]*

CONCLUSION

The studies described above illustrate that some structures are destroyed in wildfires and others are not because of multiple, often interacting, factors that variably influence the exposure and sensitivity of a property to wildfire. In an ideal world, strategies to increase community resilience to wildfire would be ranked and prioritized according to their relative potential for success in preventing structure loss in any given ecosystem. Of course, an ideal world would also not have to account for factors such as cost, effort, and feasibility, which add to the complexity of decision-making in the real world.

While most empirical research on structure loss has so far focused on either exposure or sensitivity factors independently, an integrated analysis in Southern California provided a comparison of the relative importance of different exposure-related and sensitivity-related variables (Syphard et al. 2017, Fig. 7) in distinguishing destroyed from surviving structures. Study results suggested that exposure (when measured by structure density) was the most important factor overall that distinguished destroyed from surviving structures. The relative importance of different sensitivity variables (e.g., structure age or landscaping characteristics) varied depending upon whether the structure was highly exposed (i.e., at low housing density) or less exposed (i.e., at high housing density) (Fig. 7).

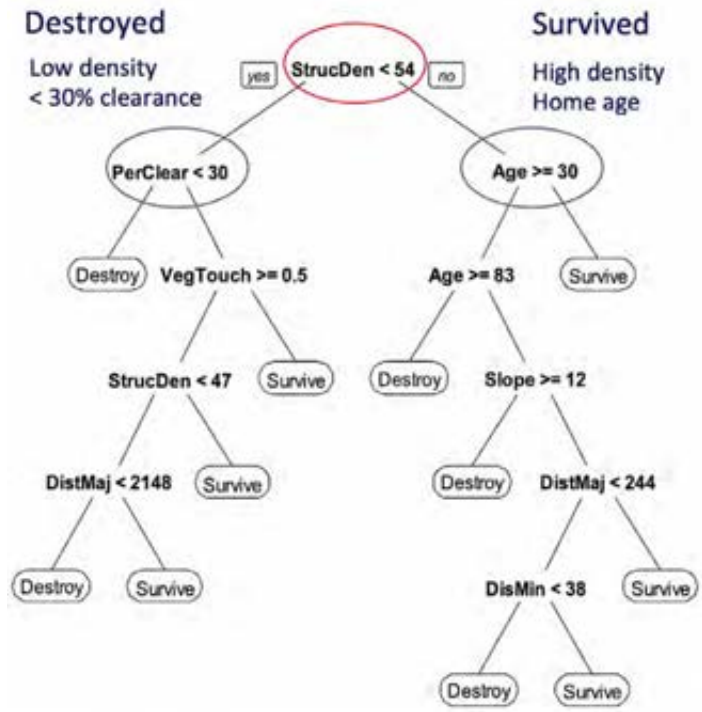

Figure 7. Classification tree showing the hierarchy of factors that best distinguished destroyed from survived structures in Southern California wildfires. Abbreviations are: StrucDen = structure density; PerClear = percentage woody vegetation clearance on property; Age = age of structure; VegTouch = number of sides of structure with vegetation touching; Slope = percentage slope on property; DistMaj = distance in meters to a major road; DisMin = distance in meters to a minor road. *Modified from Syphard et al. 2017.*

These results suggest that, in an ideal world, the most effective strategy at reducing future structure loss would focus on reducing the extent of low-density housing via careful land planning decisions. This conclusion is rather obvious given that reducing exposure reduces the chance that a wildfire could reach a structure in the first place. In the real world, regardless of land use planning decisions for future development, there is extensive existing development that may be exposed to future wildfires. Therefore, strategies like ignition prevention and strategic vegetation management could potentially reduce the exposure of these houses by focusing on the initiation or spread of the wildfire.

Once a fire reaches a property, structure sensitivity then becomes the key determinant for survival. In many areas, effective efforts to minimize sensitivity to wildfire include education and increased awareness of appropriate defensible space practices, development of Firewise Communities (Jakes et al. 2007), and improvement in building codes. Nonetheless, some communities underinvest in defensible space (Taylor et al. 2019), while in others, homeowners create excessive clearance (Fig. 3) that may increase the extent of invasive grass on the property. Conversion of native woody vegetation into grass in the non-forested landscapes of Southern California, for example, could increase the flammability of the property (Fusco et al. 2019), particularly if the grass is not irrigated regularly (Gibbons et al. 2018).

Given the importance of structural characteristics in home survival in recent California wildfires (Syphard and Keeley 2019), the improvement of building codes has been a positive development overall. However, there is already extensive existing residential development in fire-prone areas that was built prior to the adoption of new building codes. Reducing the fire sensitivity of these homes generally entails retrofits and modifications, which can be expensive (Quarles and Pohl 2018). However, some of the most effective actions, such as eave coverings and vent screens, are generally less expensive than replacing roofing or exterior siding, although window replacement can also be expensive (Quarles and Pohl 2018).

The 2017 Thomas Fire. *[Photograph courtesy of Stuart Palley/ U.S. Forest Service]*

It would appear, given recent improvements in adapting structures to withstand fire, that the increase in the numbers of houses burned in wildfire is not a matter of increased sensitivity. Instead, the answer lies somewhere in the combination of factors that govern exposure, including changes to wildfire behavior and activity, as well as exurban development that places structures in the path of these wildfires. Climate and vegetation change may increase the probability of large wildfires in some regions, such as the northern parts of California (Syphard et al. 2019c); but in other regions, like Southern California, climate change is likely to manifest differently, most likely indirectly, via factors such as long-term drought and vegetation change.

While the effects of climate change on wildfire vary from region to region, housing pattern variables have consistently been the most important factors explaining structure loss across California and elsewhere. This suggests that much of the increase in structure loss in California may be attributable to increases in this type of exposure—and that planning decisions could have broad-scale benefits in the future. Also consistent across regions is the potential for homeowner mitigation measures to provide significant improvement in structure survival probability. Those measures that focus on reduction of ember impact and penetration are most important.

Despite these overall consistencies, there is variation in the nature and strength of relationships in all of these factors. Wildfire frequency and behavior, and fuel characteristics, vary widely by ecosystem; thus, vegetation management efforts differ greatly in effects and effectiveness and should be implemented appropriately. Regardless of regional variations, everyone, from the individual homeowner, to local planning and permitting officials, to state and federal government authorities, will need to be involved in instituting preventive measures. Management appropriately informed by science and data analysis can reduce future structure losses and minimize ecological impacts to assure a more sustainable future. While these efforts may seem expensive in the present, it is much less expensive than paying for losses in the future.

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REFERENCES

Abatzoglou, J. T., J. K. Balch, B. A. Bradley, and C. A. Kolden. 2018. Human-related ignitions concurrent with high winds promote large wildfires across the USA. *International Journal of Wildland Fire* 27:377–386.

Alexandre, P. M., S. I. Stewart, N. S. Keuler, M. K. Clayton, M. H. Mockrin, A. Bar-Massada, A. D. Syphard, and V. C. Radeloff. 2016. Factors related to building loss due to wildfires in the conterminous United States. *Ecological Applications* 26.

Alexandre, P. M., S. I. Stewart, M. H. Mockrin, N. S. Keuler, A. D. Syphard, A. Bar-Massada, M. K. Clayton, and V. C. Radeloff. 2015. The relative impacts of vegetation, topography and spatial arrangement on building loss to wildfires in case studies of California and Colorado. *Landscape Ecology* 31:415–430.

Birkmann, J. 2006. Measuring vulnerability to natural hazards: towards disaster resilient societies. United Nations University Press, Tokyo.

Bistinas, I., D. Oom, A. C. L. Sá, S. P. Harrison, I. C. Prentice, and J. M. C. Pereira. 2013. Relationships between human population density and burned area at continental and global scales. *PLOS ONE* 8:e81188.

Blanchi, R., J. Leonard, K. Haynes, K. Opie, M. James, M. Kilinc, F. D. De Oliveira, and R. Van den Honert. 2012. Life and house loss database description and analysis. CSIRO.

Blanchi, R., C. Lucas, J. Leonard, and K. Finkele. 2010. Meteorological conditions and wildfire-related houseloss in Australia. *International Journal of Wildland Fire* 19:914–926.

Cal Fire. 2000. Wildland Fire Hazard Assessment. California Division of Forestry and Fire Protection, Sacramento, CA.

Cutter, S. L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20:529–539.

Doerr, S. H., and C. Santín. 2016. Global trends in wildfire and its impacts: Perceptions versus realities in a changing world. Philosophical Transactions of the Royal Society B: *Biological Sciences* 371.

Faivre, N. R., Y. Jin, M. L. Goulden, and J. T. Randerson. 2016. Spatial patterns and controls on burned area for two contrasting fire regimes in Southern California. *Ecosphere* 7:e01210.

Fusco, E. J., J. T. Finn, J. K. Balch, R. C. Nagy, and B. A. Bradley. 2019. Invasive grasses increase fire occurrence and frequency across US ecoregions. *Proceedings of the National Academy of Sciences*: 1–6.

Gibbons, P., L. van Bommel, A. Gill, G. J. Cary, D. A. Driscoll, R. A. Bradstock, E. Knight, M. A. Moritz, S. L. Stephens, and D. B. Lindenmayer. 2012. Land management practices associated with house loss in wildfires. *PLOS ONE* 7:e29212.

Gibbons, P., A. M. Gill, N. Shore, M. A. Moritz, S. Dovers, and G. J. Cary. 2018. Options for reducing house-losses during wildfires without clearing trees and shrubs. *Landscape and urban planning* 174:10–17.

Halsey, R. W., and A. D. Syphard. 2015. High-Severity Fire in Chaparral: Cognitive Dissonance in the Shrublands. The Ecological Importance of Mixed-Severity Fires: Nature's Phoenix.

Haynes, H. J. G. 2015. *Fire loss in the United States during 2014*. National Fire Protection Association, Fire Analysis and Research Division.

Jakes, P., L. Kruger, M. Monroe, K. Nelson, and V. Sturtevant. 2007. Improving wildfire preparedness: lessons from communities across the US. *Human Ecology Review*:188–197.

Jin, Y., M. Goulden, S. Faivre, V. Veraverbeke, A. Hall, M. Hand, S. Hook, and J. Randerson. 2015. Identification of two distinct fire regimes in southern California: implications for economic impact and future change. *Environmental Research Letters* 10:094005.

Keeley, J. E., C. J. Fotheringham, and M. A. Moritz. 2004. Lessons from the October 2003 Wildfires in Southern California. *Journal of Forestry*: 102: 26-31.

Keeley, J. E., H. D. Safford, C. J. Fotheringham, J. Franklin, and M. A. Moritz. 2009. The 2007 southern California wildfires: Lessons in complexity. *Journal of Forestry* 107:287–296.

Keeley, J. E., and A. D. Syphard. 2018. Historical patterns of wildfire ignition sources in California ecosystems. *International Journal of Wildland Fire* 27:781–799.

Keeley, J. E., and A. D. Syphard. 2019. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* 15:24.

Knapp, E. E., J. M. Lydersen, M. P. North, and B. M. Collins. 2017. Efficacy of variable density thinning and prescribed fire for restoring forest heterogeneity to mixed-conifer forest in the central Sierra Nevada, CA. *Forest Ecology and Management* 406:228–241.

Kramer, H. A., M. H. Mockrin, P. M. Alexandre, and V. C. Radeloff. 2019. High wildfire damage in interface communities in California. *International Journal of Wildland Fire* 28:641.

Kramer, H. A., M. H. Mockrin, P. M. Alexandre, S. I. Stewart, and V. C. Radeloff. 2018. Where wildfires destroy buildings in the US relative to the wildland–urban interface and national fire outreach programs. *International Journal of Wildland Fire* 27:329–341.

Leonard, J. 2009. Report to the 2009 Victorian Bushfires Royal Commission. Building performance in bushfires. Highett, Victoria, Australia: CSIRO Sustainable Ecosystems.

Mangan, R. J. 2000. Improving firefighter safety in the wildland-urban intermix. USDA Forest Service, Technology and Development Program.

Maranghides, A., and W. Mell. 2009. A Case Study of a Community Affected by the Witch and Guejito Fires.

Mccaffrey, S. M., G. L. Duffner, and L. M. Decker. 2019. Chapter Twenty-Seven. Social Dynamics of Wildland Fire in California. *Fire in California's Ecosystems:* 507–516.

Miner, A. 2014. Defensible space optimization for preventing wildfire Structure loss in the Santa Monica Mountains. Johns Hopkins University.

Moritz, M. A., E. Batllori, R. A. Bradstock, A. M. Gill, J. Handmer, P. F. Hessburg, J. Leonard, S. McCaffrey, D. C. Odion, T. Schoennagel, and *Nature*: 515 (6):58-66.

Noss, R. F., J. F. Franklin, W. L. Baker, T. Schoennagel, and P. B. Moyle. 2006. Managing fire-prone forests in the western United States. *Frontiers In Ecology And The Environment* 4:481–487.

Penman, S. H., O. F. Price, T. D. Penman, and R. A. Bradstock. 2019. The role of defensible space on the likelihood of house impact from wildfires in forested landscapes of south eastern Australia. *International Journal of Wildland Fire* 28:4–14.

Penman, T. D., L. Collins, A. D. Syphard, J. E. Keeley, and R. A. Bradstock. 2014. Influence of fuels, weather and the built environment on the exposure of property to wildfire. *PLOS ONE* 9(10): e111414.

Price, O., and R. Bradstock. 2013. Landscape scale influences of forest area and housing density on house loss in the 2009 Victorian bushfires. *PLOS ONE* 8:e73421.

Quarles, S., and K. Pohl. 2018. Building a Wildfire-Resistant Home: Codes and Costs. Bozeman, MT.

Radeloff, V. C., D. P. Helmers, H. Anu Kramer, M. H. Mockrin, P. M. Alexandre, A. Bar-Massada, V. Butsic, T. J. Hawbaker, S. Martinuzzi, A. D. Syphard, and S. I. Stewart. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. *Proceedings of the National Academy of Sciences* 115:3314–3319.

Safford, H., and K. Van de Water. 2014. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California.

Schoennagel, T., T. T. Veblen, and W. H. Romme. 2004. The interaction of fire, fuels, and climate across rocky mountain forests. *Bioscience* 54:661–676.

Schumann, R. L., M. Mockrin, A. D. Syphard, J. Whittaker, O. Price, C. Johnson, C. T. Emrich, and V. Butsic. 2019. International Journal of Disaster Risk Reduction Wildfire recovery as a " hot moment " for creating fire-adapted communities. *International Journal of Disaster Risk Reduction:* 101354.

Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2014. The role of defensible space for residential structure protection during wildfires. *International Journal of Wildland Fire* 23:1165–1175.

Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2017. The importance of building construction materials relative to other factors affecting structure survival during wildfire. *International Journal of Disaster Risk Reduction* 21:140-147.

Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2019a. Extent and drivers of vegetation type conversion in Southern California chaparral. *Ecosphere* 10:e02808.

Syphard, A. D., T. J. Brennan, J. E. Keeley, and T. Vaclavik. 2019b. Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. *Diversity and Distributions* 10: 90-101.

Syphard, A. D., and J. E. Keeley. 2015. Location, timing, and extent of wildfire varies by cause of ignition. *International Journal of Wildland Fire* 24:37–47.

Syphard, A. D., and J. E. Keeley. 2019. Factors associated with structure loss in the 2013 - 2018 California wildfires. *Fire* 2:49.

Syphard, A. D., J. E. Keeley, and T. J. Brennan. 2011. Comparing the role of fuel breaks across southern California national forests. *Forest Ecology and Management* 261:2038–2048.

Syphard, A. D., J. E. Keeley, A. B. Massada, T. J. Brennan, and V. C. Radeloff. 2012a. Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLOS ONE* 14(2): e0211454.

Syphard, A. D., J. E. Keeley, A. B. Massada, T. J. Brennan, and V. C. Radeloff. 2012b. Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLOS ONE* 7:1–13.

Syphard, A. D., V. C. Radeloff, T. J. Hawbaker, and S. I. Stewart. 2009. Conservation Threats Due to Human-Caused Increases in Fire Frequency in Mediterranean-Climate Ecosystems. *Conservation Biology* 23:758–769.

Syphard, A. D., H. Rustigian-Romsos, M. Mann, E. Conlisk, M. A. Moritz, and D. Ackerly. 2019c. The relative influence of climate and housing development on current and projected future fire patterns and structure loss across three California landscapes. *Global Environmental Change* 56:41–55.

Taylor, M. H., L. Christman, and K. Rollins. 2019. Targeting policy to promote defensible space in the wildland-urban interface: evidence from homeowners in Nevada. *Land Economics* 95:531–556.

Viegas, D. X. 2018. Wildfires in Portugal. *Fire Research.*

WILDFIRES AND FOREST RESILIENCE: THE CASE FOR ECOLOGICAL FORESTRY IN THE SIERRA NEVADA

Rodd Kelsey

INTRODUCTION

Forests of the Sierra Nevada and across the western U.S. are experiencing an unprecedented increase in the size and severity of wildfires,[1-6] along with widespread tree mortality due to drought and insect outbreaks.[7-9] Over the last six years alone, five separate wildfires in the Sierra Nevada have burned 100,000 acres or more with unusually large patches of forest burned at high severity, with greater than 75 percent tree mortality.

Several of these fires behaved in ways unlike any experienced in recorded memory and were uncharacteristic of the way that the forests burned before Euro-American arrival in California. These developments are detrimental to forest sustainability as the climate continues to warm,[10-13] not only threatening lives and communities but seriously compromising forest health and resilience, degrading many of the important benefits forests provide to people.

The forested watersheds of the Sierra Nevada provide clean water for over 25 million people[14], support rural economies and tourism[15], and play a critical role in carbon storage and climate control.[16-18] Healthy Sierra forests are also home to abundant and diverse wildlife, with over 500 vertebrate species (24 of which occur nowhere else) and 3,500 plant species (400 of which occur nowhere else).[19]

Above: Example of ecological thinning on lands owned by the American River Conservancy. *[Photograph by David Edelson / The Nature Conservancy]*

This paper focuses on fire in the forests of the Sierra Nevada. Importantly, the causes and consequences of a changing fire regime vary among the different kinds of ecosystems in California. The now more frequent and devastating fires of coastal and inland shrub communities are driven by different factors and, thus, require different solutions.

We know how to manage forests so that they are less prone to megafires and drought and how to decrease the likelihood of large tree mortality events from insect and disease outbreaks.[9,10,20,21] Through targeted ecological thinning, prescribed fire, and managed wildfire we can reduce high fuel loads, promote more resilient forests, reduce the risk of large, high-severity wildfires, and protect sensitive species. Unfortunately, the current pace and scale of these activities is inadequate given the widespread scope and long-term consequences of the problem.

An important obstacle to increasing the pace and scale of ecologically sound forest management in the Sierra Nevada is widespread misunderstanding among policy makers and the public of the two important approaches required to restore our forests: thinning trees to reduce fuels and using fire as a natural restorative process. In this article, we explain how our forests became overgrown and at risk from uncharacteristic, high-severity wildfire and tree mortality. Then, we make the scientific case for ecological forestry—a combination of strategic thinning, prescribed fire, and managed wildfire—as the best solution to the challenges our forests face.

A LEGACY OF LOGGING AND FIRE SUPPRESSION HAS CREATED FORESTS PRONE TO SEVERE WILDFIRES

Why do California's fires burn differently than they did 200 years ago? One critical factor is that, despite the large and destructive wildfires of recent years, many of the forests of the Sierra Nevada are fire-starved.

Prior to the 20th century, wildfires roamed over large areas in the Sierra Nevada every year.[22-25] These were both naturally caused by lightning and intentionally set by Native Americans for the many benefits fire can create, like regenerating valuable food and textile plants. Prior to European settlement, 400,000 to 500,000 acres burned each year on what are now National Forest lands of the Sierra Nevada.[3,26]

Most of these fires were of low or moderate severity. (Low severity generally means less than 25 percent tree mortality, while moderate severity refers to a mortality rate of 25-75 percent.) The majority of trees survived them, except for patches that created openings in the forest.[13,23,27] This patchy mosaic created a wide array of forest conditions, including open, shrubby patches, pocket meadows, and shady stands of large, fire-resistant trees.[27-32] This maintained the health and resilience of the forest and the biota that depend on it. Frequent low-to-moderate intensity fires also reduced the likelihood of megafires in some forests, by removing surface fuels and keeping the shrubs and understory trees that fuel intense fires in check.[27,29-33] The fires also regenerated and increased the variety of understory plants.[134,135] In contrast, today's high intensity fires tend to favor mostly shrubby species over uncharacteristically large patches, in some cases lowering diversity indefinitely.[136]

California's lack of ecologically appropriate fire is the result of the aggressive elimination of fire, beginning in the mid-19th century when Native American burning was drastically reduced. Widespread fire suppression followed in the 20th century, based on the well-intentioned but now disproved assumption that all fire is bad.[13,34-38]

Another important contributor, also beginning in the mid-1800s, was logging—specifically, timber management practices that removed most of the large, fire-resistant trees in old-growth forests and favored uniform "plantations" of trees of the same age and species. These practices removed trees that provide habitat for sensitive species like the California spotted owl and made many forests in the Sierra Nevada highly homogenous and—combined with fire suppression—overly dense with small trees and shrubs.

Today, many of California's forests are dominated by fire-intolerant species, like firs, where there were once mixed conifer forests. The resulting forests have few large fire-resistant trees, continuous canopy cover, and heavy understory fuel loading from litter and woody debris.[13,31,36,37,39-43] Many private timberlands also have relatively homogenous, even-aged stands of trees. Overall, these uncharacteristically uniform, dense, young forests are more prone to high-severity fire.

As a consequence, while the overall frequency of fires remains lower than it once was, in recent decades we have experienced a rapid increase in the area burned by fires.[5,44] There's also strong evidence for an increase in the severity of fires (as measured by trends in fire-driven tree mortality)[1,3,11,34,45] and area burned at high severity.[1,3,34,46] At high elevations, where fire was historically infrequent, the number of fires burning and the annual area burned also appear to be increasing.[3,47] Of particular concern is the potential for more of the largest, most severe fires, like several experienced within the last five years.[48] One recent example of such a "megafire" is the 2014 King Fire, in which half of the 97,000 acres affected burned so severely that it formed a few very large contiguous patches of mostly dead trees. This reflects the change in forests over the

A California spotted owl parent and its chick, recently out of the nest. Most of the large, old trees that spotted owls need for nesting were removed by early logging efforts; those that remain are at risk from high-severity fires. *[Photograph by Danny Hofstadter]*

last hundred years.[49] Based on the best available evidence on historical fire regimes, in contrast to what we witnessed with the King Fire, high-severity burn areas would have been fewer and distributed across many smaller patches.[2,3,27]

The King Fire also burned 30 spotted owl breeding territories where pairs nest and hunt. About half of each of these owl territories was severely burned, on average. In 14 of the territories, the high-severity burn area averaged 89 percent (Gavin Jones, personal communication). The result was a sevenfold higher incidence of abandonment of territories compared to that found in unburned and low-severity burned territories.[50]

The intensity of the King Fire precipitated massive erosion events that caused millions of dollars in damage and maintenance costs for the Placer County Water Agency. It can take decades, if not hundreds of years, for large patches of severely burned forests to recover; some of the forests may be permanently converted to shrub fields if the high-severity patches are very large (like in the King Fire) or if they repeatedly burn during the warmest, driest periods of subsequent years.[51-54]

Even more concerning are the observed and potential long-term effects of a warming climate. California is on track to exceed a 2˚C increase in average temperature by 2050 and to experience more intense droughts.[44,55,56] This may push many forests into a climate regime they have not experienced for millenia, or ever,[57] and intensify fire and tree mortality in Sierra forests.[10,12] Increasingly early snowmelt is likely to increase fire frequency and lengthen the fire season.[5] Overall, burned area is expected to increase with a drier and warmer future: By the end of century, we can expect a roughly 50 percent increase in the frequency of extreme wildfires that burn more than 25,000 acres.[58,59]

Dense and young forests are also more prone to the impacts of drought,[60,61] including water stress, insect outbreaks, and some diseases.[9,20,21,62–65] During the 2012-2016 drought, for example, an estimated 130 million trees died in the Sierra, including up to 50 percent of pines in lower and middle elevation watersheds in the central and southern Sierra.[66,67] These conditions can lead to high-intensity fires that endanger human communities and forests.[21]

CURRENT FOREST CONDITIONS ARE BAD FOR PEOPLE AND NATURE

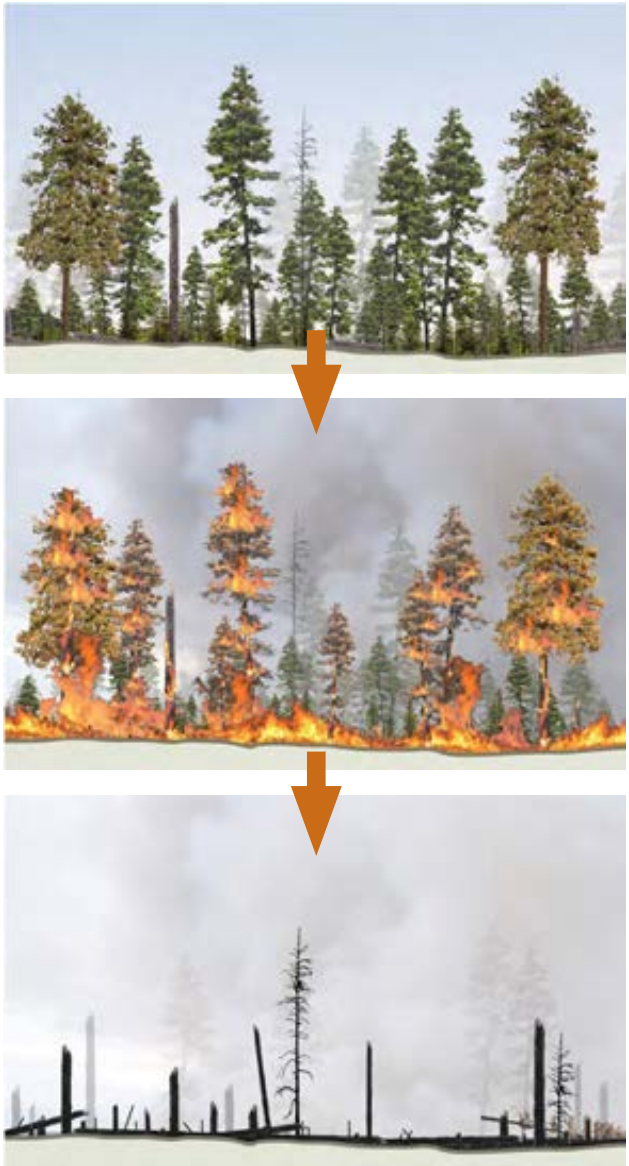
Not only do severe fires near communities threaten lives and properties, they can lead to erosion and mudslides that damage homes and water supplies.[68-71] The effects of severe wildfires also go well beyond the forest. Large, intense wildfires degrade air quality around the state and even across the country.[72-74] This increases the duration of smoke exposure,[75] leading to acute and chronic human health impacts such as increased asthma-related hospital visits, respiratory disease, and cardiovascular disease.[76-78]

Forests are a significant source of carbon storage in terrestrial ecosystems, but the value of Sierra Nevada forests as a vital carbon sink is in jeopardy.[12,16,18] Further, the many imperiled species that depend on older, closed-canopy forests and suffer from the legacy of past logging—including California spotted owls[79]—are increasingly threatened by the impact severe fires can have on the little remaining old-growth forest they occupy.[50,80-83]

Many more people live in the forest now than did a century ago. This has intensified the challenges of managing fire, especially at the wildland-urban interface.[84] But eliminating wildfire is not a practical, affordable, or ecologically desirable solution. As recent events have demonstrated, it is also impossible.

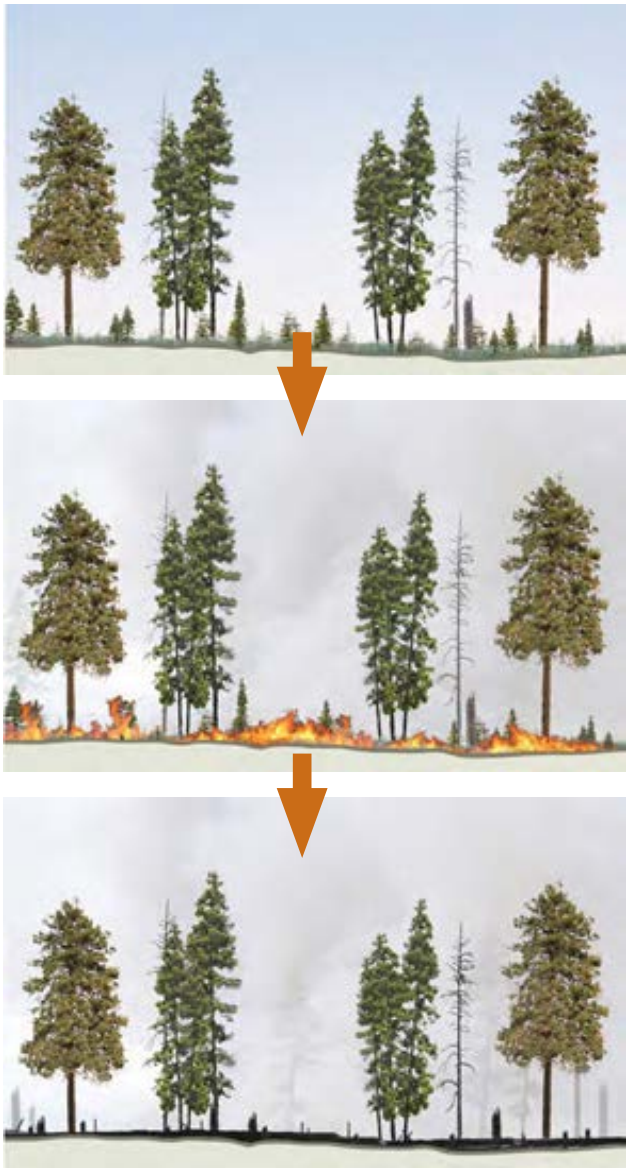
In sum, our fire-adapted forests need more of the right kind of fire, yet existing conditions and a warming climate make it unsafe for people and nature to allow all fires to burn under unmanaged conditions. So what is the solution?

Fire-suppressed forest



Fire-starved forests that have not experienced fire in many decades are prone to high-severity fires that burn very hot and kill 75% or more of trees, including large, fire-resistant trees.

Ecologically managed forest



By carefully thinning the understory of some forests to reduce fuel load, we can safely reintroduce fire as a restorative process.
[Graphics courtesy of The Nature Conservancy]

ECOLOGICAL FORESTRY

Forests are diverse and complex, as are the changes they have experienced. There is not a one-size-fits-all answer to restoring their resilience, diversity, and safety.[85-88] The good news is that we largely know what needs to be done. There's robust science showing what the forests used to look like, and how to reduce high-severity fire risk while protecting forests in a changing climate.

Many low- and mid-elevation forests of the Sierra Nevada need to be restored to a more open, patchy, and diverse structure, in order to make them more resilient to drought and a warming climate.[87,89] This will require increasing the scale of ecological forestry: targeted thinning of smaller trees and shrubs where it is needed most combined with more frequent low- and moderate-severity fire. Reducing the impacts of fire on people will also require fire-hardening communities and reducing development in fire prone areas. All three measures will be necessary, and none of them will be sufficient on its own.

California spotted owl nesting and roosting habitat.
[Photograph by David Edelson / The Nature Conservancy]

Ecological forestry will also need to include proactive measures to ensure the resilience and adaptive capacity of the forests to a changing environment over the long term. This may include active replanting of seeds from drought tolerant populations or facilitating the expansion of tree and shrub genotypes that are better adapted to future climates and disturbance regimes.[90,91]

ECOLOGICAL THINNING

As counter-intuitive as it may seem, given that historical logging created some of the challenges our forests face, cutting some trees is now a necessary part of the solution.[28,92-96] Under current conditions, healthy fire cannot be safely reintroduced to some forested areas without some preliminary fuel reduction. This is particularly important in areas that are closest to homes and communities and in areas that can transport high-intensity fire to the wildland-urban interface, as happened in the 2018 Camp Fire. Targeted and ecologically based thinning in accessible areas is needed to open up the forest where it is unnaturally dense. Done well, this kind of thinning can recreate a diverse forest structure that protects wildlife and plant diversity and facilitates the reintroduction of fire where it would currently be unsafe to do so.[95-97]

Ecological forestry has little in common with historical logging practices. Ecological thinning does not mean clearcutting, old-growth forest logging, or extensive salvage logging after fires. It is explicitly focused on protecting the oldest trees and creating a diverse mosaic of natural features that are essential for forest diversity and regeneration.[96,98]

Intensive logging can negatively affect sensitive wildlife and the diversity and function of the forests, so this must be done carefully to balance the trade-offs between short-term impact and long-term benefits. That means prioritizing the removal of the surface and ladder fuels that contribute most to wildfire hazard[99], while minimizing ground disturbance and impacts to those trees and shrubs that will not be removed. It also means maintaining higher canopy cover in some locations and protecting stands of large trees in high quality habitat of sensitive species, such as the California spotted owl and Pacific fisher.

There remains some uncertainty about how sensitive species respond to severe wildfire compared to ecological thinning. For example, further research is needed to compare how ecological thinning affects spotted owls compared to varying amounts and severities of fire. However, it is clear that some thinning in strategic areas will be needed to reduce the risks that high-severity wildfire poses to these species.[50,101] Otherwise, the benefits of avoiding near-term impacts from ecological thinning will be overwhelmed by the devastating loss of habitat due to high-severity wildfires.[50] Ongoing and future research will build on our understanding of how species respond to forest management and megafires, and we will be able to adapt our forest management strategies in response.

PRESCRIBED FIRE AND MANAGED WILDFIRE

Reintroducing fire to many of our forested watersheds is the second key ingredient in ecological forestry, and ultimately will be the most important contributor to restoring forest health and resilience. Both prescribed and managed wildfires will be important. Prescribed fires are intentionally planned, ignited, and managed fires targeted to specific places and often preceded by thinning of small trees and shrubs where needed. Managed wildfires are those that are unintentionally started by natural causes like lightning, but then allowed to burn where weather conditions permit and managed for resource benefits and human safety. Managed wildfires require advanced planning so that when fires start the appropriate measures can be taken to manage them.

Reestablishing more frequent fires of relatively low severity in places where this was once the natural regime will keep the most flammable fuels in check, protect the larger trees, and recycle nutrients in the forest to develop a healthier canopy and a less flammable and more diverse understory. It also means allowing and managing smaller patches of moderately and severely burned forest where safe and appropriate. Such patchiness moderates the intensity of future fires[30,103-105] and is essential for supporting the full diversity of plants and wildlife that are unique to the Sierra Nevada, including those that are adapted to and benefit from severely burned forest patches.[83,102,106-110]

There is now ample evidence that thinning, combined with prescribed fire, works best to restore Sierra Nevada forests. Areas treated with both approaches have more species diversity, and the reduction in potential fire severity lasts longer than if thinning or fire are implemented alone.[11,26,28,89,113-117] In fact, following thinning with fire may be essential in many areas, because forests can grow back quickly after a single thinning treatment.[99,116-119]

As a practical matter, given the many constraints on applying prescribed and managed wildfire, ecological thinning will be an important part of the solution, at least in the near to mid term. Management guidelines for federal and state lands often encourage wildfire suppression, regardless of the potential to safely manage them for resource benefits, and fewer than 1 percent of Forest Service lands are currently being managed with fire each year,[26] which likely reflects the scale across other federal and state lands. It will take years to build the capacity and social will to manage fire for resource benefits at large scales, and some areas (e.g. near communities) may never be suitable for fire, even in the long term.

ECOLOGICAL FORESTRY WILL PROVIDE MANY BENEFITS

While it is a daunting challenge, implementing ecological forestry broadly across Sierra Nevada forests will help ensure that we are able to protect the natural diversity and beauty of California's fire-prone forests. Done thoughtfully, it will protect habitat for, and mitigate high-severity fire risks to, the imperiled species that have been pushed to the brink. It will also help to protect California's largest supply of clean water, the Sierra snowpack and runoff,[120-125] and make forests more resilient to drought.[10,60,126,127] Further, protecting our forests from the most extreme fire and tree mortality events will protect the forests against more extreme losses of carbon storage that would come with widespread and severe wildfires, as well as help stabilize carbon stores in these forests over the long term.[44,128-132]

Taking a large scale, ecologically based approach to forest management is also important for human safety. Focusing California's forest management resources exclusively on defensible space around communities and fire hardening homes may not be enough. These defenses can be overwhelmed by an intense and fast-moving fire coming out of the forest, as recent fires like the 2018 Camp Fire have demonstrated. Late season fires of this intensity, fueled by large fuel loads, dry weather, and high winds, can quickly move out of the wildlands and send embers flying miles to land on homes in the middle of densely populated communities. Instances like these are becoming more frequent in California and forcing the state to rethink how it maps fire hazard zones.

There could also be important indirect benefits of ecological forestry to public health and the economy. Lower-severity fires (including prescribed fires and managed wildfires) can have lower emissions per fire event, and thus may reduce the potential human health impacts and costs over time compared to unplanned megafires.[72,75]

California also has the opportunity to lead in the development of a forest restoration economy. At present, there are few innovative uses for the small wood material that will be removed and not enough facilities to process the material. There are also far too few trained personnel in ecological forestry and the application of prescribed fire. Those that are trained can

barely keep up with managing the dangerous wildfires that need to be contained. Ramping up investments and training in ecological forestry, bio-energy, and small diameter wood products (e.g. cross-laminated timber, a product made from gluing layers of lumber together) could create new jobs and revitalize struggling rural communities (see Kusel, page 36).[133]

California's fire-prone forests are unhealthy and at serious risk of uncharacteristic, high-severity wildfire, drought, and insect outbreaks. There is compelling evidence that ecological forestry—ecological thinning, prescribed burning, and managed wildfire—can reduce these risks and promote healthier, more resilient forests. We urge policymakers to maintain and increase funding for ecological thinning and prescribed fire and to take steps to address the policy and practical barriers to implementing ecological forestry at a scale and pace appropriate to the challenge at hand.

Acknowledgements

This paper benefitted from thorough review, edits, and comments from the following experts: John Battles, PhD, Sue Britting, PhD, Dick Cameron, David Edelson, Matthew Hurteau, PhD, Gavin Jones, PhD, Jon Keeley, PhD, Pat Manley, PhD, Kerry Metlen, PhD, Malcolm North, PhD, Zach Peery, PhD, Hugh D. Safford, PhD, Edward Smith, MFS, and Scott L. Stephens, PhD.

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REFERENCES

1. Miller, J. D., Safford, H. D., Crimmins, M. & Thode, A. E. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. *Ecosystems* 12, 16–32 (2009).
2. Miller, J. D. & Safford, H. Trends in wildfire severity: 1984-2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California USA. *Fire Ecology* 8, 41-57 (2012).
3. Mallek, C., Safford, H., Viers, J. & Miller, J. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. *Ecosphere* 4, art153 (2013).
4. Singleton, M. P., Thode, A. E., Sánchez Meador, A. J. & Iniguez, J. M. Increasing trends in high-severity fire in the southwestern USA from 1984 to 2015. *Forest Ecology and Management* 433, 709–719 (2019).
5. Westerling, A. L. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society, London B* 371, 20150178 (2016).
6. Collins, B. M., Miller, J. D., Knapp, E. E. & Sapsis, D. B. A quantitative comparison of forest fires in central and northern California under early (1911–1924) and contemporary (2002–2015) fire suppression. *International Journal of Wildland Fire* (2019).
7. Marlon, J. R. et al. Long-term perspective on wildfires in the western USA. *Proceedings of the National Academy of Sciences* 109, E535–E543 (2012).
8. Preisler, H. K., Grulke, N. E., Heath, Z. & Smith, S. L. Analysis and out-year forecast of beetle, borer, and drought-induced tree mortality in California. *Forest Ecology and Management* 399, 166–178 (2017).
9. Kolb, T. E. et al. Observed and anticipated impacts of drought on forest insects and diseases in the United States. *Forest Ecology and Management* 380, 321–334 (2016).
10. Restaino, C. M. & Safford, H. D. *Fire and climate change, in Fire in California's Ecosystems* (eds. Van Wagtendonk, J. W. et al.) 493–505 (University of California Press, 2018).
11. Miller, J. D. & Safford, H. D. Corroborating evidence of a pre-Euro-American low- to moderate-severity fire regime in yellow pine-mixed conifer forests of the Sierra Nevada, California, USA. *Fire Ecology* 13, 58–90 (2017).
12. Dettinger, M. D. *et al.* Sierra Nevada summary report. California's Fourth Climate Change Assessment. (California Energy Commission/Natural Resources Agency, 2018).
13. Safford, H. D. & Stevens, J. T. Natural Range of Variation (NRV) for yellow pine and mixed conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen.Tech. Rep. PSW-GTR-256. (USDA Forest Service, Pacific Southwest Region, 2017).
14. Klausmeyer, K. R. & Fitzgerald, K. Where Does California's Water Come From? Land conservation and the watersheds that provide California's drinking water. (The Nature Conservancy, 2012).
15. Case, D., Fowler, D., Morgan, H., Schwellenbach, S. & Culbertson, K. Moving to the Mountains: Amenity migration in the Sierra and southern Appalachian mountains, in *Political Economies of Landscape Change: Places of Integrative Power* (eds. Wescoat, J. L. & Johnston, D. M.) 77–88 (Springer Netherlands, 2008).
16. Gonzalez, P., Battles, J. J., Collins, B. M., Robards, T. & Saah, David, S. Aboveground live carbon stock changes of California wildland ecosystems, 2001-2010. *Forest Ecology and Management* 348, 68–77 (2015).
17. Hurteau, M. D. & Brooks, M. L. Short- and long-term effects of fire on carbon in US dry temperate forest systems. *BioScience* 61, 139–146 (2011).
18. Hurteau, M. D., Bradford, J. B., Fulé, P. Z., Taylor, A. H. & Martin, K. L. Climate change, fire management, and ecological services in the southwestern US. *Forest Ecology and Management* 327, 280–289 (2014).
19. Manley, P. N. The Future of Biodiversity in the Sierra Nevada through the Lake Tahoe Basin Looking Glass 1, in *Proceedings of the Sierra Nevada Science Symposium*, October 7-10, 2002.
20. Guarín, A. & Taylor, A. H. Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. *Forest Ecology and Management* (2005).
21. Stephens, S. L. et al. Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire. *BioScience* (2018).
22. Agee, J. K. Fire ecology of Pacific Northwest forest. *International Journal of Wildland Fire* 4, 493 (1993).
23. McKelvey, K. S. et al. An Overview of Fire in the Sierra Nevada, in Sierra Nevada Ecosystem Project (SNEP)-*Final Report to Congress (Vol. II): Assessments and scientific basis for management options* 1033–1040 (University of California, Davis, Centers for Water and Wildland Resources, 1996).
24. Van De Water, K. M. & Safford, H. D. A summary of fire frequency estimates for California vegetation before Euro-American settlement. *Fire Ecology* 7, 26–58 (2011).
25. Safford, H. D. & Van De Water, K. M. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California. Research Paper PSW-RP-266. (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2014).

26. North, M. P., Collins, B. M. & Stephens, S. L. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110, 392–401 (2012).
27. van Wagtendonk, J. W. *et al.* Fire in California's ecosystems. (University of California Press, 2018).
28. Hessburg, P. F. et al. Tamm Review: Management of mixed-severity fire regime forests in Oregon, Washington, and Northern California. *Forest Ecology and Management* 366, (2016).
29. Hessburg, P. F., Agee, J. K. & Franklin, J. F. Dry forests and wildland fires of the inland Northwest USA: Contrasting the landscape ecology of the pre-settlement and modern eras. *Forest Ecology and Management* 211, 117–139 (2005).
30. Perry, D. A. et al. The ecology of mixed severity fire regimes in Washington, Oregon, and Northern California. *Forest Ecology and Management* 262, 703–717 (2011).
31. Beaty, R. M. & Taylor, A. H. Fire history and the structure and dynamics of a mixed conifer forest landscape in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. *Forest Ecology and Management* 255, 707–719 (2008).
32. Beaty, R. M. & Taylor, A. H. Fire disturbance and forest structure in old-growth mixed conifer forests in the northern Sierra Nevada, California. *Journal of Vegetation Science* (2007).
33. Hessburg, P. F. & Agee, J. K. An environmental narrative of Inland Northwest United States forests, 1800–2000. *Forest Ecology and Management* 178, 23–59 (2003).
34. Steel, Z. L., Safford, H. D. & Viers, J. H. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* 6, art8 (2015).
35. Lydersen, J. M., North, M. P., Knapp, E. E. & Collins, B. M. Quantifying spatial patterns of tree groups and gaps in mixed-conifer forests: reference conditions and long-term changes following fire suppression and logging. *Forest Ecology and Management* 304, 370–382 (2013).
36. Parsons, D. J. & DeBenedetti, S. H. Impact of fire suppression on a mixed-conifer forest. *Forest Ecology and Management* 2, 21–33 (1979).
37. North, M., Hurteau, M. & Innes, J. Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. *Ecological Applications* 19, 1385–1396 (2009).
38. Calkin, D. E., Gebert, K. M., Jones, J. G. & Neilson, R. P. Forest Service large fire area burned and suppression. *Journal of Forestry* 103, 179–183 (2005).
39. Knapp, E. E., Skinner, C. N., North, M. P. & Estes, B. L. Long-term overstory and understory change following logging and fire exclusion in a Sierra Nevada mixed-conifer forest. *Forest Ecology and Management* 310, 903–914 (2013).
40. Lutz, J. A., van Wagtendonk, J. W. & Franklin, J. F. Twentieth-century decline of large-diameter trees in Yosemite National Park, California, USA. *Forest Ecology and Management* 257, 2296–2307 (2009).
41. Dolanc, C. R., Safford, H. D., Dobrowski, S. Z. & Thorne, J. H. Twentieth century shifts in abundance and composition of vegetation types of the Sierra Nevada, CA, US. *Appl. Veg. Sci.* 17, 442–455 (2014).
42. Bouldin, J. Twentieth-century changes in forests of the Sierra Nevada, California (Doctoral dissertation). (University of California, Davis, 1999).
43. Stephens, S. L., Lydersen, J. M., Collins, B. M., Fry, D. L. & Meyer, M. D. Historical and current landscape-scale ponderosa pine and mixed conifer forest structure in the Southern Sierra Nevada. *Ecosphere* 6, 1–63 (2015).
44. Bedsworth, L., Cayan, D., Franco, G., Fisher, L. & Ziaja, S. California's Fourth Climate Change Assessment: Statewide summary report. Publication number: SUM- CCCA4-2018-013. (2018).
45. Steel, Z. L., Koontz, M. J. & Safford, H. D. The changing landscape of wildfire: burn pattern trends and implications for California's yellow pine and mixed conifer forests. *Landscape Ecology* 33, 1159–1176 (2018).
46. Keyser, A. R. & Westerling, A. L. Predicting increasing high severity area burned for three forested regions in the western United States using extreme value theory. *Forest Ecology and Management* 432, 694–706 (2019).
47. Schwartz, M. W. et al. Increasing elevation of fire in the Sierra Nevada and implications for forest change. *Ecosphere* 6, 121 (2015).
48. Stephens, S. L. et al. Temperate and boreal forest mega-fires: characteristics and challenges. *Front. Ecol. Environ.* 12, 115–122 (2014).
49. Stephens, S. L., Stevens, J. T., Collins, B. M., York, R. A. & Lydersen, J. M. Historical and modern landscape forest structure in fir (Abies)-dominated mixed conifer forests in the northern Sierra Nevada, USA. *Fire Ecology* 14, (2018).
50. Jones, G. M. et al. Megafires: an emerging threat to old-forest species. *Frontiers in Ecology and Environment* 14, 300–306 (2016).
51. Stevens, J. T., Collins, B. M., Miller, J. D., North, M. P. & Stephens, S. L. Changing spatial patterns of stand-replacing fire in California conifer forests. *Forest Ecology and Management* 406, (2017).
52. Welch, K. R., Safford, H. D. & Young, T. P. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. *Ecosphere* 7, e01609 (2016).
53. Walker, R. B., Coop, J. D., Parks, S. A. & Trader, L. Fire regimes approaching historic norms reduce wildfire-facilitated conversion from forest to non-forest. *Ecosphere* 9, e02182 (2018).
54. Coppoletta, M., Merriam, K. E. & Collins, B. M. Post-fire vegetation and fuel development influences fire severity patterns in reburns. *Ecological Applications* 26, (2016).
55. He, M., Schwarz, A., Lynn, E. & Anderson, M. Projected Changes in Precipitation, Temperature, and Drought across California's Hydrologic Regions in the 21st Century. *Climate* 6, 31 (2018).
56. Diffenbaugh, N. S., Swain, D. L. & Touma, D. Anthropogenic warming has increased drought risk in California. *Proceedings of the National Academy of Sciences* 112, 3931–3936 (2015).
57. Thorne, J. H. et al. The impact of climate change uncertainty on California's vegetation and adaptation management. *Ecosphere* 8, (2017).
58. Westerling, A. L. et al. Climate change and growth scenarios for California wildfire. *Clim. Change* 109, 445–463 (2011).
59. Westerling, A. L. *Wildfire simulations for California's Fourth Climate Change Assessment: projecting changes in extreme wildfire events with a warming climate.* 57 (California Energy Commission, 2018).
60. Young, D. J. N. et al. Long-term climate and competition explain forest mortality patterns under extreme drought. *Ecol. Lett.* 20, 78–86 (2017).
61. Voelker, S. L. et al. Fire deficits have increased drought sensitivity in dry conifer forests: Fire frequency and tree-ring carbon isotope evidence from Central Oregon. *Global Change Biology* 00, 1–17 (2019).
62. Williams, A. P. et al. Temperature as a potent driver of regional forest drought stress and tree mortality. *Nature Climate Change* 3, 292–297 (2013).
63. Allen, C. D., Breshears, D. D. & McDowell, N. G. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere* 6, art129 (2015).

64. Allen, C. D. et al. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259, 660–684 (2010).

65. Carnicer, J. et al. Widespread crown condition decline, food web disruption, and amplified tree mortality with increased climate change-type drought. *Proceedings of the National Academy of Sciences* 108, 1474-1478 (2011).

66. Fettig, C. J., Mortenson, L. A., Bulaon, B. M. & Foulk, P. B. Tree mortality following drought in the central and southern Sierra Nevada, California, U.S. *Forest Ecology and Management* (2019).

67. Buluç, L., Fischer, C., Ko, J., Balachowski, J. & Ostoja, S. Drought and tree mortality in the Pacific Southwest Region: a synopsis of presentations and work group sessions from the science and management symposium - lessons learned from extreme drought and tree mortality in the Sierra Nevada. (U.S. Department of Agriculture, California Climate Hub, 2017).

68. Larsen, I. J. et al. Causes of Post-Fire Runoff and Erosion: Water Repellency, Cover, or Soil Sealing? *Soil Science Society of America Journal* 73, 1393-1407 (2009).

69. Moody, J. A. & Ebel, B. A. Hyper-dry conditions provide new insights into the cause of extreme floods after wildfire. *Catena* 93, 58–63 (2012).

70. Moody, J. A., Shakesby, R. A., Robichaud, P. R., Cannon, S. H. & Martin, D. A. Current research issues related to post-wildfire runoff and erosion processes. *Earth-Science Reviews* 122, 10–37 (2013).

71. Aha, N., Boorman, M., Leidman, S. & Perry, S. The Effect of sediment deposition on Sierra riverine ecosystems following high-intensity fires. (2014).

72. Schweizer, D. Fine particulate matter and wildland fire smoke: integrating air quality, fire management, and policy in the California Sierra Nevada. (University of California, Merced, 2016).

73. Preisler, H. K. et al. Estimating contribution of wildland fires to ambient ozone levels in National Parks in the Sierra Nevada, California. *Environmental Pollution* 158, 778–787 (2010).

74. Preisler, H. K. et al. A statistical model for determining impact of wildland fires on particulate matter (PM 2.5) in central California aided by satellite imagery of smoke. *Environmental Pollution* 205, 340–349 (2015).

75. Long, J. W., Tarnay, L. W. & North, M. P. Aligning smoke management with ecological and public health goals. *Journal of Forestry* 116, 76–86 (2017).

76. Reid, C. E. et al. Critical review of health impacts of wildfire smoke exposure. *Environmental Health Perspectives* (2016).

77. Reid, C. E., Jerrett, M., Tager, I. B., Petersen, M. L., Mann, J. K., Balmes J. R. Differential respiratory health effects from the 2008 northern California wildfires: A spatiotemporal approach. *Environmental Research* (2016).

78. Liu, J. C., Pereira, G., Uhl, S. A., Bravo, M. A. & Bell, M. L. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. *Environmental Research* (2015).

79. Jones, G. M., Keane, J. J., Gutiérrez, R. J. & Peery, M. Z. Declining old-forest species as a legacy of large trees lost. *Diversity and Distributions* 24, 341-351 (2017).

80. Jones, G. M., Gutiérrez, R. J., Tempel, D. J., Zuckerberg, B. and Peery, M. Z. Using dynamic occupancy model to inform climate change adaptation strategies for California spotted owls. *Journal of Applied Ecology* 53, 895-905 (2016).

81. Tempel, D. J. et al. Evaluating short- and long-term impacts of fuels treatments and simulated wildfire on an old-forest species. *Ecosphere* 6, 1–19 (2015).

82. Tempel, D. J. et al. Effects of forest management on California spotted owls: Implications for reducing wildfire risk in fire-prone forests. *Ecological Applications* 24, 2089–2106 (2014).

83. Miller, J. E. D., Root, H. T. & Safford, H. D. Altered fire regimes cause long-term lichen diversity losses. *Global Change Biology* 24, 4909–4918 (2018).

84. Dombeck, M. P., Williams, J. E. & Wood, C. A. Wildfire policy and public lands: integrating scientific understanding with social concerns across landscapes. *Conservation Biology* 18, 883–889 (2004).

85. Schoennagel, T., Veblen, T. T. & Romme, W. H. The Interaction of fire, fuels, and climate across Rocky Mountain forests. *BioScience* 54, 661–677 (2004).

86. Moritz, M. A. *et al.* Learning to coexist with fire. Nature 515, 58–66 (2014).

87. Schoennagel, T. *et al.* Adapt to more wildfire in western North American forests as climate changes. *Proceedings of the National Academy of Sciences* 114, (2017).

88. Stephens, S. L. et al. Managing Forests and Fire in Changing Climates. *Science* 342, 41–42 (2013).

89. Stevens, J. T., Safford, H. D. & Latimer, A. M. Wildfire-contingent effects of fuel treatments can promote ecological resilience in seasonally dry conifer forests. *Can. J. For. Res.* 44, 843–854 (2014).

90. North, M. P. et al. Tamm Review: Reforestation for resilience in dry western U.S. forests. *Forest Ecology and Management* 432, 209–224 (2019).

91. Stevens, J. T., Safford, H. D., Harrison, S. & Latimer, A. M. Forest disturbance accelerates thermophilization of understory plant communities. *J. Ecol.* 103, 1253–1263 (2015).

92. North, M. P. *et al.* Constraints on Mechanized Treatment Significantly Limit Mechanical Fuels Reduction Extent in the Sierra Nevada. J. For. 40–48 (2014). doi:http://dx.doi.org/10.5849/jof.14-058

93. Agee, J. K. & Skinner, C. N. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211, 83–96 (2005).

94. Noss, R. F., Franklin, J. F., Baker, W. L., Schoennagel, T. & Moyle, P. B. Managing fire-prone forests in the western United States In a nutshell : *Front. Ecol. Environ.* 4, 481–487 (2006).

95. Fulé, P. Z., Crouse, J. E., Roccaforte, J. P. & Kalies, E. L. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? *Forest Ecology and Management* 269, 68–81 (2012).

96. North, M. P., Stine, P., Hara, K. O., Zielinski, W. & Stephens, S. L. An ecosystem management strategy for Sierran mixed- conifer forests, Gen. Tech. Rep. PSW-GTR-220. (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2009).

97. Krofcheck, D. J., Hurteau, M. D., Scheller, R. M. & Loudermilk, E. L. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Global Change Biology* 24, 729–737 (2018).

98. North, M. P. (ed). *Managing Sierra Nevada forests.* (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2012).

99. Stephens, S. L. et al. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19, 305–320 (2009).

100. Chiono, L. A., Fry, D. L., Collins, B. M., Chatfield, A. H. & Stephens, S. L. Landscape-scale fuel treatment and wildfire impacts on carbon stocks and fire hazard in California spotted owl habitat. *Ecosphere* 8, e01648 (2017).

101. Ganey, J. L., Wan, H. Y., Cushman, S. A. & Vojta, C. D. Conflicting perspectives on spotted owls, wildfire, and forest restoration. *Fire Ecology* 13, 1–20 (2017).

102. Stephens, S. L. et al. California spotted owl, songbird, and small mammal responses to landscape fuel treatments. *BioScience* 64, 893–906 (2014).
103. Finney, M. A. Design of Regular Landscape Fuel Treatment Patterns for Modifying Fire Growth and Behavior. *Forest Science* 47, (2001).
104. Ager, A. A., Vaillant, N. M. & Finney, M. A. A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. *Forest Ecology and Management* 259, 1556–1570 (2010).
105. Finney, M. A. et al. Simulation of long - term landscape - level fuel treatment effects on large wildfires. *Int. Journal of Wildland Fire* 16, 712–727 (2007).
106. Ponisio, L. C. et al. Pyrodiversity begets plant-pollinator community diversity. *Global Change Biology* 22, 1794–1808 (2016).
107. Tingley, M. W., Ruiz-Gutiérrez, V., Wilkerson, R. L., Howell, C. A. & Siegel, R. B. Pyrodiversity promotes avian diversity over the decade following forest fire. *Proceedings of the Royal Society of London, B* 283, 1–9 (2016).
108. Converse, S. J., White, G. C., Farris, K. L. & Zack, S. Small mammals and forest fuel reduction: national-scale responses to fire and fire surrogates. *Ecological Applications* 16, 1717–1729 (2006).
109. Meyer, M. D., North, M. P. & Kelt, D. A. Short-term effects of fire and forest thinning on truffle abundance and consumption by Neotamias speciosus in the Sierra Nevada of California. *Canadian Journal of Forest Research* 35, 1061–1070 (2005).
110. DellaSala, D. A. & Hanson, C. T. *The ecological importance of mixed-severity fires : nature's Phoenix*. (Elsevier, 2015).
111. Converse, S. J., White, G. C. & Block, W. M. Small mammal responses to thinning and wildfire in ponderosa pine–dominated forests of the southwestern United States. 70, 1711–1722 (2006).
112. DellaSala, D. A., Bond, M. L., Hanson, C. T., Hutto, R. L. & Odion, D. C. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? *Natural Areas Journal* 34, 310–324 (2014).
113. Graham, R. T., Harvey, A. E., Jain, T. B. & Tonn, J. R. Effects of thinning and similar stand treatments on fire behavior in western forests, General Technical Report, PNW-GTR463. (USDA Forest Service, Pacific Northwest Research Station, 1999).
114. Safford, H. D., Stevens, J. T., Merriam, K., Meyer, M. D. & Latimer, A. M. Fuel treatment effectiveness in California yellow pine and mixed conifer forests. *Forest Ecology and Management* 274, 17–28 (2012).
115. Clyatt, K. A., Keyes, C. R. & Hood, S. M. Long-term effects of fuel treatments on aboveground biomass accumulation in ponderosa pine forests of the northern Rocky Mountains. *Forest Ecology and Management* 400, 587–599 (2017).
116. Stephens, S. L., Collins, B. M. & Roller, G. Fuel treatment longevity in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 285, 204–212 (2012).
117. Stephens, S. L. et al. The effects of forest fuel-reduction treatments in the United States. *Bioscience* 62, 549–560 (2012).
118. Krofcheck, D. J., Hurteau, M. D., Scheller, R. M. & Loudermilk, E. L. Restoring surface fire stabilizes forest carbon under extreme fire weather in the Sierra Nevada. *Ecosphere* 8, e01663 (2017).
119. Stephens, S. L. & Moghaddas, J. J. Experimental fuel treatment impacts on forest structure , potential fire behavior , and predicted tree mortality in a California mixed conifer forest. *Forest Ecology and Management* 215, 21–36 (2005).
120. Boisramé, G., Thompson, S., Collins, B. & Stephens, S. Managed wildfire effects on forest resilience and water in the Sierra Nevada. *Ecosystems* 20, 717-732 (2017).
121. Smith, H. G., Sheridan, G. J., Lane, P. N. J., Nyman, P. & Haydon, S. Wildfire effects on water quality in forest catchments: a review with implications for water supply. *Journal of Hydrology* 396, 170–192 (2011).
122. Buckley, M. *et al.* Mokelumne watershed avoided cost analysis: why Sierra fuel treatments make economic sense: A report prepared for the Sierra Nevada Conservancy, The Nature Conservancy, and U.S. Department of Agriculture, Forest Service. (Sierra Nevada Conservancy, 2014).
123. Elliot, W. J., Miller, M. E. & Enstice, N. Targeting forest management through fire and erosion modelling. *International Journal of Wildland Fire* 25, 876–887 (2016).
124. Ellison, D. et al. Trees, forests and water: Cool insights for a hot world. *Global Environmental Change* 43, 51–61 (2017).
125. Ellis, C. R., Pomeroy, J. W., Link, T. E. & Rivers, M. Modeling increases in snowmelt yield and desynchronization resulting from forest gap-thinning treatments in a northern mountain headwater basin. *Water Resource Research* 49, 1–14 (2013).
126. D'amato, A. W., Bradford, J. B., Fraver, S. & Palik, B. J. Effects of thinning on drought vulnerability and climate response in north temperate forest ecosystems. *Ecological Applications* 23, 1735–1742 (2013).
127. Kerhoulas, L. P., Kolb, T. E., Hurteau, M. D. & Koch, G. W. Managing climate change adaptation in forests: a case study from the U.S. Southwest. *Journal of Applied Ecology* 50, 1311–1320 (2013).
128. Collins, B. M. et al. Beyond Reducing Fire Hazard. *Ecological Applications* 23, 515–522 (2013).
129. Hurteau, M. D. & North, M. Carbon recovery rates following different wildfire risk mitigation treatments. *Forest Ecology and Management* 260, 930–937 (2010).
130. Hurteau, M. D. Quantifying the carbon balance of forest restoration and wildfire under projected climate in the fire-prone southwestern U.S. *PLOS ONE* 12, e0169275 (2017).
131. Loudermilk, E. L., Scheller, R. M., Weisberg, P. J. & Kretchun, A. Bending the carbon curve: fire management for carbon resilience under climate change. *Landscape Ecology* (2017).
132. Liang, S., Hurteau, M. D. & Westerling, A. L. Large-scale restoration increases carbon stability under projected climate and wildfire regimes. *Frontiers in Ecology and Environment* 16, 207–212 (2018).
133. Wu, T., Kim, Y.-S. & Hurteau, M. D. Investing in natural capital: using economic incentives to overcome barriers to forest restoration. *Restoration Ecology.* 19, 441–445 (2011).
134. Wayman, R. B., and M. North. 2007. Initial response of a mixed-conifer understory plant community to burning and thinning restoration treatments. *Forest Ecology and Management* 239:32–44.
135. Webster, K. M., and C. B. Halpern. 2010. Long-term vegetation responses to reintroduction and repeated use of fire in mixed-conifer forests of the Sierra Nevada. *Ecosphere* 1:1–27.
136. Richter, C., M. Rejmanek, J. E. D. Miller, K. R. Welch, J. Weeks, and H. Safford. 2019. The species diversity and fire severity relationship is hump-shaped in semiarid yellow pine and mixed conifer forests. *Ecosphere* 10(10):e02882. 10.1002/ecs2.2882
137. Lake, F.K., Giardina, C., Parrotta, J.A., and Davidson-Hunt, I. 2018. Considering diverse knowledge systems in forest landscape restoration-Chapter 3. In: Forest Landscape Restoration: Integrated Approaches to Support Effective Implementation. S. Mansourian and J. Parrotta (eds), Routledge Press:37-46, ISBN: 978-1-315-11187-2 (ebk).

FIRE IN CALIFORNIA: THE LONG ROAD TO RECOVERY

Craig Thomas

California has one of the most fire-prone climates on the planet, with mild, wet winters and long, dry summers. We share this adventure with only a handful of other places on Earth, among them Portugal, central Chile, and South Africa. We hear about these places regularly in the news, most recently, with the deadly bushfires in Australia.

There's nothing new about California's tendency to burn. Before the 1800s, wildfires ignited by lightning and deliberately set by Native Americans burned 4.5 million acres each year, according to research on early California fire patterns by UC Berkeley fire scientist Scott Stephens (Stephens et al. 2007). Fire scientists now call that early 1800s condition a "reference" condition that we can consider in many ways to be a reasonable landscape restoration goal for much (but not all) of California's remaining wildlands. Well-founded science tells us what we must do to restore Sierra Nevada forest heterogeneity and health (see Kelsey, page 22 of this issue).

If fire is a constant in California, why is it taking so long for us to adapt to living with it? It has much to do with cultural history and misunderstanding of the landscape in which we live. In this article, I will lay out the history of our aversion to fire, and signs that we're moving toward a healthier relationship with the fires that sustain California's landscapes.

IN THE BEGINNING

A fundamental misunderstanding of our relationship with fire is deeply rooted in our culture. As a first step, with all due respect to the authors, we would do well

Above: Caples Creek prescribed fire, June 2018. *[Photograph by Craig Thomas]*

to reinterpret the marching orders "...fill the earth and subdue it. Rule over the fish in the sea and the birds in the sky and over every living creature that moves on the ground" (Genesis 1:28). Compared to other traditions that include more nature-centered worldviews, "ruling over" and "subduing" are taking a heavy toll on the Garden of Eden.

In California, trouble began during the Mission period in the late 1700s (Taylor 2016). The establishment and expansion of agrarian-based Spanish missions led to the removal of, and disease outbreaks in, the Native American population, putting an end to their frequent use of fire to increase food supplies and weaving materials.

In 1904, a program of active fire suppression on federal lands led to the lowest level of average fire activity in the past 400 years. Most of the lower montane forests of the Sierra Nevada have not burned in more than a century (Steel et al. 2015) because of effective early detection and initial attack efforts in this era.

Smokey Bear's arrival on the scene 75 years ago fostered a new awareness of fire threat (for an historical perspective, read *The Big Burn* by Timothy Egan). In the 1970s, well-meaning environmental policies began to take hold in natural resource management decisions and carried an anti-fire bias into the current era.

In 1976 the U.S. Forest Service was governed by the National Forest Management Act (NMFA), a positive move forward that helped the agency improve its natural resource management planning process. This began an era of science-based consideration and management of multiple resources. Yet fire is mentioned only three times in the text of NFMA, and all in the context of a catastrophe. The goal was to grow lots of trees and put all fires out.

AN ERA OF SCIENCE-BASED MANAGEMENT

In the 1980s, the effectiveness of fire suppression began to unravel due to increased climate warming, extended fire seasons, and early snowmelt, along with higher levels of forest fuels due to the absence of natural fire. In recent years, fire science has been pushing fire policy into a new and deeper understanding of fire's role in ecosystem resilience and diversity.

The 2009 Guidance for Implementation of Federal Wildfire Management Policy and the 2014 National Cohesive Wildland Fire Management Strategy supported management of planned and unplanned ignitions for multiple resource benefits, such as wildlife habitat, fuels reduction, and watershed protection. These federal policies allow for the management of multiple objectives—which can change during a wildfire's progression—and recognize the science and professionalism of the modern federal fire cadre, fostering a major step forward and bringing Smokey Bear in to the modern fire management arena.

CHANGING FIRE'S PUBLIC IMAGE

Fire is regenerative, reduces fuels, enhances biodiversity, and creates resilience. But it can also burn down entire towns when we mistakenly assume we can control nature and eliminate a natural ecological process.

In the past most Californians rarely saw fire in action, on the rare occasion when a wildfire made the evening news. But over the last 20 years the situation has changed dramatically in California, and increasingly large and severe wildfires have begun to dominate the news locally and nationally.

Our culture has evolved very different attitudes about fire and rain, though both are critically important ecological processes in our California landscape. Fire has gotten a century of bad press (Schweizer and Cisneros 2018) even though rainfall can be equally destructive. One need only recall recent floods and the eroded dam spillway in Oroville to be reminded of the high costs associated with rain, yet we tend to look forward to rain and fear fire. Many media outlets reinforce that attitude.

Beneficial aspects of fire, such as fire's role in habitat enhancement, nutrient recycling, and soil health, as well as the lower smoke emissions outputs from strategically planned fire, are rarely part of the public discourse. Yet they need to be if we are to reestablish a positive relationship with fire and value its nurturing role in our landscapes. Efforts to change public attitudes took a major step forward in the California Legislature in 2018 with the signing of SB 1260 (Jackson 2018) at the end of the Brown Administration. Also positive were the 2017 California Biodiversity Initiative and the 2018 Little Hoover Commission Report, "Fire on the Mountain," which pointed toward fire's benefits in California. While prescribed fire is not a cure-all and can't be guaranteed to halt all incoming wildfires, resilient landscapes that include frequent fire applications are a much better choice for our ecosystems, community protection, and public health.

Fire that benefits nature and humans has been operating alongside precipitation for tens of thousands of years. Scientists from California and throughout the

West have been calling for the reestablishment of fire as a critical ecological process for 30 years, and warning of some dire consequences if we don't heed their warning. It is now clear that those dire consequences have arrived. The West is burning, but mostly not in the way it should be.

GOING FORWARD

Have we reached a critical point in our shared cultural history to embrace a positive relationship with fire? The answer is yes. Our forests, watersheds, carbon sequestration goals, safety, and health all require that we embrace active fire use if we want to maintain a California landscape that is recognizable, productive, and resilient. While scientists warn of increasingly large, high-intensity fires, increased release of forest carbon into the atmosphere, and increased mega-emission events causing massive public health and economic impacts, there is one consistent recommendation stated in most of the published science pertaining to forest resilience, climate change and public health: to reestablish fire's role as a key part of natural resource management.

Multiple efforts are underway throughout the state to reintroduce fire into fire-excluded forests at appropriate scale, intensity, and timing. One example of a collaborative, landscape-level effort to restore natural fire in California is the expansion of prescribed burn programs across the Forest Service and National Park Service, such as the Fire MOU Partnership, and the State Forest Management Task Force and its Prescribed Fire Working Group.

With astronomical fire suppression costs, growing public health impacts and resource damage from mega-emission wildfires, and the state's forest carbon sequestration goals, these groups are forging a new path forward. Their recommendations are key to overcoming barriers to burning (Schultz et al. 2018) and restoring ecologically significant fire in California.

Calculate the avoided costs and co-benefits of a resilient California landscape

How do we balance what we take from our forests with what we restore, maintain, and rebuild, and how does achieving such balance pencil out economically? First and foremost, we must place real value in the avoided costs and co-benefits associated with a resilient and fire-restored California landscape. Real value means an honest accounting of the costs of restoring landscapes in the economic and political equation, including all major categories of avoided costs.

One example is the $300 million estimate of the cost to remove the carcinogen benzene from the Paradise, Calif. water supply (Bizjak, Tony. "Rare toxic cocktail from Camp Fire is poisoning Paradise water," *The Sacramento Bee*, April 2019.) Another example is the carbon emissions from large fires that will eventually happen in the absence of treatment, and the health impacts and cost of hospital admissions from such events.

Also important to consider are co-benefits created when forest landscapes are maintained with ecologically appropriate fire. For example, fire reduces use of toxic herbicides on forest landscapes, which pollute our air, water supplies, forest workers, and native food sources. Another co-benefit occurs from stabilization or realignment of carbon stocks in larger, fire resilient trees, which is a more secure way to store forest carbon in our highly fire-associated landscapes.

Expand fire manager–air regulator collaborations throughout the state

Since the initiation of the California Clean Air Act in the 1970s, the state has made major improvements in air quality. After the act was passed, the state began to regulate emissions of six primary pollutants, including carbon monoxide (CO), lead (Pb), particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2, and sulphur dioxide (SO_2).

There is no question that we need the Clean Air Act statutes, nationally and in their strengthened form in California. But there is one enormous problem with the National Ambient Air Quality Standards (NAAQS) regulating pollution outputs in the state: They are too aggressive in limiting ecologically necessary fire. Fire has been interacting with vegetation as a regulating natural and critical ecological process for tens of thousands of years in California, along with rainfall, snow, wind, floods, and other natural disturbances. Unfortunately, when the new Clean Air Act regulations were drafted in the 1970s, much less was known about fire science or what a natural fire regime was, what it would mean to sustain aggressive fire suppression, or the mega-emissions that would result.

While the California Clean Air Act has made significant improvements in automobile and industrial pollution reductions since its inception, uncharacteristically frequent and intense wildfires and resulting smoke emissions have risen to hazardous levels in multiple events across the state. Recently, several air quality scientists, along with air quality regulators, medical doctors, and policy makers have taken a second look at

the harm to public health from denying fire its appropriate role in building resilience in California's forests and wildlands.

The California Air Resources Board, local air districts, the California Air Pollution Control Officers Association, federal air quality experts, and atmospheric scientists have also joined with fire managers in California (Forest Service, Bureau of Land Management, National Park Service, and the state fire agency, Cal Fire) to expand planned burning, and at the same time support the best smoke management and public health protection efforts in the country. This is a positive trend that needs to continue.

Capacity, capacity, capacity

If we had all the necessary plans and permits in place to increase prescribed and managed burning today, there still wouldn't be enough trained people to do the work. We must increase our prescribed fire workforce. Ideas on the table today include expanded prescribed fire training, support for multi-partner cross-jurisdictional burning, and increased logistical support of larger landscape burning. There is also discussion of setting up permanent, flexible wildfire crews capable of carrying out complicated burns across the state. Other issues include expanded burn windows for larger landscape fire restoration efforts, the need to resolve liability protection for prescription burning, and establishing Prescribed Burn Associations to bring private rural landowners into the restoration and maintenance fire culture.

Finally, it is critical to sustain public education and outreach regarding the need for fire restoration in California. Where there's fire, there's smoke, and we will all be affected by it. We need to include media, policy makers, and the public health community in conversations about fire and emissions tradeoffs, air quality monitoring, and fire prevention at the individual and collective scales.

The goal should be a state in which natural levels of smoke from science-based fire restoration efforts are considered normal background conditions (Schweizer and Cisneros 2016) and are exempted from regulatory limitations. Prescribed fire and smoke management collaboration efforts are expanding. When we reach meaningful ecological scales of fire restoration, we will have reached the best ecological and social outcome possible for our fire-prone landscape.

–Craig Thomas is co-founder of Sierra Forest Legacy and founder of the Fire Restoration Group.

REFERENCES

Cisneros, R., Schweizer, D. 2018. The efficacy of news releases, news reports, and public nuisance complaints for determining smoke impacts to air quality from wildland fire *Air Quality, Atmosphere & Health*. 11(4):423–429.

Egan, Timothy. *The Big Burn.* 2009.

Fire MOU Partnership. Accessed Jan. 29, 2020. https://www.sierraforestlegacy.org/CF_ManagingFire/FireMOU.php

Hurteau, M.D., Westerling, A.L., Wiedinmyer, C., Bryant, B.P. 2014. Projected Effects of Climate and Development on California Wildfire Emissions through 2100. *Environmental Science & Technology* 48 (4): 2298-2304

Liu, X., et al. 2017. Airborne measurements of western U.S. wildfire emissions: Comparison with prescribed burning and air quality implications, *J. Geophys. Res. Atmos.* 122: 6108– 6129.

Long, J.W., Tarnay, L.W., North, M.P. 2018. Aligning Smoke Management with Ecological and Public Health Goals. *Journal of Forestry* 116 (1): 76–86.

North, M., Collins, B.M., Stephens, S. 2012. Using Fire to Increase the Scale, Benefits, and Future Maintenance of Fuels Treatments. *Journal of Forestry* 110 (7): 392-401.

Prescribed Fire Working Group. Accessed Jan. 2020: https://fmtf.fire.ca.gov/working-groups/prescribed-fire/

Schultz, C., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G., Moseley, C. 2018. Prescribed Fire Policy Barriers and Opportunities: A Diversity of Challenges and Strategies Across the West.

Sally Jewell, Secretary of the Interior, Thomas J. Vilsack, Secretary of Agriculture. 2014: The National Strategy: The Final Phase of the Development of the National Cohesive Wildland Fire Management Strategy.

Schweizer. D., Cisneros, R. 2017. Forest fire policy: Change conventional thinking of smoke management to prioritize long term air quality and public health. *Air Quality, Atmosphere & Health*: 10 (1): 33-36.

Schweizer, D., Cisneros, R., Traina, S., Ghezzehei, T. A., Shaw, G. 2017. Using National Ambient Air Quality Standards for fine particulate matter to assess regional wildland fire smoke and air quality management. *Journal of Environmental Management* 201: 345-356.

Steel, Z.L., Safford, H.D., Viers, J.H. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* 6 (1): 1-23.

Stephens, S. L., Martin, R. E., Clinton, N. E. 2007. Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands. *Forest Ecology and Management* 251: 205-216.

Taylor, A.H., Trouet, V., Skinner, C.N., Stephens, S. 2016. Socioecological transitions trigger fire regime shifts and modulate fire-climate interactions in the Sierra Nevada, USA, 1600-2015 CE. Proceedings of the National Academy of Sciences 113 (48) 13684-13689.

U.S. Dept of the Interior, U.S. Dept of Agriculture. *Guidance for Implementation of Federal Wildland Fire Management Policy,* 2009.

DEVELOPING THE INFRASTRUCTURE NEEDED TO RESTORE FOREST HEALTH: TURNING WOODY BIOMASS INTO ENERGY IN THE NORTHERN SIERRA

Jonathan Kusel

In September 2007, the Moonlight Fire burned 65,000 acres of forest land in the northern Sierra, emitting the annual carbon equivalent of 750,000 gasoline-powered cars. The fire also ravaged habitat for several sensitive species, including nesting habitat for spotted owls and goshawks. The U.S. Forest Service reported that 38,000 acres had burned at high severity.

Six years later, in 2013, an agency survey of the area found that shrubs now occupied 29 percent of the landscape, compared to only three percent before the fire. Sierra mixed conifer, true fir, and yellow pine forest types all gave way to the shrub encroachment (USDA Forest Service, 2013). Researchers from the University of California at Davis examined large fires that burned between 1999 and 2008, including the Moonlight Fire, and reported in the October 2019 issue of *Ecosphere* that high severity fires not only destroy forests but lead to reduced plant diversity. Other researchers have found that the shrub fields emerging five to ten years after high severity wildfires have more limited plant diversity than the forests that preceded them (Richter, 2019). What can be done to reduce this type of risk in our subalpine forests, where a legacy of fire suppression has led to dangerously high levels of forest biomass that contribute to the severity of these modern wildfires?

The nonprofit Sierra Institute for Community and Environment has been working for more than 10 years to improve forest and watershed health while also revitalizing rural economies and reducing the risk of catastrophic wildfire by increasing the utilization of low-value wood from forests of the Upper Feather River Watershed. In our rural Plumas County home in the northern Sierra, we are advancing community-scale wood utilization projects that create a market for woody biomass: the small diameter trees and other woody material that need to be removed from the forest to reduce fire risk and restore forest health.

To advance this vision, in 2018 the Institute completed installation of a small-scale, biomass-fired combined heat and power boiler system in Quincy, California. The system, one of the first of its kind in the state, generates both heat and electric power for the Plumas County Health and Human Services Center (HHSC), one of the largest buildings in the county, and one that has historically had high heating costs.

Wood chips derived from material removed as part of forest restoration projects fuel the boiler, which uses up to 400 tons a year of this fuel-reduction wood product (to produce 800 kW of heat). The boiler system burns the chips to heat water that is circulated throughout the building to provide heat. The heated

Above L-R: Biomass boiler burning inside the novel cross-laminated timber building; cross-laminated wood wall panels lowered into place; roof panel being lowered onto the structure. *[Photos courtesy of the Sierra Institute for Community and Environment]*

Right: Moonlight Fire, 2007. *[Photograph courtesy of Wikimedia Commons]*

water is also used to heat an organic thermal oil to produce electricity through an Organic Rankine Cycle (ORC) power generator. The ORC generator converts thermal energy into mechanical power. As the thermal oil vaporizes, it creates pressure that spins a turbine that makes the power for electricity (up to 35 kW), which has the added advantage of being a closed system: As the organic fluid cools, it is condensed and reused. Another advantage is that, unlike water, the organic fluid does not corrode metal parts of the turbine. Together, the boiler and ORC unit are called a combined heat and power (CHP) system.

The boiler uses wood removed from nearby forest restoration projects, and in so doing creates value for this material that would otherwise be disposed of through burning. Compared to open pile burning in the woods, the most economical disposal method, burning forest biomass in a boiler results in a 98 to 99 percent reduction in emissions of fine particulate matter, carbon monoxide, non-methane organic compounds, methane, and black carbon, among other pollutants.

Like in many rural counties across California, inexpensive natural gas is unavailable in Plumas County, and most public facilities rely on expensive fossil fuels transported from afar for heating. Biomass fuel, on the other hand, is locally derived and relatively inexpensive, with prices more stable than those of fossil fuels. This helps counties avoid scrambling to meet costs when fossil fuel prices spike. Using biomass for heat and power can therefore reduce energy costs, fossil fuel use, and harmful emissions, at the same time that it supports essential fuels reduction work to lessen the risk of high severity wildfire and associated emissions. The biomass per boiler installed at the HHSC saves the county $30,000 year in heating costs over a standard electric boiler for heat, and further reduces GHG emissions by securing fuel locally.

This project is also innovative in another way: The HHSC biomass system is housed in a full cross-laminated timber (CLT) building, the first of its kind in California. CLT is made out of multiple layers of solid lumber that are laid flat against one another, with each layer of lumber lying at 90 degrees to the layers above and below it. Layers are glued together, creating a strong, durable panel of wood. The walls of the HHSB boiler building are five layers thick and the roof is seven layers thick. Because CLT panels are multi-layered with no air space between layers, they have proven to be extremely fire resistant and seismically sound, as compared to the two-by-four lumber that is used in standard stud and fiberboard home construction. Use of CLT in buildings also offers a tremendous opportunity to have carbon sequestered in a durable building product.

Construction of the CLT building was completed in two days. Use of local contractors for construction of the CLT building and biomass facility resulted in nearly $1 million being pumped into the local economy. The project was made possible by a $2.3 million California Energy Commission grant to fund development of the combined heat and power system; Plumas County contributed another $400,000 for the building, with the remaining funds donated by the U.S. Forest Service, Sierra Nevada Conservancy, and the Barrett Foundation.

This biomass system and its CLT building at the HHSC are an example of how locally-sourced and abundant biomass material can be used to benefit both forests and local communities. Sierra Institute is working with the county school district and sheriff's department to install biomass boilers at a local high school and a new jail, respectively. A similar system based on the HHSC boiler is under development at a Lake Tahoe ski resort.

Of course, one or two or three such HHSC boilers can only make a limited dent in the abundant biomass that needs to be cleared from the currently overstocked forests of the northern Sierra. But as philosopher Lao Tzu said, "The journey of a thousand miles begins with one step." The HHSC biomass system in a CLT building is a first step and an important example of the wood utilization infrastructure needed to successfully reduce risks of catastrophic wildfire, restore forest health, and sustain the diversity of animal and plant species on which we depend, while also supporting rural communities.

–Jonathan Kusel, PhD, is the founder and executive director of the Sierra Institute for Community and Environment

REFERENCES

Richter et al, 2019. The species diversity × fire severity relationship is hump-shaped in semiarid yellow pine and mixed conifer forests. *Ecosphere.* 10: 2150-8925

USDA Forest Service, 2013. Moonlight Fire Restoration Strategy Forest Service, Plumas National Forest, Mt. Hough Ranger District.

LOOKING FOR MULTI-BENEFIT SOLUTIONS: RESPONDING TO FIRE IN THE SONOMA VALLEY

CONVERSATION WITH CAITLIN CORNWALL OF THE SONOMA ECOLOGY CENTER

David Loeb

In October 2017, Sonoma and Napa counties were hit almost simultaneously by three separate wildfires (Tubbs, Nuns, and Atlas) that are collectively referred to as the Wine Country Fires. At the time, the Tubbs Fire was the most destructive wildfire in California history (a title it held for only a year, when it was surpassed by the November 2018 Camp Fire). These fires burned over 210,000 acres, claimed 44 lives, destroyed some 7,800 homes and other structures, and introduced a new narrative about the capacity of wind-driven wildland fires to cause significant damage in urbanized areas.

The Sonoma Ecology Center is a nonprofit organization that has been advocating for the environmental health of the land and people of the Sonoma Valley since 1990, and will celebrate its 30th anniversary on Earth Day, 2020. In response to the burning of more than one quarter of the landscape of the Sonoma Valley in the Nuns Fire, the Center's staff quickly rolled out a number of programs to help the community respond to the fire and heal from it. Soon thereafter, the work shifted to advocacy for initiatives and practices to make the valley's human and natural communities more resilient to future fires.

In October 2019, as the smoke from the Kincade Fire in northern Sonoma County was still impacting air quality in the county, I traveled to the modest offices of the Sonoma Ecology Center in portable trailers along the banks of Sonoma Creek to talk to Caitlin Cornwall, who directs planning and partnerships for the Center, and Restoration Manager Jason Mills. We discussed the Center's perspectives on living with and responding to fire in Sonoma County.

DL – Your organization's website talks about a three-part response to the 2017 fires: education, active response, and prevention. Is that still a good way to frame your response to wildfire in Sonoma Valley?

CC – You know, I don't think these are the right categories now. The one that's not working for me is "prevention." There's no such thing as preventing fire in California. Collectively we could do a much better job of preventing harm to people and their stuff from fire, but it would be impossible and counterproductive to try to prevent fire.

The categories that I thought you were going to ask about are the three that we use to talk to people about

Above: After the 2017 fires, the Sonoma Ecology Center led "fire recovery walks" through the burned areas of Sugarloaf Ridge State Park, to demonstrate the resilience of the native landscape. *[Photograph courtesy of Sonoma Ecology Center]*

fire in its causes and appropriate responses. Those categories still ring true: One is the direct effects of fire on people. Second is how fire behaves in a healthy natural setting. And the third is what fire means in places that are already disturbed.

We devised those categories because what people should do is really different in those different categories. Impacts on people is all about emergency response, fire prevention, defensible space, fire-ready houses; land use, that is, where we put houses; electrical infrastructure; human caused ignitions; and social services.

The second category is wild places; that's where we talk about the incredibly extensive pattern of fire during Indian times, fire adaptations of all of the native flora and fauna, the potential benefits of prescribed fire (if it's done right), how fire rejuvenates plant communities (if it's on the right return interval). That's a huge topic.

And then the third category includes things like erosion, invasive plants, biodiversity, those parts of the landscape that need a lot of stewarding and active work that they aren't currently getting—invaded grasslands, areas near roads. By the way, there was a scientific study that came out the other day that showed how invasive plants have increased the risk of fire as much as climate change.

DL – Let's go back to the question of the Ecology Center's response to the October 2017 fires. What were some of the programs you developed to deal with the fires and their aftermath?

CC – One of the very first things we did right after the fire was respond to the crisis posed by the number of charred wrecks of houses with the rains coming on. These were essentially piles of toxic ash and debris. If you think about it, most of what's in a house, if it burns, is toxic. It was going to start raining soon, and all of this toxic stuff was going to wash into our creeks. And that was especially a problem here in the Sonoma Valley because we weren't going to be first on the EPA's list for containment work, because our population density here is much less than Santa Rosa's.

So we had no idea when they [EPA] would get here, they were so completely overwhelmed by the scale of the problem—the number of houses—that required containment. So we came up with this emergency program, with volunteer crews and emergency funding from the State Water Board, to map out the location of burned structures in Sonoma Valley, and where they were in relation to steelhead streams. Then we located

Caitlin Cornwall leading a spring hike at Van Hoosear Preserve, a privately protected grassland preserve in Sonoma Valley managed by the Sonoma Ecology Center. *[Photograph by David Loeb]*

nearby staging areas, and got truckloads of straw wattles and sand bags, and trained volunteers to install them. And more important than the materials was our experience in this area. We do a lot of erosion control in normal times, so we have the experience of thinking like water, putting the wattles in the right place, etc. So our restoration staff already had a background for this task. The hardest part about this project was reaching the residents [of the burned homes] to get permission to work on their properties. So many of them had left the area.

DL – What was the scale?

CC – Oh, hundreds of houses. And we just did it in Sonoma Valley.

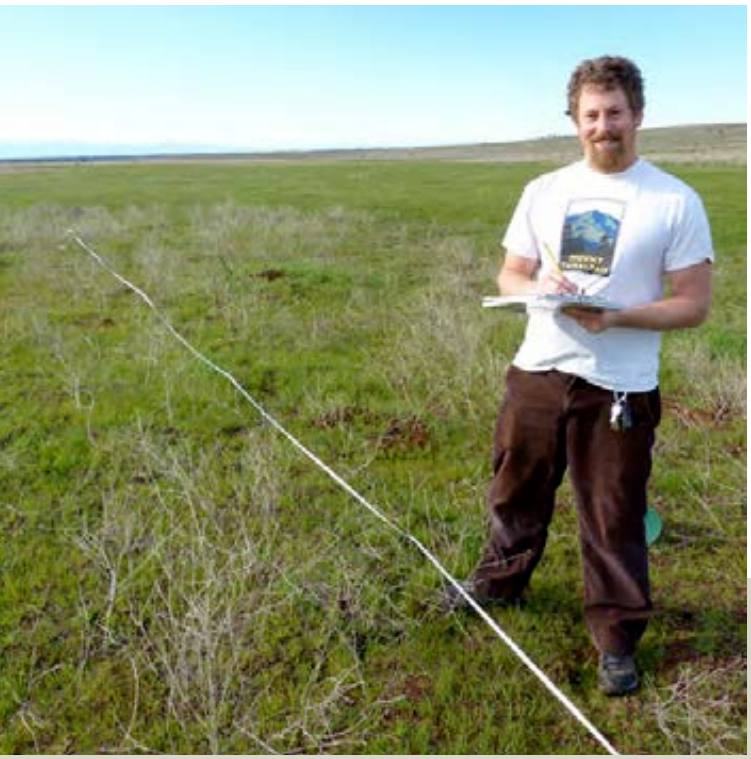
DL – What other programs did you institute in response to the fires?

CC – Immediately following the fires we created pop-up day camps, to address the unbelievable level of chaos and disruption that happens when the schools are shut down. Children are so stressed out by the uncertainty; when they see that adults are uncertain about what's going to happen next, they can get really upset. When we do stuff with kids, we talk about the fires, about climate change, about why this is happening.

Then after the immediate emergency of the fires had passed, we took hundreds of people on fire recovery walks, primarily at Sugarloaf Ridge State Park, but other places around the Valley as well. We worked hard to craft the messages we wanted to get across. We wanted to address people's emotional trauma as well as educate them about the resilience of the landscape and the benefits of fire. No one on those walks had ever really touched these topics in this fashion. It felt really revelatory. Both to deliver this content and for people to receive it. It was pretty emotional. People were in a very ripped-open state emotionally, and we

wanted to be with them in that state, to acknowledge it, and at the same time let the vitality of the land help them be healed. And that's what happened. For most people, those topics were utterly novel, and we felt it was important to experientially convey to people—not just with words, but by walking and touching and smelling—that the land knows fire and was not harmed by it.

There were people on some of the earlier walks who work in the healing professions, who ended up bringing whole groups of their peers on later walks, because they needed the sort of metaphorical language of the land healing to help other people heal.



DL – And you also did other kinds of education about fire ecology?

CC – Yes, we integrated fire ecology into our existing environmental education curriculum that we do in all the schools in the Valley, including field trips. We do these programs for the 2nd, 4th, 5th, and 6th grades.

But beyond that, one of our biggest concerns was that people would take their fear of fire and use it to rationalize cutting down everything that grows on their property. For most people living in California now, fire is a new topic. Or at least it's newly relevant, and it's complicated. People usually get confused or overwhelmed or they apply a fact they've heard about fire to a situation that's not appropriate.

The biggest misapplication of fire facts that we see all over California is the belief that fire suppression is a major reason that we have these dangerous fires. That may be true in some plant communities, but it's not in others. Fire suppression in the forests in the Sierra, yes. But fire suppression in chaparral is not a reason we have lots of fire in chaparral. So when people misapply some of the facts, it can lead them to support problematic solutions.

So one of our projects was to produce a brochure putting out the message that your property can be

Left: Jason Mills doing post-fire transect monitoring at Upper Bidwell Park outside Chico as part of a study on the effects of prescribed burning on species composition in California grasslands. *[Photograph by Ayla Joy Mills]*

Jason Mills: Fire Resilience for Homeowners

Jason Mills is the Restoration Manager and Fire Ecologist for the Sonoma Ecology Center. One of his roles is to respond to requests for advice from local landowners who want to make their properties more fire resilient.

We have a program where we advise landowners in the Valley on what's happening on their properties and how to manage them to be more fire resilient. People don't have the time with their busy lives to understand this on their own. We go out and take a look at what's going on and provide an assessment. And I'll probably say that you don't want any vegetation within that first five feet from your house. Pathways, hardscaping, whatever it is, could be used, but you might have to sacrifice whatever you have growing there.

Then in the next 30 feet out, that's generally where people have their ornamental, irrigated, maintained landscape. That's a really sensitive subject, because these are the plants that people paid for, cared for, feel connected with. We don't get involved with clearing those plants, though we might point out that this is a woody plant full of oils that is more flammable than that plant. But we're not going to recommend decimating people's ornamental landscapes. And it's been shown that if these areas are receiving irrigation and are maintained and limbed and properly attended to, it lowers their flammability. Also, rather than take all the trees out, let's preserve them, so you can have shade and allow for herbaceous, rhizomatous, low-growing native plants to get established as ground cover. The more shade you have, the more you can do your irises, your blue-eyed grass, heuchera, carex, juncus, all of these low-growing natives. And that's going to be your best planting option within

made ready for fire *and* be wildlife friendly *and* water conserving. You don't have to choose. There are design and maintenance practices that can achieve all three objectives.

And now we're following up the brochure with workshops in neighborhoods that are at high risk of fire. The challenge for landowners is that they're receiving all these different messages that tend to be driven by just one issue at a time, and it's our job to integrate all of these admirable objectives—being ready for fire, being good wildlife habitat stewards, using less water, and being climate smart—into a unified set of practices.

Our society has a whole set of complicated problems right now in relation to the planet, and the right course of action isn't to try to solve these problems as if they are separate. That's just playing whack-a-mole. The right solution is to paint a picture of a better way of living on Planet Earth that addresses all these problems at once.

Yet it's important not to present all these problems as a horde of ten thousand, because that just paralyzes people. But it turns out that the solutions *do* reinforce each other and make for a better life overall. So if people can do their defensible space in a way that maintains their tree canopy and that focuses on long-lived native plants, they really will be conserving water, providing habitat, and making their house safer. Whereas if they do it in a scorched earth way, and open up their yard to too much sun, and disturb the soil, they're going to invite in a whole crop of invasive, short-lived grasses, and make their property less safe. *And* require a ton of maintenance. *And* be ugly!

DL – I've heard you talk about the tension between the need to get people back into their homes as soon as possible, and the need to have those homes rebuilt in a more sustainable way.

CC – Unfortunately, land use policies and construction standards have not really changed. Polling shows that people think that housing should not be allowed in high fire risk areas, but they don't think that they themselves are in such an area. And of course, California *as a whole* is a high-risk area, so we can't eliminate all risks. But every new house in California is required to be built earthquake-ready, so why on earth don't we require houses to be fire-ready? And on the land use question, there are so many reasons to prioritize compact development and avoid isolated houses out in the woods. We're not the frontier anymore!

So the right community response to the belated realization that we live in a fire-prone place would be things like compact development, distributed power generation, renewable energy, electrification of things previously powered by combustion, microgrids. And having healthier land would help too, dealing with invasive plants, getting fire back to being a beneficial tool instead of a demon of chaos and destruction.

30 feet of the home. But if you cut everything down, and get all this sun in there, it's going to be harder to keep all of this wet and happy through the fire season.

Once you get outside that 30 feet, that's generally where you encounter wild vegetation. In that area, we advise and do active management to protect those resources. People really want to be proactive, anything that's burned they want it gone. Like, they want to take down burned trees, and yet that costs a lot. And when you bring in the tree companies, they may not be looking at this from an ecological perspective. So we're seeing a lot of damage being done to native trees that might have recovered if left alone. So when we come in, we can look at the trees for canopy damage, cambium damage, fungus and insect infestation. And come up with the likelihood of specific trees making it. UC Extension has a recent paper on recovery and mortality of burned oaks, and the US Forest Service has a paper on burned conifers, and those are great. But it would be really nice to have species-specific protocols for assessing post-fire tree mortality for hardwoods, such as madrone and buckeyes.

And then out there in the wildland, we prioritize removing the invasive weeds. Because the most aggressive plants are going to be your fuels. All this new growth in the spring is going to be flashy, flammable fuel in the peak fire season. And if you wait too long, until it starts turning brown, in late May, and the seeds are already forming, then you hire landscapers to go mow it all, and they're spreading the seed all around. But if you can get in there on those annuals in March, start mowing early, you could actually knock back the seed trajectory and start transforming the landscape back into an area that has more native beneficial habitat. And then if you shift to establishing native perennial grasses, they'll stay green longer going in to fire season.

DL – Is there funding for instituting any of these practices?

CC – There's funding for cutting down vegetation, which if done badly, is more of a harm than a benefit. Well, I shouldn't be so glib. The state as a whole is groping toward a long-term response to the problem. But just throwing money at people with chainsaws is not helpful.

There is a new initiative called Taking Action that's still in the discussion stage. It comes out of a realization that there are millions of acres of land in private hands that aren't being taken care of very well. People just don't have the knowledge or resources to do it right. This is everything from managing invasives to managing erosion; thinning forests where that's called for; etc. The basic concept of Taking Action is to create a self-financing mechanism for getting that work done. Not just for fire resilience, but for healthier lands overall. There are so many benefits that could come from this—water availability, biodiversity, jobs, etc., on top of reduced fire risk. So there ought to be a way to monetize these benefits of healthier wildlands. It would use science and mapping to figure out priority areas for which kinds of treatments; it would have its own equipment and crews, sort of like a utility. The way it is now, the agencies fund individual projects, but it's opportunistic instead of being systematic.

Sonoma Ecology Center staff and volunteers install fiber wattles to prevent toxic materials and erosion from burned homesites reaching local creeks.
[Photograph courtesy of the Sonoma Ecology Center]

DL – What about the Sonoma Valley Wildlands Collaborative? Is that a step toward a regional response?

CC – It's a start. The collaborative is made up of six large conservation landowners—public and private—in the valley [California State Parks; Sonoma County Regional Parks; Sonoma Land Trust; Audubon Canyon Ranch (Bouverie Preserve); Sonoma County Ag & Open Space; Sonoma Mountain Ranch Preservation Foundation] who are banding together to develop permitted plans for vegetation management. The permits would come from Cal Fire. They're hoping that they can save time and money by doing it all as one entity, because their lands are almost contiguous. The Collaborative has been granted about $1 million so far by Cal Fire, which basically just covers the cost of CEQA analysis for the work they want to do, not the work itself. But the work has already started on a small scale: County Parks has done some small prescribed burns; Bouverie did a burn. State Parks is by far the biggest player. The Ecology Center isn't officially part of the Collaborative because we don't own land, but we do work very closely with State Parks because we operate Sugarloaf Ridge State Park for them. We've already done some post-fire work for them on weed mapping there, and also mapping areas of burned Douglas fir forest, because they have Doug fir invasion issues—like many other landowners here—and the fire was actually positive on that front because it took out a lot of Doug fir, which had been part of their management plans even before the fire.

DL – Is it the objective of the Collaborative to make their conservation lands more fire resilient?

CC – There's some subtlety here. The money that was made available after the fires is coming from fire people, fire-*fighting* people. So that funding tends to be all about reducing fuels. But the mission of these landowners in the Collaborative is about biodiversity and conservation. So they want to use vegetation management as a tool for increasing the health of their lands. And of course that could also have the effect of reducing the risk of loss of life and property from fire. "Fuel reduction" can mean very different things. It can look like clear-cutting, or it can look like restoration. How much you cut, what you cut, when you cut, and how often you cut.

The Nuns Fire burns in the near distance in Sonoma Valley during the North Bay wildfires of October 2017. *[Photograph courtesy of the Sonoma Ecology Center]*

DL – It seems that a lot of fire science and fire management practices have been developed around forests in the Sierra Nevada, or Southern California chaparral. But might we need a different set of practices here in the northern and central California coast ranges?

CC – Yes, as I said before, people can misapply facts from other parts of the state to areas where they're not relevant. Unlike in the Sierra, there's very little natural lightning in coastal California, for example. So fires on the coast have mostly been caused by people, intentionally or not. And so the natural return interval of fire is different than it is in the lightning-prone mountains. And the concept that fires are now more severe due to fire suppression in the past, is not as relevant. Here, we have some plant communities that are vulnerable to too-frequent fires. Chaparral is a poster child for that; the natural fire return interval for chaparral is long, very long. We don't need to be doing prescribed fire in chaparral. If we do, we're in danger of losing it. While in other areas, prescribed burning is useful. In the coast ranges, we humans need to decide what we want these lands to support and then we need to work toward a fire regime that supports them.

DL – But it's my understanding that chaparral IS fire-adapted.

CC – Everything here is fire adapted, including oaks and redwoods; look at their bark. But fire in chaparral needs to be pretty rare. Otherwise, there's not enough time for it to regrow—chaparral grows really slowly.

DL – But in oak woodland, my understanding is that there *was* frequent low-intensity burning under Native Californian stewardship.

CC – Yes, that's right. But then you have to deal with the fact that many of our oak woodlands are completely infested with nonnative grasses, and when you burn them, these grasses do really well. So if I were designing a fire regime for oak woodland, I would design it around what's left of the native understory. Burn at the time of year that's good for those natives. The oaks are fine with a cool fire. But the timing and frequency can have a real impact on the understory plants. And so you want the timing to benefit those long-lived natives instead of the short-lived invasives.

DL – Do you think the response, both public and private, to this year's fires was improved by what was learned in 2017?

CC – Definitely. In 2017 we didn't have the content yet. Now we have this brochure. And we have developed workshops for both residents and agency personnel that focus on fire-wise, wildlife-friendly landscaping.

One thing going on now that wasn't happening in 2017 is that there are all these forces in the county working to get homeowners to implement defensible space. The county has an ordinance with inspectors going out; insurance companies are asking people to clear stuff. And PG&E is out clearing much more than it has before. And so our messaging, via the brochure and the workshops, is really important now that those programs are rolling. Because people are getting these messages to cut cut cut, but without a lot of nuance.

So it's very easy for people to believe that cutting more is going to make them safer. Some of the guidelines can be interpreted in problematic ways. For instance, there are horizontal and vertical spacing guidelines and nobody really knows where they came from. And if you followed all of them, you could do a lot of damage and make yourself less safe. So we're working actively with the county, with the fire chief, to make sure that we can be on the same page, that we figure out what people really need to know. They want to do a better job training their inspectors; they're really glad we're doing these workshops.

And again, problems arise when you look at the land through a single lens. The most fire-resistant thing you can have on your land is a paved parking lot and nothing else. So if you just pursue one objective, you won't get a desirable result. We all want to be safe, and to live in a beautiful place, in a functioning community. Generally people live here in Sonoma because they love the beauty of the land, they like being close to wildlife. So we're trying to help people see how then can have all of those values through multi-benefit solutions.

CNPS FELLOWS

CELEBRATING THOSE WHO SPEAK FOR NATIVE PLANTS

[Photograph by Catherine Traub]

Early in my tenure at CNPS, I was struck by a simple but profound statement I heard volunteers and staff repeat: *"We are the voice for plants."*

For those sensitive enough to hear, our native plants have something to say.

The people working to protect,study, and nurture California's native plants are connected by the common understanding that native plants are the foundation of this place we call home. When we save these plants, we save everything else.

CNPS Fellow Ileene Anderson, the Center for Biological Diversity's public desert lands director and former CNPS Sourthern California conservation botanist, once said, "If the bug has bitten you or the cactus has stuck you, and you're hooked on plants, keep that alive! I do believe that the plants choose you."

On the following pages, we celebrate an extraordinary group of people who heard that call of the green world and gave it voice—the 2016–2019 CNPS Fellows. To be named a CNPS Fellow is the highest honor given to members of the California Native Plant Society.

With this issue of *Fremontia*, we've got quite a few people to recognize. Please join us in thanking each of them for their service and contributions to California's native plants.

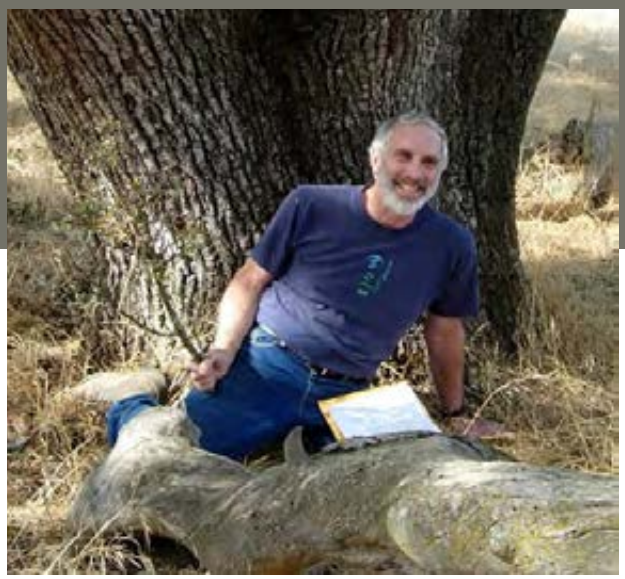
In that same spirit of gratitude, we have four incredible lives to remember: Celia Kutcher, Les Rowntree, Steve McLaughlin, and Mac Laetsch, the first president of CNPS. While we mourn their loss, we celebrate their memories and their lasting contributions to California.

Together, these voices have made the voice for plants a cause for all Californians, and we are indebted.

~ Liv O'Keeffe is the CNPS senior director of communications and engagement

CNPS FELLOW

Michael Barbour



Michael Barbour is a national leader in vegetation conservation who guided the publication of the first CNPS *Manual of California Vegetation in 1995*. [Photograph by Jennifer Buck Diaz / CNPS]

To be respected in the scholarly world as well as the practical, boots-in-the-dirt plant world takes a special person. Michael Barbour is one of those rare individuals who moves freely between both realms, earning plaudits on all sides. A longtime leader for CNPS in vegetation conservation, he is also a widely published author and researcher, cherished educator, and a passionate spokesman for plants. As his Fellow nomination letter notes, he is one of California's most influential plant ecologists.

Michael graduated magna cum laude from Michigan State University, was a Fulbright Fellow in Australia, then received his doctorate in botany from Duke University in 1967. He then joined the faculty of the University of California, Davis, becoming a professor of botany and environmental horticulture. At Davis he earned a reputation for finely tuning his lectures for his audience, whether they were laypeople or graduate students. Since his retirement from UC Davis in 2008, he has remained actively involved in CNPS on many fronts, including his most recent publication through CNPS, the beautiful *California's Botanical Landscapes* (2016).

Michael has been the author or co-author of textbooks on botany, plant ecology, landscape ecology, and vegetation. He co-wrote one of the most widely used texts on plant ecology, *North American Terrestrial Vegetation*, with his major professor at Duke University, W.D. Billings. Along with his UC Davis friend and mentor Jack Major, Michael also edited and wrote portions of the first two editions of the extensive compendium on California vegetation ecology, the *Terrestrial Vegetation of California*, the second edition of which was published by CNPS in 1988. These books have set the stage for many developments in the study of Californian and western North American vegetation. His research work into plant ecology has taken him to many countries across the globe, including Argentina, Spain, Israel, Australia, and South Africa. He also welcomed European vegetation scientists to work with him on refining California's vegetation classification. He has published more than 50 books, book chapters, and papers, including several articles in *Fremontia*.

Michael has been involved in a number of conservation issues, demonstrating the power of conservation through scientifically defensible means. This includes the conservation and understanding of California's vernal pools. He and his co-authors developed a quantifiable approach to vernal pool classification that led to a means for putting metrics on vernal pool restoration by quantifying the deviance between created vernal pool communities and naturally occurring ones. The Environmental Protection Agency and other regulatory agencies have adopted this same methodology.

His efforts for CNPS have been as far-reaching as his academic work. In 1989 he was chosen to lead the new Plant Communities Committee, now known as the Vegetation Committee. He and his group established a sampling protocol for vegetation throughout the state, developed a database to contain collected vegetation transect and plot data, and trained many CNPS chapter members on the selection of rare communities and their sampling. Most important, his committee guided the development and writing of the first *Manual of California Vegetation* published by CNPS in 1995.

Michael not only has been a state leader in vegetation conservation, but also a national leader. He was the first chair of the Ecological Society of America's Vegetation Committee, which published the first U.S. National Vegetation Classification in 1998. And throughout his distinguished career, Michael has been a congenial, even-handed, and humorous member of the plant ecology community. As his nominators note, "CNPS and the conservation world has been extremely fortunate to have him in 'our corner.'"

–Kathy Morrison

Under Julie Evens' leadership, the CNPS Vegetation Program became an important partner for county, state, and national agencies. (Left) Julie with her children Leo and Daphne Cox at Carrizo Plain National Monument. *[Photographs by Jeffrey Cox]*

CNPS FELLOW

Julie Evens

Being the first of anything can be tough, especially when expectations are high. That was the situation Julie Evens faced when she became the first full-time CNPS vegetation ecologist in 2001. Thanks to her efforts, the CNPS Vegetation Program has since grown in size and prominence, earning state and national respect as a leading force in ecosystem classification and conservation. CNPS recently recognized Julie Evens for her dedicated advocacy and support of the program with its highest honor, the title of Fellow.

Julie grew up in the Midwest and arrived in California to attend the University of California Santa Cruz (UCSC). As a horticulture intern at the UC Santa Cruz Arboretum, Julie assisted in the California collections, especially Channel Islands endemic plants. She graduated in 1995 with two BA degrees in environmental studies and biology/botany with honors.

Fresh out of college, Julie worked as a scientific aide with the Natural Diversity Database Natural Communities Program, where she helped inventory valley oak riparian forest in the Sacramento and San Joaquin valleys. She went on to be a field team leader in the joint State and Federal Mojave Desert Ecosystem Program, Central Mojave Vegetation Database Project. She and others collected more than 1,200 relevés throughout the central Mojave. This information formed the basis of the Mojave Desert Ecoregional vegetation classification, which was used to make a map of approximately 12 million acres of desert.

As a Humboldt State graduate student, Julie decided to explore the ecological intricacies of desert wash systems and spent two field seasons collecting relevé samples in the Sweeney Granite Mountains Reserve. Her master's thesis was an analysis and definition of the Eastern Mojave wash vegetation. It remains the authoritative work on the subject.

As a field team leader for two seasons in the Vegetation Classification project for Sequoia and Kings Canyon National Parks, Julie grew interested in CNPS' work. Allen Barnes had recently become the organization's first executive director, and CNPS was searching for its first full-time vegetation ecologist. Julie was selected for the position over stiff competition. Her goals for the Vegetation Program included increasing chapter involvement, and improving methods in data collection and description of vegetation. She also helped drive active conservation planning of natural communities through development of new vegetation information for key areas.

These goals took root in a project with the Santa Clara Valley Chapter, which resulted in a detailed report on the classification of Coyote Ridge, one of the premier serpentine grassland landscapes in California. To help raise awareness of vegetation conservation—a goal of the CNPS Vegetation Committee—Julie and her growing program delved into immensely detailed regional projects, such as the classification of the vegetation of Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP).

To accomplish these increasingly complex tasks, Julie became a diligent and creative grant writer and project manager. She received a competitive National Fish and Wildlife Foundation grant to test and develop efficiency and effectiveness of field data collection (Peoria Wildlife Area). Since then, she and her staff have won many contracts and grants with the California Division of Fish and Wildlife, NatureServe, National Parks Service, and others. Funding stability has allowed her program to address goals such as the writing of the second edition of the *Manual of California Vegetation*, and development of the online MCV and the MCV database.

On a more personal level, Julie has two young children and is active in the Sacramento Valley Chapter, showing off her native-plant-filled front yard during garden tours. Above all, as her Fellow nomination letter notes, "It has been Julie's strong sense of passion for her work, belief in the power of grass-roots involvement, and familial loyalty to her staff and her cooperators that has brought such statewide recognition to Vegetation Conservation."

–Kathy Morrison

Brett Hall and Tori Bauman with *Arctostaphylos montereyensis* in the Maritime Chaparral section of the California Conservation Gardens at UCSC Arboretum. *[Photograph courtesy of Brett Hall]*

CNPS FELLOW

Brett Hall

Educator, advocate, enthusiast— all are characteristics that describe Brett Hall and his invaluable contributions to the California native plant community. As California Native Plant Program director of the UC Santa Cruz Arboretum, he has been deeply involved in teaching about and conserving native plants. Having served as president of the state CNPS board as well as the Santa Cruz and Tahoe chapters, he has spread the mission of CNPS and worked tirelessly on projects such as the new Important Plant Area (IPA) initiative. His botanical pursuits cover everything from plant sales to seed banks.

This dynamo of native plant advocacy was born in Carmel and grew up exploring the flora of the Santa Lucia Range. After working in his family's landscaping and garden design business, he enrolled in UC Santa Cruz and received a bachelor's in natural history and biology. Ken Norris and Ray Collett were among his instructors; their legendary Natural History Field Quarter courses launched many environmental careers. While at UCSC, Brett worked at the Arboretum, which was still in its early days, and his senior project was a study of the rare plants of Santa Cruz County.

In 1975, Brett became an official staff member of the Arboretum, and two years later was promoted to botanical garden manager. About this time, he joined the Santa Cruz Chapter of CNPS and became one of its great champions. His nominator, colleague and fellow CNPS member Dylan Neubauer, says, "Indeed, a more exemplary advocate for the organization would be hard to find."

The Santa Cruz Chapter, though small in those days, was able to preserve several special botanical areas in the county, including the Bonny Doon sandhills and the Glenwood grasslands, both home to federally and state-listed taxa. "Brett's earnest and hands-on style (never one to wear a suit to a meeting or hearing!) was invaluable during those early efforts as well as later ones," recalls botanist Laurie Kiguchi. "His trustworthiness and dedication were apparent, and he always came across as calm, thoughtful, and open."

Brett became director of horticulture at the UCSC Arboretum in 1985 and worked to expand its holdings, traveling and bringing in many ornamental plants that then were new to California horticulture but became popular in the nursery trade. He was director of collections and conservation in 2014-15 before assuming his current position as California Native Plant Program director. The Arboretum now is well known for its collections of Mediterranean-climate plants, including California natives. One of Brett's long-term projects, the California Conservation Garden, houses a large collection of rare manzanitas, a favorite genus of his.

Brett's passion for native plants is a common thread of his Arboretum work and his efforts for CNPS. For many years he served as coordinator of the semiannual CNPS plant sales, which were held alongside the spring and fall Arboretum sales. The venue for CNPS meetings for many years, the Arboretum also hosted chapter council meetings in 2009 and 2013 while Brett was chapter president. He joined the CNPS state board of directors in 2007, served as state president from 2009-13, then rejoined the board in 2016. He added numerous roles to his Santa Cruz Chapter activities, then helped revive the Tahoe Chapter in his "second home," becoming its president in 2014.

Brett has been deeply involved in the California Rare Plant (CaPR) initiative, seedbanking of rare and locally rare plants, and CNPS' Vegetation Program and new Important Plant Area initiative. His students benefit from his knowledge and enthusiasm for all these projects. As Neubauer notes in his nominating letter, "A true educator, Brett knows how to convey his expertise about California places and plants in a way that gets people turned on—for life."

–Kathy Morrison

CNPS FELLOW

Dave “Kim” Imper

Dave Imper, also known as “Mr. Lily,” has worked across government agencies to establish protections for rare plants. *[Photographs courtesy of Dave Imper]*

David Kimberly Imper answers to both “Dave” and “Kim” but plant folks like to call him “Mr. Lily,” for his work with the endangered Western lily (*Lilium occidentale*). Now retired from his position as a U.S. Fish and Wildlife (USFWS) biologist, Imper is respected in the North Coast region for his academic and professional knowledge, as well as his willingness to stand up for the plants, even putting his job on the line when necessary.

Dave earned a BS degree in botany from Cal Poly San Luis Obispo and a master’s in botany and plant pathology from Oregon State. His professional career included time with the U.S. Forest Service, LACO Engineering Consultants, SHN Engineers & Geologists Inc., and finally USFWS, where the service hired three botanists to replace him after his retirement. His professional ethics always were foremost, say the writers of his Fellow nomination. They offer these examples:

“He reported a timber company to the Army Corps for illegally filling part of Crescent City Marsh. When Pacific Lumber Co. demanded that a section on obligate wetland plants be removed from a report on a timber harvest survey, Dave said, ‘Why don’t we call the Army Corps and see what they think?’ You can guess how that debate ended! He did wait until he retired to confront the Six Rivers National Forest on their lack of stewardship of the Lassics Lupine and then to proceed with the listing petition.”

Dave did not shy away from working with other agencies to protect rare plants. His partnerships ranged from the Bureau of Land Management to the Humboldt County Roads Department, from the California Department of Fish and Wildlife to cannabis farmers. Through these efforts, projects such as the Two-Flower Pea Reserve became reality, and the Crescent City Marsh drainage issue was fixed for the benefit of the Western lily. Drivers along Highway 101 appreciate his work with Caltrans to establish a “botanical management area” where a large, gorgeous array of native Columbia lily (*Lilium columbianum*) blooms annually.

He also was an early and dedicated supporter of the concept that loss and alteration of natural ecological disturbance is as much a threat to rare plants and natural communities as the other more typical threats. Dave helped local conservationists understand that conservation is more than just roping off land and not touching it. Many rare plant populations need a certain fire, flooding, or grazing regime, or they will not persist.

As a botanist, Dave’s experience includes botanical surveys, protection measures, conservation and recovery plans, habitat restoration and purchase, monitoring, status reviews, listing petitions, genetic studies, publications, lectures, and field trips. So it’s no surprise he has been a cherished resource for the CNPS North Coast Chapter, which he joined in 1981. He has taken on many board roles, including chapter president in 1987. He has also led field trips, served as speaker at CNPS programs, written articles for *Darlingtonia*, and built an educational booth for use at fairs and other occasions. He was an important organizer of the 2002 Rare Plant Symposium, one of the chapter’s most ambitious projects, and developed an Adopt-a-Rare Plant program for the chapter. He was also the first recipient of the chapter’s highest award, the Gilded Darlingtonia.

For the last word on the invaluable contributions of Dave “Kim” Imper, here is James P. Smith, one of the founders of the North Coast Chapter: “Few indeed have been the combination of a person with such a strong professional background, active field experience, dedication to the cause of rare plant studies and conservation, and willingness to devote his time, knowledge, energy, and personal resources to the cause.”

–Kathy Morrison

Four taxa have been named in Dave Keil's honor, pictured here receiving his Fellow award. *[Photograph by Melissa Mooney]*

CNPS FELLOW

David Keil

Was David Keil born with a plant key in his hand? At the very least, he carries one around in his head. Now retired from Cal Poly San Luis Obispo, where he taught for 37 years, Dave influenced generations of botany and biology students through his classes, field trips, and research. He continues to inspire and influence his fellow members of CNPS, and especially the San Luis Obispo Chapter, as a CNPS Fellow.

Dave attended Arizona State University, earning both a bachelor's and master's of science. In 1973, he completed his PhD at Ohio State University. He joined the faculty at California Polytechnic State University in 1976, and two years later was appointed director of the Robert F. Hoover Herbarium. Students have described his field botany course as both the hardest and best of their college careers. Not surprisingly, Dave is an avid plant collector; over the years, many of his more than 30,000 specimens became part of the herbarium's collection. He received the university's Distinguished Teaching Award in 1980.

Not long after his arrival in SLO, Dave joined the CNPS San Luis Obispo Chapter. In 1978, he served as the chapter president, and has since filled many other roles, including vice president. He has regularly presented chapter meeting programs and workshops that were fun and surprising, including new discoveries and unusual findings, members say.

CNPS members have also benefited from Dave's knowledge on chapter field trips, including for the chapter's annual Wildflower Weekend event; Sierra Madre and Mt. Pinos weekend ventures; trips to the Carrizo Plains; and trips focusing on coastal, riparian and serpentine endemic plants. Some trips were spur of the moment, such as an evening trip to the Irish Hills for grass identification, or a quick trip to West Cuesta Ridge.

Another example of Dave's dedication is related in his Fellow nomination letter: In 2009, he volunteered for a "quick" CNPS committee to develop a guide to common plants, for distribution by the city of San Luis Obispo, and the effort turned into a multi-month project. Dave later became editor of the 86-page guide, *Wildflowers of San Luis Obispo, California*, of which an expanded second edition was recently published. In recognition of his generous contributions to the SLO Chapter, Dave was given the 1989 Hoover Award, the chapter's greatest honor.

Dave also has been active and influential at the state level of CNPS, serving on numerous committees and boards, including the Rare Plant Scientific Advisory Committee and the *Fremontia* Editorial Advisory Board. He most recently sat on the 2019-20 Education Grants Committee, a roll he also volunteered for from 2014 through 2016. He also has conducted multiday workshops on California flora for the State Education Program.

Beyond CNPS, Dave has lent his expertise to the California botanical community through his contributions to *The Jepson Manual* Project. He wrote the "Key to California Plant Families" and served as the editor and primary author of the *Asteraceae* for both editions of *The Jepson Manual*. Key writing has always been one of his strengths, colleagues say, and it is a major part of his legacy. Fittingly, four taxa have been named in this plant expert's honor: Santa Ynez groundstar (*Ancistrocarphus keilii*); Keil's daisy (*Erigeron inornatus* var. *keilii*); *Wedelia keilii* B.L. Turner, and *Chrysanthellum keilii* B.L. Turner.

–Kathy Morrison

A NEW FELLOW REMEMBERED

Celia Kutcher

(December 1938 – November 2019)

Members of the CNPS Orange County Chapter celebrate Celia's Fellow recognition last spring. Celia at center in green. *[Photographs courtesy of the CNPS Orange County Chapter]*

California native plants have lost one of their greatest champions. Last spring, CNPS awarded Celia Kutcher its highest honor of CNPS Fellow, recognizing Celia for four decades of native plant conservation advocacy and service to the organization. Now, we honor her passing.

In reviewing the nomination packet submitted by members of the CNPS Orange County Chapter, one is struck by one theme more than any other: the powerful example Celia set for others. Whether drafting meticulous comment letters in defense of endangered species, creating native gardens, or cleaning up after events, Celia did it all. Her nominators say the other chapter volunteers couldn't help "but follow her lead." Celia's example was an inspiration, and for so many reasons.

Celia is perhaps best known for her steadfast conservation work at the local level, where she served as the CNPS Orange County Conservation chair for 25 years, and statewide, as a member of the Conservation Program, Litigation, and Policy Committees. In 1997, she formed and chaired the Dana Point Headlands Action Coalition, taking on powerful interests to protect the last undeveloped headland in Orange County. The group's partial victory saved two federally endangered species and set aside a large Environmentally Sensitive Habitat Area for rare native plants.

Celia was an expert across many of California's most complex environmental issues, providing valuable input on behalf of her chapter and the statewide organization. "Whether on realistic fire/fuel management strategies, watershed issues, toll road proposals, legislative attacks on CEQA and many other CEQA-related issues, DEIR and EIR biological resources reviews, invasive plant topics, or NCCP actions, her detailed language is accurate and well supported, her tone is never strident or accusatory, always courteous and professional," said her nominators.

Celia held degrees in both botany and plant ecology and a master's in environmental studies from California State University Fullerton, where she served as the Fullerton Arboretum's curator of plant collections for 22 years. During that time, she directed the planting of Chaparral Hill, a native plant collection with trails and interpretive signage spanning more than an acre. She also designed the native landscape around the Oak Hall complex and organized CNPS Orange County Chapter members to install the garden. Both Fullerton landscapes were the first public native gardens in Orange County. Later, Celia organized a similar effort for the UC Irvine Arboretum, leading the chapter's creation of three California Gardens.

Celia directed her chapter's early efforts at controlling invasive weeds in county wildlands and served as an active member of the Orange County Chapter's award-winning Invasive Plant Program's Early Detection/Rapid Response Group. A founding member of the Orange County Chapter, Celia filled nearly every volunteer leadership role at one time or another, from vice president and historian to plant sales chair. Not surprisingly, her fellow volunteers awarded her the chapter's "Native Perennial Award" in 2008 and Board Member of the Year in 1999.

It is with much admiration and gratitude that we honor Celia Kutcher's contributions and life. A remembrance by her fellow Orange County Chapter member and friend Dan Songster appears on page 60.

–Liv O'Keeffe

CNPS FELLOW

Dianne Lake

CNPS Fellow Dianne Lake was one of the first advocates for the concept of "locally rare" plants. She continues her work monitoring locally rare plants today and has authored a guide to helped other chapters do the same. *[Photograph courtesy of CNPS East Bay Chapter]*

Dianne Lake discovered botany during summers spent eating blackberries and caring for her grandmother's garden in St. Charles, Illinois. These childhood pleasures formed an early stewardship ethic, which Dianne has enacted through decades of observation, advocacy, and leadership on behalf of California's native flora.

A self-taught botanist, Dianne gained her knowledge of the flora of the East Bay by joining CNPS hikes, taking courses at Peralta and Merritt College, "pestering" the former director of the Tilden Botanic Garden, as she puts it, and hiking in the wilds of the East Bay with her kids.

While on East Bay Chapter outings in the 1980s, Dianne noticed that certain native plants were present all the time, while others could be found only occasionally, and some very rarely. She concluded that a list of East Bay plants with five or fewer known locations should be compiled. In this way, Dianne became an early advocate for the concept of "locally rare" plants that scientists consider sensitive or unique in a specific region.

Dianne's observations kicked off a collaborative search for botanical information, including chapter and East Bay Regional Park District plant lists, conversations with other botanists, herbarium vouchers, field notes, and Environmental Impact Reports. The resulting list included 861 plants, and prompted Dianne to develop criteria for listing and ranking each plant.

In the years since, Dianne and her partners have produced eight hardcopy editions of the *Unusual and Significant Plants of Alameda and Contra Costa Counties*, which they converted to an online database in 2010. In all, they've tracked more than 1,000 plant taxa and compiled 18,000 observation records from 1,050 people. Dianne herself has personally reported 4,993 observations.

Dianne has been a member of CNPS for decades. She served on the board of the East Bay Chapter for approximately 28 years, continuing as a board member today. When Franklin Canyon in Contra Costs County was slated for development in 2004, Dianne went from door to door, collecting signatures to support the *Protect Franklin Canyon Area Initiative*.

Her efforts helped get the initiative on the ballot, ultimately saving Franklin Canyon and the nine locally rare plants that live there. In addition, Diane participated in the efforts to get Richmond to include protection of locally rare plant species as a priority in its general plan.

Since Dianne started her work, many others have been inspired to develop lists for their chapters and counties—helped in no small part by Dianne's how-to guide, *Establishing a Locally Rare Plants Program for Your Chapter*, which can be found online at cnps.org/locally-rare-chapter-program-guide.

Not one to slow down, Dianne continues her work alongside other chapter volunteers to continually monitor plants and update their knowledge of the East Bay flora. Dianne's energy, conservation ethic, and steadfast study of the East Bay flora are an inspiration to all.

–Adapted by CNPS staff from text by Heath A. Bartosh

CNPS FELLOWS

Carol LeNeve and Brian LeNeve

Carol LaNeve has been a driving force behind seminal Monterey County botanical texts, including *The Plants of Monterey County*. *[Photograph by Michael Mitchell]*

Working both together and separately, Brian and Carol LeNeve have dedicated decades to California native plants and habitats, and to CNPS. Their story starts with Carol, "the glue that has held together the Monterey Bay Chapter," as her Fellow nomination letter puts it. She joined the chapter in 1980 and quickly became involved in the annual plant sale. At that time the sale was held on the lawn of Carmel High School. By the late 1980s, Carol was in charge of the event, raising its profile so it became the primary fundraising source for the chapter.

The sale moved to the Monterey Peninsula College parking lot by the early 1990s, where high-quality plants chosen from local wholesalers drew a growing clientele of native plant gardening lovers. Carol developed sales aids, too, including cards for each species with color photographs and informative labels. The sale has since moved to the Hilton Bialek habitat area at Carmel Middle School, and Carol retired from sole management of the event in 2012, but she set the standard and helped establish stability for the Monterey Bay Chapter.

On the statewide level, Carol served as editor of the CNPS state bulletin from 1988 to 1994 and sat on the state book publication committee. She selected titles to be offered at the plant sale and chapter meetings. Proceeds from those book sales went into a special educational fund. In 1997 "a longtime goal was realized" with the publication of (Corky) Matthews' *Illustrated Field Key to the Flowering Plants of Monterey County,* note Chris Hauser and Peggy Grier in their nominating letter. Corky Matthews "was the first to say that the project would not have succeeded without Carol's management," they add.

The book has subsequently been revised, each time with Carol's careful oversight. In 2012, a revision of *The Jepson Manual* in turn required an update on Monterey flora. So in 2015 a new third edition was published, written by Michael Mitchell and retitled *The Plants of Monterey County*. Carol again had a hand in the work: She enabled Mitchell to get started by taking on the huge project of creating a "crosswalk" database of old and new plant names.

Early on she joined the weekly day trips of Matthews, Vern Yadon, and Ron Branson, seeking out rare or unusual plants in the little-traveled areas of the county. (Interestingly, some of these trips wound up at the LeNeves' ranch in Priest Valley, in the southeast corner of Monterey County.) She assisted Matthews and Yadon in the long-term project of updating the herbarium of the Pacific Grove Museum of Natural History, where Yadon was the director. She also compiled a display of the Ten Most Wanted (weeds) of Monterey County, which she toted to any and all meetings of environmental groups. Her dedication, knowledge, and attention to detail—not to mention her famous chocolate chip cookies—have made her an invaluable member of the chapter and the Monterey region plant community. At present she serves on the chapter board.

With Carol deeply involved in CNPS, it was bound to rub off on Brian. It took a while, but he became so interested in native plants and conservation that he's now known as "Mr. Clarkia." Brian grew up in the Carmel area, following in his father's footsteps as a painting contractor. At first he was just an occasional driver on those plant-hunting drives around the county. As Carol took on more responsibility with the chapter plant sales, Brian became her go-to delivery man, banner installer, and general laborer. The couple

An expert in riparian habitat and clarkia, Brian LeNeve has been an adviser on the project to remove the San Clemente dam and redirect the headwaters of the Carmel River. *[Photograph courtesy of CNPS]*

developed a tight organization behind the scenes that became their trademark.

Brian eventually expanded his involvement to the Pacific Grove Wildflower Show, which Yadon and Beatrice Howitt founded at the Pacific Grove Museum. This annual event, now in its 59th year, requires a huge amount of legwork from CNPS members and other plant lovers. In his Fellow nomination letter, Grier and Hauser describe how Brian sets up tables and collection lists for the show, handles all coordination with museum staff, then oversees set-up day when the work crew transforms a sea of plant specimens in buckets in to a highly organized show that attracts many hundreds of plant lovers."

A few years ago Brian finally was joined by a CNPS co-chairman to relieve him of some of the duties of the wildflower show. Since retiring from his painting business, he also has served three terms as president of the CNPS chapter, as well as serving on the state board of directors and the chapter council.

So how did he become Mr. Clarkia? About 15 years ago, Brian took on a year-long study of species occurring in a quadrant at the Church Creek divide, near Chews Ridge and China Camp, and later presented a program on the area at a chapter meeting. His long-term interest in clarkias took him to the Jepson Herbarium at UC Berkeley to review clarkia species across California, and he decided to track them all down, as well as species in neighboring states. Corky Matthews, herself a CNPS Fellow, now calls him a leading authority on the genus.

The longtime hunter-fisherman also jumped into helping with the problems of steelhead in the Carmel River, eventually becoming president of the Steelhead Association. In the course of his steelhead involvement he developed expertise on riparian habitats, and now serves as consultant and adviser on the monster project of removing the San Clemente dam and redirecting the very headwaters of the Carmel River. (In winter months he takes time for multiple trips to fish the streams of Northern California.)

Brian's newest role is chapter representative to the BLM monitoring of the Clear Creek area in the interior of Monterey County. The mission is protecting rare plant species in a serpentine area frequented by off-road vehicles, a mission with its share of risks. "Brian has been our chapter's lead person in the filing of litigation against BLM, and the result has been to ensure enforcement of their management plans," Grieg and Hauser note.

By the way, that ranch in Priest Valley, which the LeNeves bought originally so Brian could pursue his love of hunting, is now leased to neighbors for grazing. Carol and Brian have their own "plant preserve"—they are valuable stewards of the Monterey County flora and invaluable members of CNPS and the plant community.

–Kathy Morrison

For more than four decades, Larry Levine has quietly helped lead CNPS efforts like the CNPS Phytophthora policy, chapter council, and technology innovation. *[Photograph courtesy of CNPS North Coast Chapter]*

CNPS FELLOW

Larry Levine

CNPS is an organization dedicated to plants, but its success relies on tending to the human side of the operation. Not many people understand this more than North Coast Chapter member Larry Levine, whose peers named him a CNPS Fellow in 2018.

Larry balances his scientific savvy with social acumen, excelling not only in rare plant research but hospitality and communications. He has conducted research into rare plants like Bensoniella (*Bensoniella oregona*) and Howell's alkali grass (*Puccinellia howellii*), and was also the first in his chapter to point out the need to serve refreshments at chapter meetings.

He instituted accessible, two-hour plant walks for his community, organizing 18 consecutive walks in one year, and was also an early technology pioneer, advocating for putting the CNPS Rare Plant Inventory online in the early 1990s.

"Larry is a solid scientific thinker and an experienced, ace botanist who has both a deep and a broad knowledge of the California flora, natural history, and ecological principles," said North Coast chapter leaders Carol Ralph and Gordon Leppig in their nomination letter.

Larry also knows how to grow an organization and its mission. As co-organizer of the North Coast chapter's wildflower show, he developed a teacher's guide for the show, managed the database and species identification cards, and supervised the plant identification crew. In his respective roles as publicity chair and webmaster, he overhauled his chapter's website and provided website mentorship to other chapters. He also wrote, edited, and compiled hundreds of public service announcements, articles, and news releases.

Not limited to the chapter level, Larry's efforts extend to the entire organization. Over 30 years of service to CNPS, he served as CNPS chapter council vice chair for 10 years and, since 2003, has served as a chapter delegate.

As vice chair, he initiated the round table approach to facilitate discussion at meetings, and took an active role in developing and organizing CNPS policies across a wide range of complex issues. He was the Phytophthora Subcommittee chair and a major contributor to the development of the CNPS policy of preventing the spread of harmful pathogens via native plant nursery and plant sale stock.

"Larry always strives for thoughtful, effective engagement that focuses on active listening, finding common ground, seeking consensus, deescalating tensions, conflict resolution, facilitating creative solutions, and diminishing interpersonal issues while focusing instead on the substance of the issue," said Larry's nominators of his ability to bring people together—a much-needed gift in today's deeply polarized world.

–Liv O'Keeffe

Award-winning horticulturalist, author, and former *Fremontia* editor Bart O'Brien helped write the book(s) on native plant gardening. *[Photograph by Ashika Narayan]*

CNPS FELLOW

Bart O'Brien

One of California's leading experts in native plant horticulture, Bart O'Brien's impact is felt statewide. A long time member and former president of the Santa Clara Valley Chapter of CNPS, he is the current director of the Regional Parks Botanic Garden in Tilden Regional Park in the Berkeley hills. Before that, from 1990 to 2013, he worked at the Rancho Santa Ana Botanic Garden in Southern California. In 2005, the Southern California Horticultural Society named him Horticulturist of the Year.

A fifth-generation California native from Hollister, Bart received his BA in Environmental Planning at U.C. Davis and then an MA in Landscape Architecture from the Harvard School of Design. In 1981, he returned to the Bay Area to pursue a career in landscape design, eventually becoming manager of Yerba Buena Nursery, the pioneering native plant nursery in the South Bay, from 1988–1990. He credits Gerda Isenberg, the visionary founder of the nursery, with stimulating his lifelong passion for native plants.

In 1982, Bart joined the Santa Clara Valley chapter of CNPS, becoming an active member right away. He served as chapter vice president in 1983–1984 and then as president in 1985–1986, increasing public awareness of native plants through field trips, lectures, and plant sales. In 1987, Bart became editor of the chapter newsletter, starting his career as a prolific writer about native plants. He also chaired the Edgewood Park Committee, which worked to keep this botanically important open space in San Mateo County from being developed as a golf course. This resulted in the permanent protection of important serpentine grasslands and the creation of Edgewood County Park and Natural Preserve in 1993.

In 1990, Bart was lured away from the South Bay to become director of horticulture at the Rancho Santa Ana Botanic Garden (RSABG). In his 24 years at this revered Southern California institution, he introduced generations of homeowners—and water agency officials—to the beauty of native plants adapted to the region's dry climate. His years of experience and knowledge in cultivating native plants for California gardens resulted in the authoritative *California Native Plants for the Garden* (Cachuma Press, 2005), which he co-authored with David Fross and Carol Bornstein, and which won the American Horticultural Society's annual Book Award.

Bart then shifted to the role of director of special projects, giving lectures on the benefits of native plant gardening and pursuing his research into the flora of Baja California. This latter area of interest has continued even after his subsequent move back north, as Bart continues to serve on the board of Terra Peninsular, a Mexican nonprofit dedicated to the preservation of the native flora of northern Baja.

One of Bart's greatest contributions to California horticulture has been his concentration on native cultivars, reflected in the new cultivar garden he created at RSABG and an accompanying guide. Bart also served CNPS as editor of *Fremontia* from 2006 through 2009, and he remains a member of the *Fremontia* Advisory Board. He has been active in the Education Committee's Horticultural Program and continues to serve on CNPS' Horticultural Experts Committee.

In 2013, Bart returned to Northern California when he was hired to take over the position of manager of the Regional Parks Botanic Garden from retiring longtime director Steve Edwards. There, at one of the most significant collections of California native plants in the world, he has continued as a leading advocate for the use of native plants in home gardens, while expanding the garden's dedicated community of volunteers and supporters. And he has worked to deepen the garden's partnership with California Plant Rescue, an ambitious effort to create a seed bank of all of California's native plants as a hedge against extinction.

–David Loeb

One of California's most influential botanists, Dieter Wilken managed the first edition of *The Jepson Manual.* *[Photograph courtesy of Santa Barbara Botanic Garden]*

CNPS FELLOW

Dieter Wilken

Dr. Dieter Wilken has been a pillar of California botany since he was a graduate student in the late 1960s, and has made tremendous contributions toward the appreciation and conservation of California Flora throughout his long career. His pioneering work in systematizing the identification and classification of rare native plants has set the gold standard in that field. As the lead manager of the first edition of *The Jepson Manual* (1993) and the lead editor of the second edition (2012), Dieter has provided resources of incalculable value to those working with native plants. He continues to serve the broad community of native plant adherents in his position as Director of Conservation at the Santa Barbara Botanic Garden (SBBG), an institution he has worked for since his return to California in 1993.

Like the plants that he knows so well, Dieter Wilken is himself a California native, born in East Los Angeles in 1944. Since graduating from UC Santa Barbara with his PhD in 1971, Dieter has worked tirelessly to support the understanding and conservation of native plants in western North America, including California. He is a broadly trained systematist and a world expert on several plant groups, including the charismatic California lilacs (*Ceanothus*, Rhamnaceae), showy *lpomopsis* (Polemoniaceae), and the genus *Hu/sea* (Asteraceae). Dieter was also a trailblazer in specimen digitization, and thanks to his guidance, the herbarium at SBBG is now nearly completely digitized.

Toward the end of his two decades teaching at Colorado State University, Dieter was hired to serve as Project Manager for the ambitious *Jepson Manual* project. At the time, the project was behind schedule, over budget, and at risk of total collapse. Dieter was able to right the ship, and the first edition of the *Manual* immediately became an invaluable resource for learning about and identifying California native plants. It would later form the basis for *The Jepson Desert Manual* (2002} and the second edition of *The Jepson Manual* (2012), on both of which Dieter served as a primary editor. Dieter also published two other important books: *Ceanothus* (2006}, and the complete flora of the plants of Santa Cruz Island (1995). He completed these important books while leading applied rare plant conservation on the Central Coast through SBBG and the California Native Plant Society.

Following publication of the *Manual*, Dieter returned to California to become Director of Research at SBBG. There, Dieter founded and ran all aspects of the Garden's rare plant program from 1993 to 2013. For the Central Coast and Channel Islands, there is no one more knowledgeable or passionate about regionally important rare plants; his work with many regional stakeholders has translated into direct conservation action on behalf of native plants and habitats in the region. In 2008, Dieter received the Center for Plant Conservation's Star Award for his work in protecting rare plants.

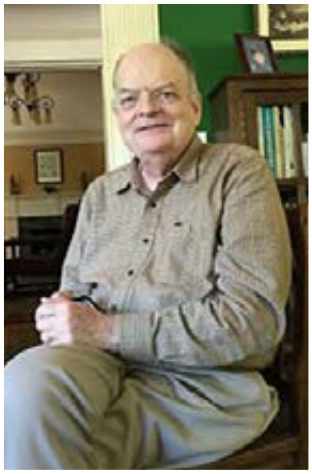
Dieter has also provided his expertise and knowledge as a contributor to the CNPS Rare Plant Forum, the primary vehicle for soliciting information from experts for decision making pertaining to the CNPS Rare Plant Inventory (e.g., listing and delisting of taxa). From 2008 until 2017, Dieter served as a founding member of the CNPS Rare Plant Program Committee. Through this committee, Dieter evaluated hundreds of plants for CNPS listing and worked with Jim Andre and other members to standardize and formally describe the process for listing a plant through CNPS. Andre describes Dieter as "our most experienced advisor on California's rare plants."

Finally, Dieter is a prolific contributor to CNPS's very active Facebook page, where he provides patient, thorough answers to posted queries from amateurs and professionals alike. In what other venue could one receive direct feedback from the Project Manager of the first edition of *The Jepson Manual* and one of the godfathers of specimen digitization?

–David Loeb

CNPS FELLOW

Joe Willingham



As a landscaper, Joe Willingham was an early advocate for native plant landscaping back in the 1970s. He's since served his chapter in myriad ways, from conservation and rare plant advocacy to website development. *[Photograph courtesy of CNPS East Bay Chapter]*

Most people know Joe Willingham as the indefatigable editor of the *Bay Leaf* newsletter and the computer-savvy manager of the East Bay Chapter's website. Joe's decades of service to CNPS began in 1977, after he took a landscaping course at UC Extension on California native plants taught by the legendary David Bigham. Already employed as a landscaper, Joe quickly started using California natives on his clients' properties, and has continued to use them throughout his career.

Joe joined the East Bay Chapter board of directors in 1989. He has since held more than a dozen chapter board positions, including rare plant chair, chair of local conservation issues, and several years as chapter president and vice president.

As the rare plant chair, Joe participated in scouting expeditions, wrote monthly articles and led field trips. As local conservation issues chair, he kept abreast of the issues and wrote articles to keep the membership informed. He also served many years as one of the "plant experts" available to shoppers at the yearly plant sales at Merritt College and the chapter's Native Here Nursery.

In 2003, Joe became the editor of the East Bay Chapter newsletter, the *Bay Leaf*, learning the printing business from Phoebe Watts and Brett Boltz. Joe and his wife, Doris, hosted monthly mailing parties too numerous to count, and were always generous with wine and snacks.

In 2005, he created the chapter's website and later a website for the chapter's Native Here Nursery. Joe continues to work as *Bay Leaf* editor, coordinating capable proofreading by David Margolies, Holly Forbes, and Doris Willingham.

Joe served on the chapter council from 2004–2005, following state legislation. In that capacity, he played a key role in hiring now-retired CNPS lobbyist Vern Goering, serving as Vern's liaison to the CNPS board of directors. "Joe has indeed made so many outstanding contributions to our chapter and CNPS and continues to do so," say his nominators. Those of us fortunate enough to know him will agree that Joe Willingham deserves the Society's highest honor.

–Adapted by CNPS staff from text by Delia Taylor

See a listing of all CNPS Fellows dating back to 1973 at cnps.org/fellows.

Photograph by Ger Ericson

Vern Yadon on the trail named after him in gratitude for his decades of service on behalf of Monterey County flora.
[Photograph by Lynn Bomberger]

CNPS FELLOW

Vern Yadon

The Monterey area, and particularly Pacific Grove, owes many of its nature traditions and resources to Vern Yadon, the "grand old man of the plant community," as his nominators for Fellow dubbed him. Yadon was the first director and curator of the Pacific Grove Museum of Natural History and was instrumental in starting the Pacific Grove Wildflower Show, now in its 59th year. He also was a founding member of the Monterey Bay Chapter of CNPS in 1966.

"I can't overestimate his value to our chapter," says Brian LeNeve, chapter president and, like Vern, a CNPS Fellow. "He's the go-to person for questions about local botany, and is well thought of in the statewide botany community."

Vern Yadon might be considered a well-adapted transplant. He grew up in the San Joaquin Valley, and went on to study biology at Oregon State University. Hired in 1957 at the Pacific Grove Museum, which has a history dating to the 1880s, he dove into establishing the museum's plant collection. He assisted Beatrice Howitt and John Thomas Howell in gathering information for the original edition of *Vascular Plants of Monterey County, California* (1964).

In 1961, Yadon and Howitt founded the Pacific Grove Wildflower Show with about 100 species that he and a few others had collected. The show grew into an important tradition under the CNPS banner, and now includes 600-700 species on display over a three-day weekend.

No corner of Monterey County has gone unexplored by Vern, who early in his career made it his business to learn all the plants in Howitt and Howell's book. This plant bible became a detective story for the intrepid plant lover, who took weekly car trips on his day off to obscure sites such as Fort Hunter Liggett, Salmon Creek, Burro Creek and Clear Creek, and Fort Ord. Fellow plant fans Corky Matthews, Ron Branson, and Carol LeNeve (also a CNPS Fellow) often joined him; Branson estimates they put 20,000 miles on his VW bus.

Vern is at his most cheerful out in the field, friends say. He's been known to smell a *Malacothamnus* 100 yards away. In the process of tracking down the known plants, he found new treasures: Several species are named for him, including Vern's rein-orchid (*Piperia yadonii*), Santa Lucia horkelia (*Horkelia yadonii*) and Menzies' wallflower (*Erysimum menziesii* ssp. *yadonii*). He always had his plant press with him, and his collections now grace the Pacific Grove Museum's herbarium, which he refined and expanded. He retired from the museum in 1992 but still serves as curator emeritus.

Vern has shared his knowledge of the area's botany with fellow Monterey Bay Chapter CNPS members, leading countless field trips. He trained and mentored several generations of local botanists, including Bruce Delgado of the Bureau of Land Management. "I learned so much so fast with Vern," says Delgado, who is based at Fort Ord National Monument. In addition to serving as the CNPS chapter president, over the years Vern has been a Pacific Grove City Council member and a leader in the Sierra Club. He also was on the Del Monte Forest Open Space Advisory Committee. And he's still always available to identify a mystery plant, no matter who's asking.

Now 85, Vern Yadon is seen around town on regular walks with Farley, his Dalmatian. He's also an artist, and his watercolors of local plants and animals have graced the walls of the Carmel Art Association for more than 40 years. His other areas of expertise include ornithology, carpentry, horticulture, and local Native American culture. Monterey County is richer for the myriad contributions of this renaissance man.

–Kathy Morrison

Native plant nursery expert Betty Young is a leader in phytophthora best management practices and Sonoma County Re-Oak efforts. *[Photograph courtesy of Betty Young]*

CNPS FELLOW

Betty Young

Betty Young's extensive knowledge of and experience in nursery management and native plant propagation have helped protect and beautify California landscapes throughout her career, most recently through two important CNPS initiatives: the Re-Oak California effort and the establishment of best management practices to prevent Phytophthora in CNPS chapter-sold plants.

After studying nursery management and plant science at UC Davis, Young went to work in 1985 at Filoli Garden, an historic estate in Woodside. The site is registered with the National Trust for Historic Preservation, and its extensive gardens change with the season. Young left Filoli in 1989 for a stint with the Peace Corps in Thailand, focusing on soil conservation. Returning to the U.S. in 1990, she moved to Sonoma County to work at Skylark, a wholesale nursery. Next she joined Circuit Riders, a revegetation nursery, where she gathered seeds of local natives and grew plants for use in Sonoma County revegetation projects.

In 1997, Young joined the staff of the Golden Gate National Recreation Area (GGNRA) as the director of native plant nurseries, managing six greenhouses and producing 175,000 plants annually for GGNRA revegetation efforts. While at the GGNRA, she was responsible for the recording and sharing of propagation information into a publicly available online database. She also presented on, and taught classes in, nursery management throughout California. Young worked at GGNRA until she retired in 2015, after which she moved back to Santa Rosa.

Young had joined the CNPS Milo Baker Chapter when she first lived in Sonoma County, serving as president from 1993-1997. The chapter at that time began managing Cunningham Marsh, a state Department of Fish and Game easement on private property. Young worked with the owners of the property that surrounded the marsh, winning a grant that paid for a local expert to draw up a plan for the active management of the rare plant on the property: the endangered Pitkin Marsh lily (*Lilium pardalinum* ssp. *pitkenense*). Continued maintenance of Cunningham Marsh remains an important chapter activity.

In her retirement, Young supported the CNPS Milo Baker Chapter as field trip chair, then chaired a group interested in organizing a garden tour. The chapter partnered with the Sonoma County Water Agency in its Eco-Friendly Garden Tour, held each spring.

A key initiative for Young, at both the state and local CNPS level, is putting in place best management practices (BMP) for plants grown for or sold at CNPS plant sales, to prevent the introduction and spread of *Phytophthora* root rot. This is a serious issue for nursery-grown plants, and Young has traveled around the state to assess nursery practices and help local chapters. Closer to home, she has been instrumental in getting the Milo Baker Chapter's nursery shade house built, in order for plants for its annual sale to be grown in a *Phytophthora*-free environment. In addition to working out all the details for the project, she was the main fundraiser, bringing in more than $25,000 from grants and donations. The shade house, at the Laguna Foundation site in Santa Rosa, was completed in time for the 2019 sale.

Recently, Young has been the leader in the Re-Oak Sonoma effort, a CNPS-led initiative following the huge wine country fires in the fall of 2017. She organized volunteers to gather tens of thousands of acorns from all over the region, and taught members how to evaluate, clean, store, and germinate the oak seedlings. Her work inspired a similar, statewide CNPS effort for all of California's oak woodlands. In Sonoma County the young oak trees are now being used to revegetate burned areas on public and private lands. It's safe to say that Californians, and Sonoma County residents in particular, owe much to Betty Young's continuing efforts for native plants.

–Kathy Morrison

IN MEMORIAM

CELIA KUTCHER

A GUIDING LIGHT IN ORANGE COUNTY

By Dan Songster

With great sadness we report the passing of Celia Kutcher, a vital and much loved member of the Orange County Chapter of CNPS since its founding. She was a mother, grandmother, and friend to many. She cherished her family and good company. Celia was a botanist, naturalist, and horticulturalist all rolled into one. She enjoyed the fragrance of coastal sage, the sound of its birds, the smell of winter rains, the shade of an oak woodland, and the discovery of a rare plant. She loved all of California's wildlands but Orange County was her home and we were lucky to have her. We will miss her in so many ways.

An environmental pioneer, Celia's passion for native plants and her growing awareness of conservation challenges emerged in the late 1960s and early 1970s. Even as she raised her two young sons, she resolved to return to school and pursue an education and career that would enable her to effectively work for the preservation of natural habitats. We can imagine her, having lived most of her life in Orange County, seeing the encroaching homes and roads fragmenting the lands she loved and resolving to do something about it.

It was only natural that Celia and CNPS would get together, but at the time there was no chapter here in Orange County. Celia was there in the late 1970s and early 1980s as the Chapter waxed and waned until 1982, when Celia and several other native plant lovers held a formal organizational meeting to assign roles and choose officers and in general ensure that meetings became more regular. Celia was in the heart of things then as she was throughout her life. And what a productive and fulfilling life.

She set a sterling example, serving enthusiastically and efficiently in nearly every chapter office and committee while attending almost every board and membership meeting for over 35 years. There were no "little" jobs for Celia, and her involvement extended from outreach events to chapter planning sessions and native habitat advocacy and so much more. Her practical advice on a broad range of chapter issues came with a seasoned historical perspective. Her steady commitment to the needs of the chapter, accompanied by a wry sense of humor, was inspirational to all of us who worked with her.

Celia enjoying California's botanical wonders as a child and from the trail. *[Photographs courtesy of the Kutcher family]*

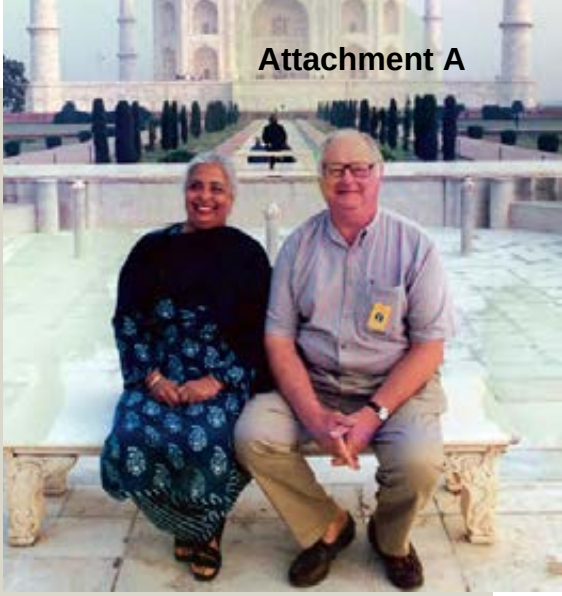
Above all else, Celia was the guiding light of our Conservation program, directing efforts to protect our county's wildlands. No matter the complexity of the situations or the applicable laws, Celia was always well prepared with a thorough understanding of the issues. Her comments, whether verbal or written, on behalf of CNPS were always succinct and clear, and in a tone that was always courteous and professional, never strident or accusatory. Celia is rightly known and applauded for her dedication over many decades to saving native habitat, rare plants, intact plant communities, and to upholding the laws that protect them. Her loss will be keenly felt for years to come in southern California conservation circles.

Her family requests that donations in Celia's honor be made to the California Native Plant Society, Orange County Chapter, with a note in the MEMO field indicating the gift is honor of Celia Kutcher. Please mail to: P.O. Box 54891, Irvine, CA 92619-4891.

IN MEMORIAM

WATSON MCMILLIAN "MAC" LAETSCH

By John Taylor



Mac and Sita Priyadarshini (Capildeo) Laetsch, his wife of 61 years. *[Photograph courtesy of the Laetsch family]*

Watson McMillan "Mac" Laetsch, a distinguished professor emeritus of plant biology and former vice chancellor of undergraduate affairs and development at the University of California at Berkeley, passed away at his home on January 5, 2020. He was 86.

Mac helped to found the California Native Plant Society and served as its first president. CNPS grew out of an ad hoc effort to save the Regional Parks Botanic Garden in Tilden Park in 1965. When the garden was saved, Mac asked, "Well, why don't we form a society to protect native plants?" Mary Wohlers, Helen-Mar Beard, and Leonora Strohmaier were also key players in starting CNPS, along with Jim Roof, then director of the Garden, and Jepson Herbarium staff members Remo Bacigalupi and Larry Heckard. The first meetings were in Mac's and Helen-Mar's homes, and the group persuaded Mac to become the first president.

Mac was born in Bellingham, Washington in 1933. His father was a Protestant minister and his mother an avid reader. Ministers and their families travel, so Mac spent his high school years in Indiana. He was an outstanding athlete and scholar in high school, earning multiple college offers, and ultimately chose to attend Wabash College, where he majored in botany, zoology, and history. At graduation, in 1956, he won a Fulbright scholarship to study in India, where he met his future wife, Sita Priyadarshini Capildeo. Sita was the daughter in a prominent Indian family in Trinidad and Tobago, and her parents had sent her to India to find a suitable Brahman husband. After a first kiss at the Taj Mahal, Mac and Sita eloped to Canada to get married.

Mac earned his PhD at Stanford in 1961, won a National Science Foundation Senior Fellowship to do postdoctoral studies at University College London, and taught briefly at SUNY Stony Brook before joining the botany department at UC Berkeley in 1963. Mac and Sita settled in Berkeley and raised a family there, while Mac became a lifelong member of the East Bay Chapter of CNPS.

As a scientist, Mac made seminal contributions to the understanding of C4 photosynthesis. His studies of leaf anatomy and chloroplast ultrastructure rounded out the biochemical studies of two Australian plant physiologists. In 1968 he wrote, "A hypothesis is presented stating that the unique morphological and biochemical characters of these plants represent adaptations for efficient and rapid carbon fixation in environments where water stress frequently limits photosynthesis." Mac's hypothesis was spot-on, and C4 grasses such as sorghum have since become the subjects of intense study owing to their ability to withstand drought.

Mac excelled as a leader, a rare quality at any university. He led the UC Botanical Garden and the Lawrence Hall of Science, and was vice chancellor for undergraduates and then vice chancellor for development. His colleague in botany, mycologist Ralph Emerson, wrote to a committee considering Mac's promotion that "Mac Laetsch walks with ease in the halls of wealth and power." Mac worked with Chancellor Ira Michael Heyman to lead the record-setting "Keeping the Promise" campaign, and later, as an emeritus professor, he worked with Heyman again to raise more than $30 million to rebuild the Bancroft Library.

Mac is survived by his elder brother, Bruce Laetsch of Indianapolis, sons Krishen and John Laetsch, daughter-in-law Jenny Hanson, and his grandson Charlie Hanson. Mac's wife, Sita, preceded him in death in 2019, after 61 years of marriage.

Donations in the professor's name may be made to the Friends of the Bancroft Library or the UC Berkeley Botanical Garden.

Thanks to the CNPS East Bay Chapter for permission to reprint this article, which appeared in March 2020 issue of The Bay Leaf *newsletter.*

The scientific publication quoted above is: Laetsch, W. M. (1968). Chloroplast specialization in dicotyledons possessing the C4-dicarboxylic acid pathway of photosynthetic CO2 fixation. *American Journal of Botany,* 55(8), 875-883.

IN MEMORIAM

STEVE MCLAUGHLIN

By Stephen Ingram

Steve McLaughlin on a field trip to McGee Creek for Friends of the Inyo, June 2013. *[Photograph by Maggie Wolfe Riley]*

Steve McLaughlin, former president of the Bristlecone Chapter of CNPS, died on December 29, 2019 at the age of 71 at his home in Santa Fe, New Mexico. Steve and his wife, author and botanist Janice Bowers, moved from Tucson to Birch Creek, southwest of Big Pine in the Eastern Sierra, in 2007 to enjoy their retirement.

Steve's knowledge of botany was broad and deep. He earned his PhD at the University of Arizona in 1978, where he taught courses in plant systematics, economic botany, and arid crops ecology. A professor of Arid Lands Resource Sciences and herbarium curator at UA, Steve studied the ecophysiology of arid lands crops, such as *Hesperaloe funifera* (giant hesperaloe) and *Grindelia camporum* (Great Valley gumweed). He also worked on the discovery and development of anti-cancer agents in plants, and on the analyses of floristic areas in the western U.S. He also named one new species, *Phacelia sonoitensis*, from southern Arizona.

In 2004 Steve received the Anson Ellis Thompson Career Service Award from the Association for the Advancement of Industrial Crops, and in 2006 was recognized by the Arizona Botanists Symposium with a Lifetime Achievement Award. Steve was sole author or co-author on more than a hundred scientific publications and presentations.

When Steve and Jan moved to the Eastern Sierra in 2007, it was inevitable that they would become involved with the Bristlecone Chapter of CNPS. Steve and Jan had joined our chapter back in 1999, but after moving here Steve wasted no time and became president within a year.

Steve was thoughtful, gentle, and generous. Michele Slaton, current vice president of the Bristlecone Chapter and an ecologist with the Inyo National Forest was asked by Steve to join the board in 2008. She says, "He made it clear this work was not about chores and busywork … but that there is important progress to be made to protect our land and native plants. He was a real mentor, and helped me with botanical writing, with forest planning, and urged me to pursue tasks and skills that felt like a good match... I will truly miss him."

Steve strengthened ties between CNPS and other conservation organizations throughout the Eastern Sierra. He served on the Owens Lake Master Project Committee, where he was in many ways, the conscience of the working groups, according to Pete Pumphrey, Steve's friend and colleague with Eastern Sierra Audubon. Steve also contributed to the GLORIA (Global Observation Research Initiative in Alpine Environments) plant surveys in the White Mountains. Jim Bishop from the Mount Lassen Chapter recalls how Steve freely shared his expertise in the surveys: "He was always very helpful and an all-around nice guy."

Steve was a popular field trip leader, organizing trips for the Bristlecone Chapter, Friends of the Inyo, and the Mono Basin Bird Chautauqua. He always refused the honorarium offered to trip leaders, and had "the patience of a saint" when teaching others about plants, according to his friend and neighbor Sydney Quinn. Steve will be missed by everyone in the Eastern Sierra who cares about conservation, as well as those who value learning about plants and birds from a consummate teacher.

An excerpt from Steve's first President's Message from the January/February 2008 Bristlecone newsletter:

> *During my academic career I was fortunate to be able to travel and work many places on this earth, but I have never been anywhere as breathtaking and fascinating as the Eastern Sierra. There are many ways to enjoy and learn more about this great area in which we are privileged to live, and one important way is to take advantage of opportunities provided by the Bristlecone Chapter. I urge you all to come to our Wednesday evening programs and participate in our field trips. Enjoy exceptional places, beautiful plants, and interesting people.*

IN MEMORIAM

LESTER BRADFORD ROWNTREE

By David Loeb

Lester Rowntree in Charleston Slough in the South Bay, in June 2004. *[Photograph by Allison Kidder]*

On August 30, 2019 the California Native Plant Society lost a good friend and California lost a dedicated teacher of environmental science. Dr. Lester B. Rowntree passed away at his home in the Berkeley hills after a protracted battle with cancer. Dr. Rowntree (or Les, as he preferred to be called) was a long-time professor for the pioneering Department of Environmental Studies at San Jose State University, which he joined in the early 1970s. He would eventually serve the department as program director and chair prior to his retirement in 2005.

Dr. Les was an integrative and open-minded scientist who sought to understand, and then educate others about, the elemental forces that shape the physical world. Nothing gave him greater pleasure than inspiring curious young students to become scientists dedicated to understanding the world and making it a better place.

In "retirement" Les dedicated himself to updating the widely-adopted environmental studies and geography course textbook, *Diversity Amid Globalization: World Regions, Environment, Development* (Pearson), of which he was the lead and coordinating author. Initially published in 2000, the textbook is now in its sixth edition.

If you were to visit Les' website, the first words you'd encounter would be "Actually there are two of us." Of course, he was referring to his more well-known grandmother, Lester Rowntree, née Gertrude Ellen Lester, the famous "California Native Plant Woman" who traveled around the state in a jerry-rigged station wagon to study the state's native flora. She was the author of *Hardy Californians* (1935) and *The Flowering Shrubs of California* (1936), and lifetime honorary president of the California Native Plant Society at its founding in 1965. Grandson Les enjoyed being able to say that he was the "other Lester Rowntree." But Les was a formidable contributor to our knowledge of California (and world) ecosystems in his own right.

Lester Bradford Rowntree was born and raised in Carmel. His interest in the natural world of California derived in part from the time he spent with his grandmother at her hillside home in Carmel Highlands. He always considered the rugged coastline of Big Sur to be his spiritual home, even after his immediate family moved to Berkeley in the late 1940s.

I got to know Les through my work for *Bay Nature* magazine, accompanying him on a field trip to the Big Sur coast in April 2009 as he was researching an article on the 2008 wildfires there. It was the height of wildflower season, but to my surprise (and mild annoyance) he wasn't able to help me identify the less common wildflowers we were seeing, and didn't seem particularly interested in doing so. Instead, Les was a big picture, macro level scientist, attuned to how vegetation patterns had shifted in response to the fires. He was able to contrast what we were seeing with his prodigious memory of the area, developing a clearer picture of how fire had shaped—and continues to shape—this region.

Another of Les's post retirement projects was the re publication of his grandmother's classic work, *Hardy Californians*, which includes additional chapters about his grandmother's life and impact. The publication of this new edition in 2006 (University of California Press) gave Les the opportunity to travel up and down the state with a slide show reintroducing Lester—in all her idiosyncratic, convention-defying glory—to a new generation of native plant lovers.

In his talk, Les related a story from a day late in Lester's life when she was in both physical and mental decline (she lived to be 100). He searched for her in the house to no avail, and finally found her lying under some bushes in the chaparral outside. "Leave me alone," she said, "Can't you see I'm trying to die."

Les the grandson was considerably less prickly than his famous grandmother. But he was similarly clear-eyed about his approaching death. He chose to die at home, surrounded by his family, right next to an open door that looked out onto a backyard garden filled with some of his favorite California native plants.

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Attachment A

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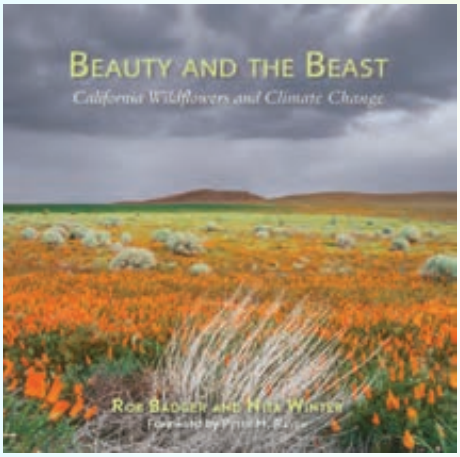

Beauty and the Beast: California Wildflowers and Climate Change
Rob Badger and Nita Winter
Hardcover $60
ISBN: 978-1-7331044-0-1

WILDFLOWERS LIKE YOU'VE NEVER SEEN BEFORE

In a book that is both art and activism, award-winning conservation photographers Rob Badger and Nita Winter take readers on a stunning tour of California's wildflowers. From the super blooms of the Tehachapi Mountains to the monkeyflowers of Yosemite, the 12 x 12" coffee table book features 190 portrait and landscape images alongside 16 thought-provoking short stories. Authors include Jose Gonzalez of Latino Outdoors, Robin Wall Kimmerer (*Braiding Sweet Grass*), Mary Ellen Hannibal (*Citizen Science*), and other leading voices in today's environmental movement. Experience for yourself why Nina Simons, author and founder of Bioneers calls this book "potent medicine for our souls."

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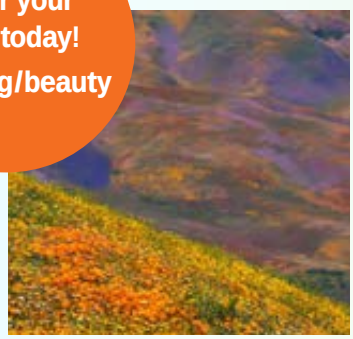


In 1992, Rob Badger and Nita Winter discovered and fell in love with California's spectacular Wildflower blooms in the Mojave Desert's Antelope Valley California Poppy Preserve. This inspired a 27-year journey photographing wildflowers throughout the West, and, in 2011, their documentary art project, *Beauty and the Beast: Wildflowers and Climate Change,* a project sponsored by Blue Earth Alliance. In 2016, they created their first joint exhibit on California's wildflowers. The beautiful book, published in conjunction with the California Native Plant Society, is a companion to the traveling exhibit.

California Native Plant Society

Winter Badger Press

APPEAL EXHIBIT H

Union of Concerned Scientists

REPORTS & MULTIMEDIA / FEATURE

Infographic: Wildfires and Climate Change

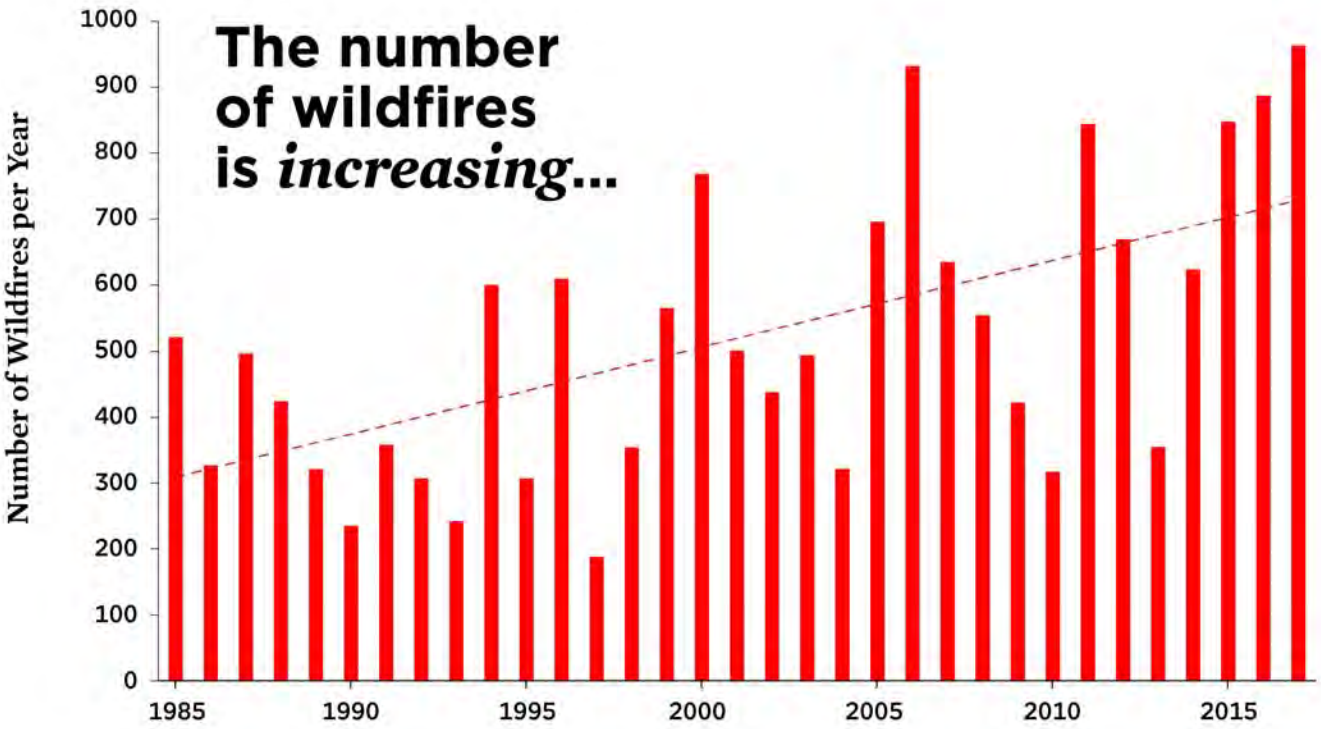
Visualizing the Connection in Five Sets of Photos and Charts

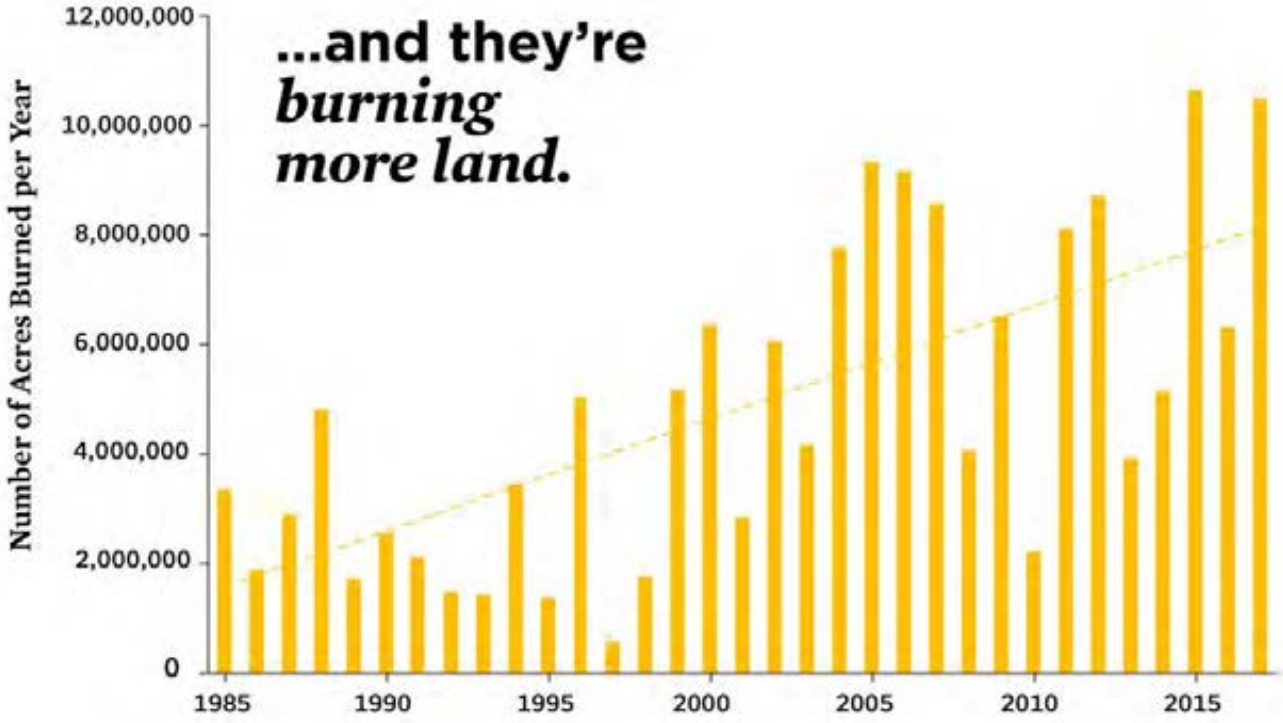
Published Sep 8, 2020 | Updated May 9, 2022

TABLE OF CONTENTS

Every year, millions of acres of land are consumed by fire in the United States. By raising temperatures, melting snow sooner, and drying soils and forests, climate change is fueling the problem. Here's what we know.

#1: Wildfires are getting worse

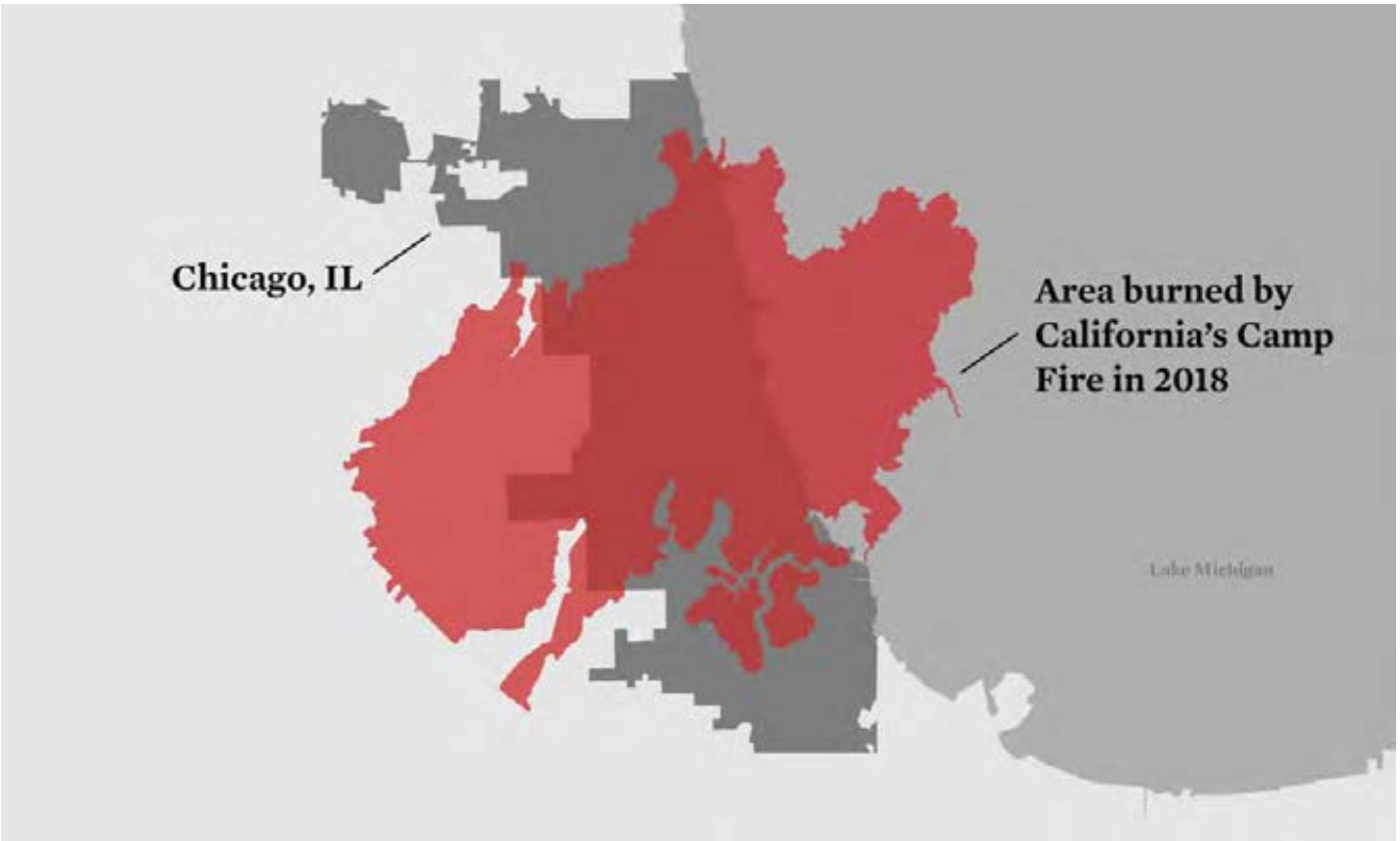

The number of wildfires is *increasing*...
Number of Wildfires per Year
1000
900
800
700
600
500
400
300
200
100
0
1985
1990
1995
2000
2005
2010
2015

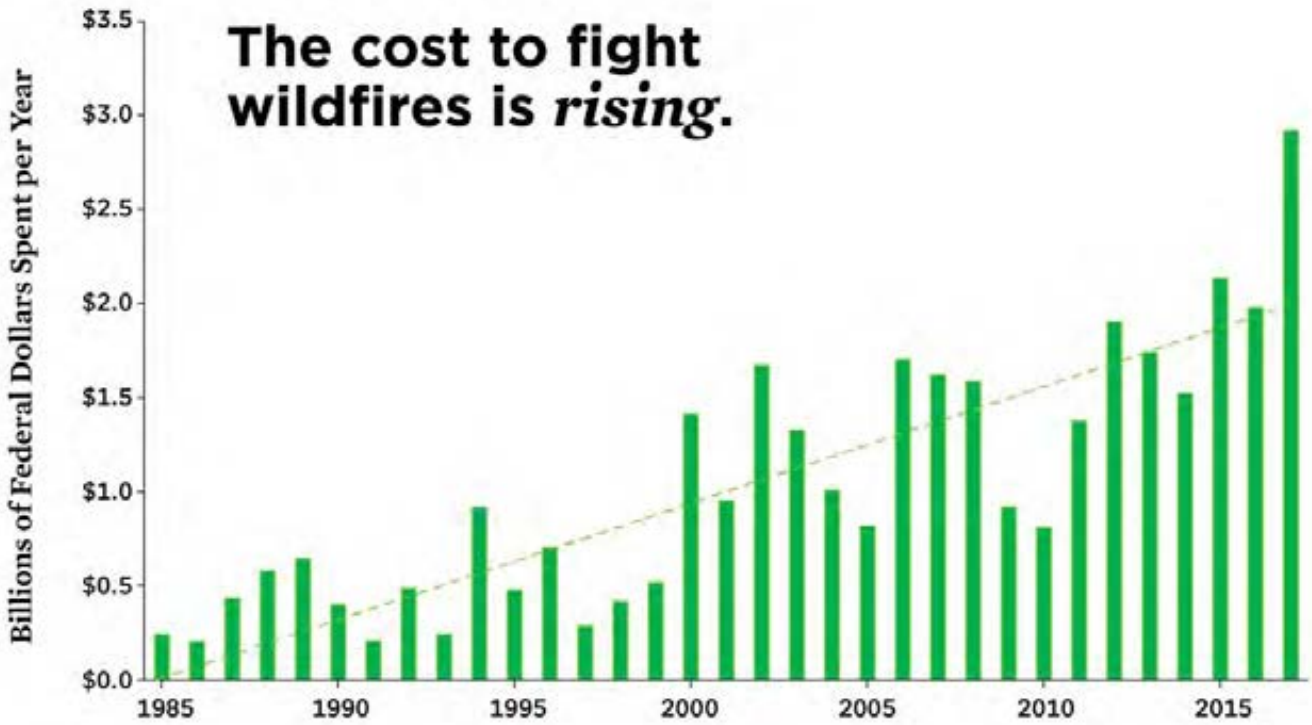

...and they're *burning more land.*
Number of Acres Burned per Year
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
1985
1990
1995
2000
2005
2010
2015

Data from the Monitoring Trends in Burn Severity program. MTBS only includes large fires in the United States (>500 acres for the eastern US, >1000 acres for the west). Prescribed fires removed.

Since 2015, the United States has experienced, on average, roughly 100 more large wildfires every year than the year before. This changes region by region, and year to year, but generally we're seeing more wildfires, more acres burned, and longer, more intense fire seasons.

#2 Wildfires are causing more harm





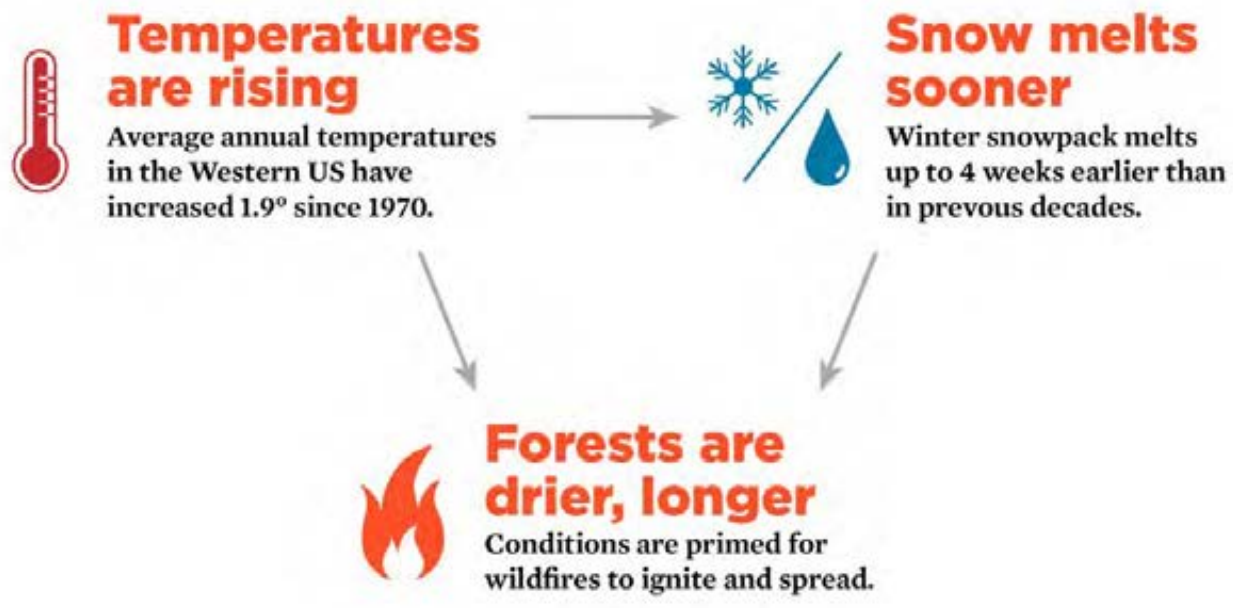
On left, the perimeter of the massive Camp Fire is overlayed on Chicago. Federal suppression costs from the National Interagency Fire Center.

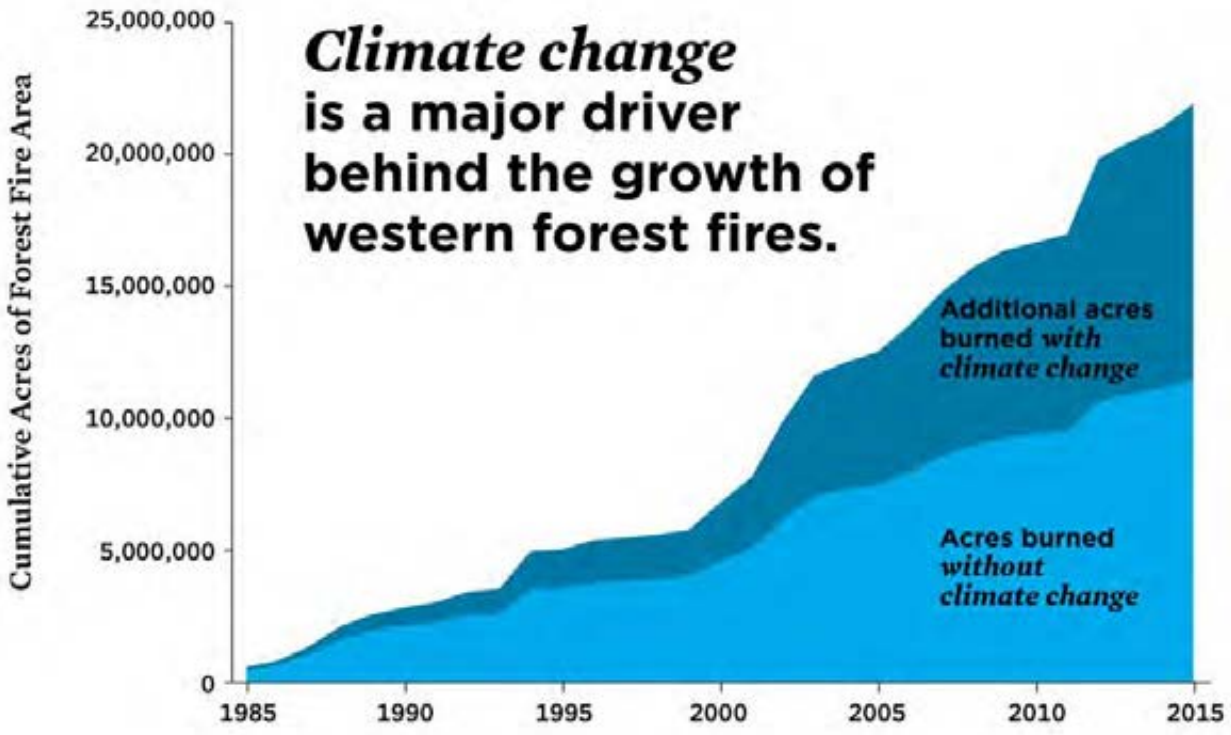
Wildfires are dangerous and destructive. The historically large Camp Fire of 2018 caused at least ninety deaths, destroyed more than 18,000 structures, and covered an area roughly the same size as the Chicago metropolitan area.

They're also expensive. Between 2014 and 2018, the federal government spent an average of *2.4 billion dollars* fighting wildfires every year. Even when adjusted for inflation, that's more than twice what we spent 20 years earlier (1994-1998).

And as the forests burn, they release carbon dioxide and other global warming gases, worsening climate change. As wildfires burn more land, emissions go up.

#3: Climate change is a key driver





Data shown are from John T. Abatzoglou and A. Park Williams, Impact of anthropogenic climate change on wildfire across western US forests, which models forest fire area as a function of fuel dryness both with and without climate change.

Fire has historically been a natural part of many wild landscapes. But global warming has changed some of the underlying variables that make wildfires more or less likely to occur every year.

Warmer temperatures increase the likelihood that fires will burn more intensely. They also cause snow to melt sooner, and lead to drier soils, forests, and plants, which act as kindling. Increased droughts, unusual rain patterns, and insect outbreaks that lead to large stands of dead trees are also connected with climate change—and they all make wildfires more likely.

#4 Management matters

Other factors also influence wildfire risk—especially management and development decisions in fire-prone areas near forests.

In the western United States, forests historically evolved with frequent, low-intensity fires that removed underbrush, debris, and fallen timber. This allowed for larger trees and made massive fires much less common.

But for the past century, almost all fires have been suppressed, even small ones. This has allowed forests to maintain denser growth and more potential fuel, leading to larger and more intense wildfires.

In addition, development near and into previously wild areas has increased fire risk and made fire-fighting more costly, challenging, and dangerous.

Government agencies have tried to lower forest density through prescribed burning (purposefully lit, low-intensity fires) and thinning (the physical removal of brush, vegetation and dead trees), but have struggled to do so at scale.

On smaller landscapes in the southeast, land managers conduct far more frequent prescribed burns. These fires bring their own risks, including poor air quality, and the chance of growing to be a damaging wildfire. But by mimicking smaller "natural" fires, prescribed burns can benefit forest ecology, and help mitigate at least some of the increased wildfire risk presented by climate change.

#5 Action is possible

In the near term, ecologically-sound forest and fire management could help limit fire risks.

Attachment A

But in the long-term, *climate action* is the best tool we have. When we reduce global warming emissions, we slow the growth of climate risks, including wildfire. Until then, summers will continue getting hotter, forests will get drier, and more and more people will face the threat of wildfire.

INFOGRAPHIC

Printable infographic

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EXPLAINER

Water, Wildfire, and Climate Change

Fires across the West, and particularly in California, are threatening the availability and quality of water for millions of people.

PODCAST

The Cascading Disasters of Wildfire Season

Climate scientist Dr. Kristy Dahl discusses how global warming is fueling wildfire season and its impacts on the most vulnerable.

Attachment A

GRAPHIC

The Impacts of Wildfires in California

Recent wildfires have wreaked havoc across California.

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Photo credits: Burning car and home, and burnt neighborhood by Josh Edelson/Getty. Smoke plume by David McNew/Getty. Firefighter carrying drip torch courtesy of the National Park Service. Protesters by Leonhard Foeger/Reuters.

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APPEAL EXHIBIT I

12. M. Gustafsson, L. Frommhold, Astron. Astrophys. 400, 1161 (2003).
13. H. C. Harris et al., Astrophys. J. 524, 1000 (1999).
14. S. T. Hodgkin et al., Nature 403, 57 (2000).
15. B. R. Oppenheimer et al., Astrophys. J. 550, 448 (2001).
16. L. R. Bedin et al., Astrophys. J. 624, L45 (2005).
17. B. M. S. Hansen, Phys. Rep. 399, 1 (2004).
18. I. N. Reid, J. E. Gizis, Astron. J. 116, 2929 (1998).
19. R. G. Gratton et al., Astron. Astrophys. 408, 529 (2003).
20. S. K. Leggett, F. Allard, P. H. Hauschildt, Astrophys. J. 509, 836 (1998).
21. S. Lepine, M. M. Shara, R. M. Rich, Astrophys. J. 602, L125 (2004).
22. I. R. King, J. Anderson, A. M. Cool, G. Piotto, Astrophys. J. 492, L37 (1998).
23. I. Baraffe, G. Chabrier, F. Allard, P. H. Hauschildt, Astron. Astrophys. 327, 1054 (1997).
24. The models in (23) have been updated (available at http://perso.ens-lyon.fr/isabelle.baraffe).
25. G. Chabrier, I. Baraffe, Annu. Rev. Astron. Astrophys. 38, 337 (2000).
26. Supported by NASA/HST grant GO-10424 (J.A., B.M.S.H., I.R.K., J.S.K., R.M.R., M.M.S.), a NASA Hubble Fellowship (J.S.K.), the U.S.-Canada Fulbright Fellowship Committee (H.B.R.), the Natural Sciences and Engineering Research Council of Canada (H.B.R.), and the University of British Columbia. H.B.R. thanks I. Ozier for fruitful discussions on CIA, as well as UCLA for support during his extended visit during which most of this paper was written. This research is based on NASA/ESA Hubble Space Telescope observations obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy Inc. under NASA contract NAS5-26555. These observations are associated with proposal GO-10424.

31 May 2006; accepted 18 July 2006
10.1126/science.1130691

Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

A. L. Westerling,[1,2]* H. G. Hidalgo,[1] D. R. Cayan,[1,3] T. W. Swetnam[4]

Western United States forest wildfire activity is widely thought to have increased in recent decades, yet neither the extent of recent changes nor the degree to which climate may be driving regional changes in wildfire has been systematically documented. Much of the public and scientific discussion of changes in western United States wildfire has focused instead on the effects of 19th- and 20th-century land-use history. We compiled a comprehensive database of large wildfires in western United States forests since 1970 and compared it with hydroclimatic and land-surface data. Here, we show that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. The greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.

Wildfires have consumed increasing areas of western U.S. forests in recent years, and fire-fighting expenditures by federal land-management agencies now regularly exceed US$1 billion/year (1). Hundreds of homes are burned annually by wildfires, and damages to natural resources are sometimes extreme and irreversible. Media reports of recent, very large wildfires (9100,000 ha) burning in western forests have garnered widespread public attention, and a recurrent perception of crisis has galvanized legislative and administrative action (1–3).

Extensive discussions within the fire-management and scientific communities and the media seek to explain these phenomena, focusing on either land-use history or climate as primary causes. If increased wildfire risks are driven primarily by land-use history, then ecological restoration and fuels management are potential solutions. However, if increased risks are largely due to changes in climate during recent decades, then restoration and fuels treatments may be relatively ineffective in reversing current wildfire trends (4, 5). We investigated 34 years of western U.S. (hereafter, Bwestern[) wildfire history together with hydroclimatic data to determine where the largest increases in wildfire have occurred and to evaluate how recent climatic trends may have been important causal factors.

Competing explanations: Climate versus management. Land-use explanations for increased western wildfire note that extensive livestock grazing and increasingly effective fire suppression began in the late 19th and early 20th centuries, reducing the frequency of large surface fires (6–8). Forest regrowth after extensive logging beginning in the late 19th century, combined with an absence of extensive fires, promoted forest structure changes and biomass accumulation, which now reduce the effectiveness of fire suppression and increase the size of wildfires and total area burned (3, 5, 9). The effects of land-use history on forest structure and biomass accumulation are, however, highly dependent upon the ''natural fire regime'' for any particular forest type. For example, the effects of fire exclusion are thought to be profound in forests that previously sustained frequent, low-intensity surface fires [such as Southwestern ponderosa pine and Sierra Nevada mixed conifer (2, 3, 10, 11)], but of little or no consequence in forests that previously sustained only very infrequent, high-severity crown fires (such as Northern Rockies lodgepole pine or spruce-fir (1, 5, 12)].

In contrast, climatic explanations posit that increasing variability in moisture conditions (wet/dry oscillations promoting biomass growth, then burning), and/or a trend of increasing drought frequency, and/or warming temperatures have led to increased wildfire activity (13, 14). Documentary records and proxy reconstructions (primarily from tree rings) of fire history and climate provide evidence that western forest wildfire risks are strongly positively associated with drought concurrent with the summer fire season and (particularly in ponderosa pine–dominant forests) positively associated to a lesser extent with moist conditions in antecedent years (13–18). Variability in western climate related to the Pacific Decadal Oscillation and intense El Niño/La Niña events in recent decades along with severe droughts in 2000 and 2002 may have promoted greater forest wildfire risks in areas such as the Southwest, where precipitation anomalies are significantly influenced by patterns in Pacific sea surface temperature (19–22). Although corresponding decadal-scale variations and trends in climate and wildfire have been identified in paleo studies, there is a paucity of evidence for such associations in the 20th century.

We describe land-use history versus climate as competing explanations, but they may be complementary in some ways. In some forest types, past land uses have probably increased the sensitivity of current forest wildfire regimes to climatic variability through effects on the quantity, arrangement, and continuity of fuels. Hence, an increased incidence of large, high-severity fires may be due to a combination of extreme droughts and overabundant fuels in some forests. Climate, however, may still be the primary driver of forest wildfire risks on interannual to decadal scales. On decadal scales, climatic means and variability shape the character of the vegetation [e.g., species populations and their drought tolerance (23) and biomass (fuel) continuity (24), thus also affecting fire regime responses to shorter term climate variability]. On interannual and shorter time scales, climate variability affects the flammability of live and dead forest vegetation (13–19, 25).

High-quality time series are essential for evaluating wildfire risks, but for various reasons (26), previous works have not rigorously documented changes in large-wildfire frequency for

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*To whom correspondence should be addressed. E-mail: awesterling@ucmerced.edu

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western forests. Likewise, detailed fire-climate analyses for the region have not been conducted to evaluate what hydroclimatic variations may be associated with recent increased wildfire activity, and the spatial variations in these patterns.

We compiled a comprehensive time series of 1166 large (9400 ha) forest wildfires for 1970 to 2003 from federal land-management units containing 61% of western forested areas (and 80% above 1370 m) (26) (fig. S1). We compared these data with corresponding hydroclimatic and land surface variables (26–34) to address where and why the frequency of large forest wildfire has changed.

Increased forest wildfire activity. We found that the incidence of large wildfires in western forests increased in the mid-1980s (Fig. 1) [hereafter, "wildfires" refers to large-fire events (9400 ha) within forested areas only (26)]. Subsequently, wildfire frequency was nearly four times the average of 1970 to 1986, and the total area burned by these fires was more than six and a half times its previous level. Interannual variability in wildfire frequency is strongly associated with regional spring and summer temperature (Spearman's correlation of 0.76, P G 0.001, n 0 34). A second-order polynomial fit to the regional temperature signal alone explains 66% of the variance in the annual incidence of these fires, with many more wildfires burning in hotter than in cooler years.

The length of the wildfire season also increased in the 1980s (Fig. 1). The average season length (the time between the reported first wildfire discovery date and the last wildfire control date) increased by 78 days (64%), comparing 1970 to 1986 with 1987 to 2003. Roughly half of that increase was due to earlier ignitions, and half to later control (48% versus 52%, respectively). Later control dates were no doubt partly due to later ignition dates, given that the date of the last reported wildfire ignition increased by 15 days, but a substantial increase in the length of time the average wildfire burned also played a role. The average time between discovery and control for a wildfire increased from 7.5 days from 1970 to 1986 to 37.1 days from 1987 to 2003. The annual length of the fire season and the average time each fire burned were also moderately correlated with the regional spring and summer temperature (Spearman's correlations of 0.61 (P G 0.001) and 0.55 (P G 0.001), respectively.

The greatest increase in wildfire frequency has been in the Northern Rockies, which account for 60% of the increase in large fires. Much of the remaining increase (18%) occurred in the Sierra Nevada, southern Cascades, and Coast Ranges of northern California and southern Oregon ("Northern California," in fig. S2). The Pacific Southwest; the Southern Rockies; the Northwest; coastal, central, and southern California; and the Black Hills each account for 11%, 5%, 5%, G1%, and G1%, respectively. Interestingly, the Northern Rockies and the Southwest show the same trend in wildfire frequency relative to their respective forested areas. However, the Southwest's absolute contribution to the western regional total is limited by its smaller forested area relative to higher latitudes.

Increased wildfire frequency since the mid-1980s has been concentrated between 1680 and 2590 m in elevation, with the greatest increase centered around 2130 m. Wildfire activity at these elevations has been episodic, coming in pulses during warm years, with relatively little activity in cool years, and is strongly associated with changes in spring snowmelt timing, which in turn is sensitive to changes in temperature.

Fire activity and the timing of the spring snowmelt. As a proxy for the timing of the spring snowmelt, we used Stewart and colleagues' dates of the center of mass of annual flow (CT) for snowmelt-dominated streamflow gauge records in western North America (32–34). The annual wildfire frequency for the region is highly correlated (inversely) with CT at gauges across the U.S. Pacific Northwest and interior West, indicating a coherent regional signal of wildfire sensitivity to snowmelt timing (Fig. 2).

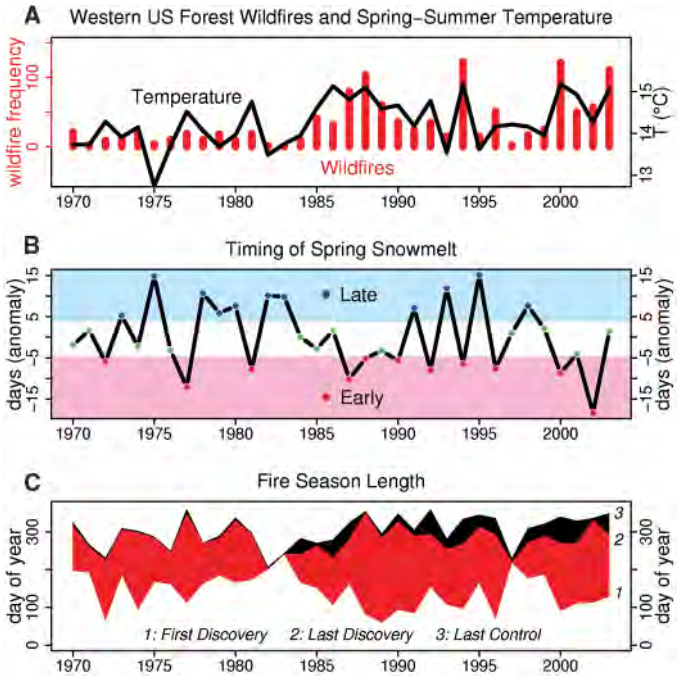

Fig. 1. (A) Annual frequency of large (9400 ha) western U.S. forest wildfires (bars) and mean March through August temperature for the western United States (line) (26, 30). Spearman's rank correlation between the two series is 0.76 (P G 0.001). Wilcoxon test for change in mean large–forest fire frequency after 1987 was significant (W 0 42; P G 0.001). (B) First principle component of center timing of streamflow in snowmelt dominated streams (line). Low (pink shading), middle (no shading), and high (light blue shading) tercile values indicate early, mid-, and late timing of spring snowmelt, respectively. (C) Annual time between first and last large-fire ignition, and last large-fire control.

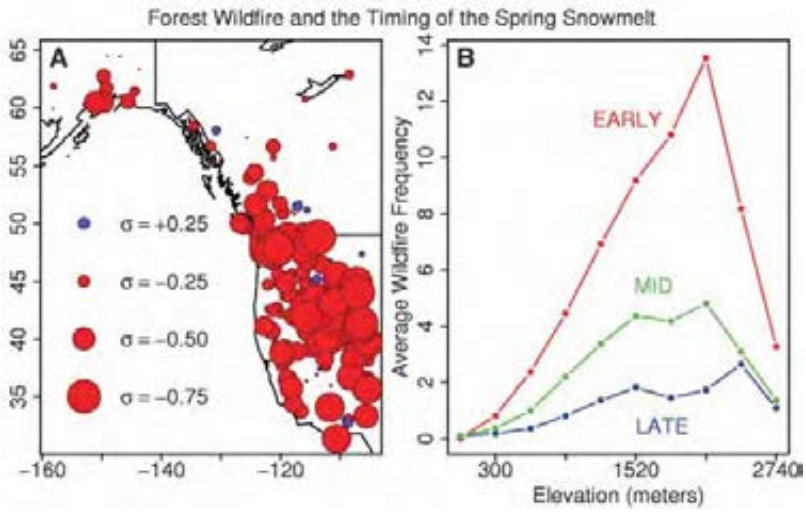

Fig. 2. (A) Pearson's rank correlation between annual western U.S. large (9400 ha) forest wildfire frequency and streamflow center timing. x axis, longitude; y axis, latitude. (B) Average frequency of western U.S. forest wildfire by elevation and early, mid-, and late snowmelt years from 1970 to 2002. See Fig. 1B for a definition of early, mid-, and late snowmelt years.

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The negative sign of these correlations indicates that earlier snowmelt dates correspond to increased wildfire frequency. Following Stewart et al., we used the first principal component (CT1) of CT at western U.S. streamflow gauges as a regional proxy for interannual variability in the arrival of the spring snowmelt (Fig. 1) (26, 32). This signal had its greatest impact on wildfire frequency between elevations of 1680 and 2590 m (Fig. 2), with a nonlinear response at these elevations to variability in snowmelt timing. Overall, 56% of wildfires and 72% of area burned in wildfires occurred in early (i.e., lower tercile CT1) snowmelt years, whereas only 11% of wildfires and 4% of area burned occurred in late (i.e., upper tercile CT1) snowmelt years.

Temperature affects summer drought, and thus flammability of live and dead fuels in forests through its effect on evapotranspiration and, at higher elevations, on snow. Additionally, warm spring and summer temperatures were strongly associated with reduced winter precipitation over much of the western United States (Fig. 3). The arrival of spring snowmelt in the mountains of the western United States, represented here by CT1, is strongly associated with spring temperature (26). Average spring and summer temperatures throughout the entire region are significantly higher in early than in late years (Fig. 3), peaking in April. The average difference between early and late April mean monthly temperatures in forested areas was just over 2-C, and it increased with elevation.

Snow carries over a substantial portion of the winter precipitation that falls in western mountains, releasing it more gradually in late spring and early summer, providing an important contribution to spring and summer soil moisture (35). An earlier snowmelt can lead to an earlier, longer dry season, providing greater opportunities for large fires due both to the longer period in which ignitions could potentially occur and to the greater drying of soils and vegetation. Consequently, it is not surprising that the incidence of wildfires is strongly associated with snowmelt timing.

Changes in spring and summer temperatures associated with an early spring snowmelt come in the context of a marked trend over the period of analysis. Regionally averaged spring and summer temperatures for 1987 to 2003 were 0.87-C higher than those for 1970 to 1986. Spring and summer temperatures for 1987 to 2003 were the warmest since the start of the record in 1895, with 6 years in the 90th percentile—the most for any 17-year period since the start of the record in 1895 through 2003—whereas only 1 year in the preceding 17 years ranked in the 90th percentile. Likewise, 73% of early years since 1970 occurred in 1987 to 2003 (Fig. 1).

Spatial variability in the wildfire response to an earlier spring. Vulnerability of western U.S. forests to more frequent wildfires due to warmer temperatures is a function of the spatial distribution of forest area and the sensitivity of the local water balance to changes in the timing of spring. We measured this sensitivity using the October-to-September moisture deficit—the cumulative difference between the potential evapotranspiration due to temperature and the actual evapotranspiration constrained by available moisture—which is an important indicator of drought stress in plants (24). We used the percentage difference in the moisture deficit for early versus late snowmelt years scaled by the fraction of forest cover in each grid cell to map forests' vulnerability to changes in the timing of spring (Fig. 4) (26). The Northern Rockies and Northern California display the greatest vulnerability by this measure—the same forests accounting for more than three-quarters of increased wildfire frequency since the mid-1980s. Although the trend in temperature over the Northern Rockies increases with elevation, vulnerability in the Northern Rockies is highest around 2130 m, where the greatest increase in fires has occurred. At lower elevations, the moisture deficit in early years is increasing from a high average value (i.e., summer drought tends to be longer and more intense at lower elevations), whereas at higher elevations the longer dry season in early years is still relatively short, and vegetation is somewhat buffered from the effects of higher temperatures by the available moisture.

Discussion. Robust statistical associations between wildfire and hydroclimate in western forests indicate that increased wildfire activity over recent decades reflects sub-regional responses to changes in climate. Historical wildfire observations exhibit an abrupt transition in the mid-1980s from a regime of infrequent large wildfires of short (average of 1 week) duration to one with much more frequent and longer burning (5 weeks) fires. This transition was

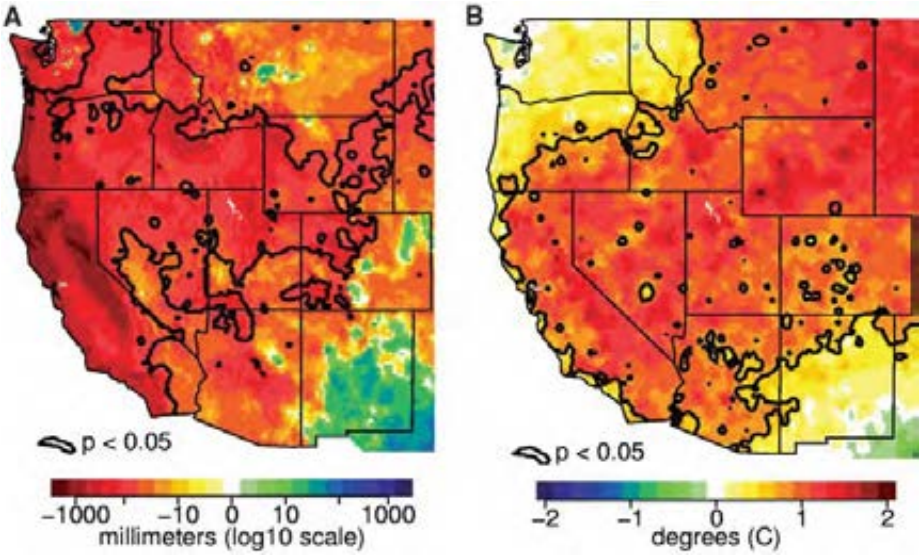

Fig. 3. Average difference between early and late snowmelt years in average precipitation from October through May (A) and average temperature from March through August (B). Contours enclose regions in which a t test for the difference in mean between 11 early and 11 late years was significant (P G 0.05). The null hypothesis that precipitation from October through May is normally distributed could not be rejected using the Shapiro-Wilk test for normality (P 9 0.05 for more than 95% of 24,170 grid cells, n 0 49 for precipitation; P 9 0.05 for more than 95% of 24,170 grid cells, n 0 50 for temperature). See Fig. 1B for a definition of early, mid-, and late snowmelt years.

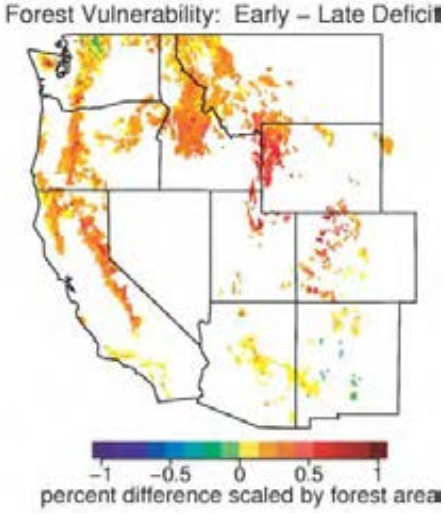

Fig. 4. Index of forest vulnerability to changes in the timing of spring: the percentage difference in cumulative moisture deficit from October to August at each grid point in early versus late snowmelt years, scaled by the forest-type vegetation fraction at each grid point, for 1970 to 1999 (26). See fig. S3 for a map of forest vulnerability for 1970 to 2003 over a smaller spatial domain. See Fig. 1B for a definition of early, mid-, and late snowmelt years.

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marked by a shift toward unusually warm springs, longer summer dry seasons, drier vegetation (which provoked more and longer burning large wildfires), and longer fire seasons. Reduced winter precipitation and an early spring snowmelt played a role in this shift. Increases in wildfire were particularly strong in mid-elevation forests.

The greatest absolute increase in large wildfires occurred in Northern Rockies forests. This sub-region harbors a relatively large area of mesic, middle and high elevation forest types (such as lodgepole pine and spruce-fir) where fire exclusion has had little impact on natural fire regimes (1, 5), but where we found that an advance in spring produces a relatively large percentage increase in cumulative moisture deficit by midsummer. In contrast, changes in Northern California forests may involve both climate and land-use effects. In these forests, large percentage changes in moisture deficits were strongly associated with advances in the timing of spring, and this area also includes substantial forested area where fire exclusion, timber harvesting, and succession after mining activities have led to increased forest densities and fire risks (10, 11). Northern California forests have had substantially increased wildfire activity, with most wildfires occurring in early years. Southwest forests, where fire exclusion has had the greatest effect on fire risks (2, 3), have also experienced increased numbers of large wildfires, but the relatively small forest area there limits the impact on the regional total, and the trend appears to be less affected by changes in the timing of spring. Most wildfires in the Southern Rockies and Southern California have also occurred in early snowmelt years, but again forest area there is small relative to the Northern Rockies and Northern California. Thus, although land-use history is an important factor for wildfire risks in specific forest types (such as some ponderosa pine and mixed conifer forests), the broad-scale increase in wildfire frequency across the western United States has been driven primarily by sensitivity of fire regimes to recent changes in climate over a relatively large area.

The overall importance of climate in wildfire activity underscores the urgency of ecological restoration and fuels management to reduce wildfire hazards to human communities and to mitigate ecological impacts of climate change in forests that have undergone substantial alterations due to past land uses. At the same time, however, large increases in wildfire driven by increased temperatures and earlier spring snowmelts in forests where land-use history had little impact on fire risks indicates that ecological restoration and fuels management alone will not be sufficient to reverse current wildfire trends.

These results have important regional and global implications. Whether the changes observed in western hydroclimate and wildfire are the result of greenhouse gas–induced global warming or only an unusual natural fluctuation is beyond the scope of this work. Regardless of past trends, virtually all climate-model projections indicate that warmer springs and summers will occur over the region in coming decades. These trends will reinforce the tendency toward early spring snowmelt (36, 37) and longer fire seasons. This will accentuate conditions favorable to the occurrence of large wildfires, amplifying the vulnerability the region has experienced since the mid-1980s. The Intergovernmental Panel on Climate Change's consensus range of 1.5- to 5.8-C projected global surface temperature warming by the end of the 21st century is considerably larger than the recent warming of less than 0.9-C observed in spring and summer during recent decades over the western region (37).

If the average length and intensity of summer drought increases in the Northern Rockies and mountains elsewhere in the western United States, an increased frequency of large wildfires will lead to changes in forest composition and reduced tree densities, thus affecting carbon pools. Current estimates indicate that western U.S. forests are responsible for 20 to 40% of total U.S. carbon sequestration (38, 39). If wildfire trends continue, at least initially, this biomass burning will result in carbon release, suggesting that the forests of the western United States may become a source of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature-increase scenario (38, 39). Moreover, a recent study has shown that warmer, longer growing seasons lead to reduced CO_2 uptake in high-elevation forests, particularly during droughts (40). Hence, the projected regional warming and consequent increase in wildfire activity in the western United States is likely to magnify the threats to human communities and ecosystems, and substantially increase the management challenges in restoring forests and reducing greenhouse gas emissions.

References and Notes

1. C. Whitlock, Nature 432, 28 (2004).
2. W. W. Covington, Nature 408, 135 (2000).
3. C. D. Allen et al., Ecol. Appl. 12, 1418 (2002).
4. J. L. Pierce, G. A. Meyer, A. J. T. Jull, Nature 432, 87 (2004).
5. T. Schoennagel, T. T. Veblen, W. H. Romme, BioScience 54, 661 (2004).
6. M. Savage, T. W. Swetnam, Ecology 71, 2374 (1990).
7. A. J. Belsky, D. M. Blumenthal, Conserv. Biol. 11, 315 (1997).
8. S. J. Pyne, P. L. Andrews, R. D. Laven, Introduction to Wildland Fire (Wiley, New York, 1996).
9. W. W. Covington, M. M. Moore, J. For. 92, 39 (1994).
10. K. S. McKelvey et al., in Sierra Nevada Ecosystems Project: Final Report to Congress (Univ. of California, Davis, CA, 1996), vol. 2, chap. 37.
11. G. E. Gruell, Fire in Sierra Nevada Forests: A Photographic Interpretation of Ecological Change Since 1849 (Mountain Press, Missoula, MT, 2001).
12. T. Schoennagel, T. T. Veblen, W. H. Romme, J. S. Sibold, E. R. Cook, Ecol. Appl. 15, 2000 (2005).
13. R. C. Balling, G. A. Meyer, S. G. Wells, Agric. For. Meteorol. 60, 285 (1992).
14. E. K. Heyerdahl, L. B. Brubaker, J. K. Agee, Holocene 12, 597 (2002).
15. K. F. Kipfmueller, T. W. Swetnam, in Wilderness Ecosystems, Threats, and Management, D. N. Cole, S. F. McCool, W. T. Borrie, J. O'Loughlin, Eds. (U.S. Forest Service, RMRS-P-15, Fort Collins, CO, 2000), vol. 5, pp. 270–275.
16. T. W. Swetnam, J. L. Betancourt, J. Clim. 11, 3128 (1998).
17. T. T. Veblen, T. Kitzberger, J. Donnegan, Ecol. Appl. 10, 1178 (2000).
18. A. L. Westerling, T. J. Brown, A. Gershunov, D. R. Cayan, M. D. Dettinger, Bull. Am. Meteorol. Soc. 84, 595 (2003).
19. T. W. Swetnam, J. L. Betancourt, Science 249, 1017 (1990).
20. A. Gershunov, T. P. Barnett, J. Clim. 11, 1575 (1998).
21. A. Gershunov, T. P. Barnett, D. R. Cayan, Eos 80, 25 (1999).
22. A. L. Westerling, T. W. Swetnam, Eos 84, 545 (2003).
23. N. L. Stephenson, Am. Nat. 135, 649 (1990).
24. N. L. Stephenson, J. Biogeogr. 25, 855 (1998).
25. T. W. Swetnam, Science 262, 885 (1993).
26. Materials and methods are available as supporting material on Science Online.
27. K. E. Mitchell et al., J. Geophys. Res. 109, D07S90 (2004).
28. E. P. Maurer, A. W. Wood, J. C. Adam, D. P. Lettenmaier, B. Nijssen, J. Clim. 15, 3237 (2002).
29. A. F. Hamlet, D. P. Lettenmaier, J. Hydrometeor. 6, 330 (2005).
30. NCDC, "Time bias corrected divisional temperature-precipitation-drought index," documentation for data set TD-9640 (DBMB, NCDC, NOAA, Asheville, NC, 1994); available online (www.ncdc.noaa.gov/oa/climate/onlineprod/drought/readme.html).
31. X. Liang, D. P. Lettenmaier, E. F. Wood, S. J. Burges, J. Geophys. Res. 99, 14415 (1994).
32. I. T. Stewart, D. R. Cayan, M. D. Dettinger, J. Clim. 18, 1136 (2005).
33. D. R. Cayan, S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, D. H. Peterson, Bull. Am. Meteorol. Soc. 82, 399 (2001).
34. J. R. Slack, J. M. Landwehr, U.S. Geol. Surv. Open-File Rep. 92–129 (1992).
35. J. Sheffield, G. Goteti, F. H. Wen, E. F. Wood, J. Geophys. Res. 109, D24108 (2004).
36. National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change (U.S. Global Change Research Program, Washington, DC, 2000).
37. J. T. Houghton et al., Eds., IPCC Climate Change 2001: The Scientific Basis (Cambridge Univ. Press, Cambridge and New York, 2001).
38. S. W. Pacala et al., Science 292, 2316 (2001).
39. D. Schimel, B. H. Braswell, in Global Change and Mountain Regions: An Overview of Current Knowledge, U. M. Huber, H. K. M. Bugmann, M. A. Reasoner, Eds., vol. 23 of Advances in Global Change Research (Springer, Dordrecht, Netherlands, 2005), pp. 449–456.
40. W. Sacks, D. Schimel, R. Monson, Oecologia, in press.
41. We thank M. Dettinger and D. Schimel for help. This work was supported by grants from the National Oceanographic and Atmospheric Administration's Office of Global Programs, the National Fire Plan by means of the U.S. Forest Service's Southern Research Station, and the California Energy Commission.

Supporting Online Material
www.sciencemag.org/cgi/content/full/1128834/DC1
Materials and Methods
Figs. S1 to S3
References

17 April 2006; accepted 28 June 2006
Published online 6 July 2006;
10.1126/science.1128834
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Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

A. L. Westerling, H. G. Hidalgo, D. R. Cayan and T. W. Swetnam

Science **313** (5789), 940-943.
DOI: 10.1126/science.1128834originally published online July 6, 2006

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APPEAL EXHIBIT J

SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA: AN OVERVIEW

WHITE PAPER

A Report From:
California Climate Change Center

Prepared By:
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Guido Franco, California Energy Commission
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DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission (Energy Commission) and the California Environmental Protection Agency (Cal/EPA). It does not necessarily represent the views of the Energy Commission, Cal/EPA, their employees, or the State of California. The Energy Commission, Cal/EPA, the State of California, their employees, contractors, and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission or Cal/EPA, nor has the California Energy Commission or Cal/EPA passed upon the accuracy or adequacy of the information in this report.

Arnold Schwarzenegger, *Governor*

February 2006
CEC-500-2005-186-SF

Acknowledgements

The authors would like to acknowledge the contributions from each one of the researchers that prepared the papers from which this overview is based. Without their valiant efforts this paper would not have been possible. We also thank Mary Tyree, of Scripps Institution of Oceanography for very rapidly and pleasantly archiving, processing, and dispensing data; and Edward Vine, with the University of California Office of the President, for managing the peer review process. Funding for the research and preparation of this report was provided by the California Environmental Protection Agency (Cal/EPA), the California Energy Commission (Energy Commission), California Air Resources Board, California Integrated Waste Management Board, and State Water Resources Control Board. In addition, Amy Luers wishes to express her appreciation for a grant received from the Robert & Patricia Switzer Foundation, which made her contribution possible.

We acknowledge the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for collecting and archiving the model data, the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) and their Coupled Model Intercomparison Project (CMIP) and Climate Simulation Panel for organizing the model data analysis activity, and the IPCC WG1 TSU for technical support. The IPCC Data Archive at Lawrence Livermore National Laboratory is supported by the Office of Science, U.S. Department of Energy. In particular, we thank the NOAA Geophysical Fluids Dynamics Laboratory global modeling group, the NCAR/DOE Parallel Climate Modeling group, and the U.K. Met Office Climate Impacts LINK Project for very responsive model output and consultation

We are grateful to Chris Field, of the Carnegie Institution of Washington; Peter Frumhoff, of Union of Concerned Scientists; and Stephen Schneider from Stanford University for their review of a draft version of this paper. We thank the reviewers for their extremely valuable comments; however, we remain responsible for the content of this paper and for any errors or omissions that may have escaped our attention.

Finally, we would like to express our appreciation to California Environmental Protection Agency (Cal/EPA) and the California Energy Commission (Energy Commission) for their leadership on climate change issues; and to Eileen Tutt, Assistant Secretary for Climate Change Activities, in particular, for entrusting the research group with this study. In the California Energy Commission, we wish to express our thanks to Kelly Birkinshaw and Martha Krebs for supporting our activities and allowing one of the authors, Guido Franco, to focus most of his energy on the work that has culminated with this paper.

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial / Agricultural / Water End-Use Energy Efficiency
- Renewable Energy Technologies

The California Climate Change Center (CCCC) is sponsored by the PIER program and coordinated by its Energy-Related Environmental Research area. The Center is managed by the California Energy Commission, Scripps Institution of Oceanography at the University of California at San Diego, and the University of California at Berkeley. The Scripps Institution of Oceanography conducts and administers research on climate change detection, analysis, and modeling; and the University of California at Berkeley conducts and administers research on economic analyses and policy issues. The Center also supports the Global Climate Change Grant Program, which offers competitive solicitations for climate research.

The California Climate Change Center Report Series details ongoing Center-sponsored research. As interim project results, these reports receive minimal editing, and the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the Center seeks to inform the public and expand dissemination of climate change information; thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov / pier / or contact the Energy Commission at (916) 654-5164.

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1.0 Summary of Key Findings and Recommendations

- Climate change impacts will affect all of the sectors considered in this report: sea-level rise, agriculture, snowpack and water supply, forestry, wildfire risk, public health, and electricity demand and supply.
- The more that greenhouse gases (GHGs) accumulate in the Earth's atmosphere over the next century, the greater the warming and the more severe and costly the impacts will be. This study considered three future GHG emissions scenarios—low, medium high, and high emissions—and explored associated climate changes through three modern climate models of differing sensitivity to GHG concentrations.
- Although climate model results are inconclusive as to whether California's precipitation will change over the next century, all climate models show increases in temperature, with the aggregate of several model runs containing a range of warming from 2000 to 2100 from about +2ºC to about +6ºC (+3.6ºF to about +10.8 ºF). Increases in temperature alone would impact the California hydrological cycle, with consequences upon the state's water supply, hydroelectric power supply, agriculture, recreation, and ecosystems.
- Climate change could produce compounding impacts—for instance, in the San Francisco Bay Delta, heightened sea levels and high river inflows from warmer storms would place levee systems in greater jeopardy of flooding.
- Some of the most dramatic climate change impacts will be experienced as increased frequency and severity of extreme events, such as heat waves, wildfires, flooding, and conditions conducive to air pollution formation.
- Even under lower GHG emissions scenarios, some impacts of climate change are inevitable. As a result, although adaptation is not the solution to climate change, it is a necessary complementary strategy to manage some of the projected impacts.
- Although there are many opportunities for California to increase its capacity to cope with many climate change impacts, these can be costly, and they require time and planning.
- More analysis—and in some cases, more information—is needed to better understand the vulnerability of California's health, economy, and environment to climate change. In particular, greater attention must focus on social dimensions of climate change for both assessing and implementing the state's mitigative and adaptive potential. Critical to this work will be evaluating and addressing the distributional and equity implications of climate changes in California.

2.0 Motivation and Overview of The Scenarios Project

Governor Arnold Schwarzenegger's Executive Order S-3-05 of June 1, 2005, called for specific emission reductions and a periodic update on the state of climate change science and the emerging understanding of potential impacts on climate-sensitive sectors such as the state's water supply, public health, agriculture, coastal areas, and forestry. In response to this Executive Order, the California Energy Commission (Energy Commission) and the California Environmental Protection Agency (Cal/EPA) commissioned an assessment of the potential impacts of climate change on key state resources ("the Scenarios Project").

The Scenarios Project was conducted under the direction of the California Climate Change Center ("the Center"), which has engaged in a long-term, California-specific climate research program. The assessment builds on earlier work that came out of the Center and other previous studies. In particular, it extends the work of a recent study that compared the projected impact of climate change in California under differing emissions scenarios (Hayhoe et al. 2004). This assessment draws upon experts within and outside of the Center to produce a collection of separate research reports on the projected impacts of climate change under multiple scenarios across six different sectors: coasts, water resources, agriculture, public health, forestry, and electricity production and demand.

This report summarizes the findings from the individual research reports and compares them with the earlier findings from the Hayhoe et al. (2004) study. This summary report compares the impacts on key sectors under multiple future scenarios of temperature changes and links these impacts to GHG emission trajectories, assuming different climate sensitivities.

3.0 Core Research Papers

This document summarizes and integrates the results of several studies listed in the following table. The California Institute for Energy and Environment (CIEE, associated with the Office of the President, University of California) is conducting an external review on all the papers listed in this table. Dr. Edward Vine is managing the peer review process. These papers are available at www.climatechange.ca.gov/.

Research Papers	
Dan Cayan et al.	Climate Scenarios for California
Dan Cayan et al.	Projecting Future Sea Level
Dennis Baldocchi et al.	An Assessment of Impacts of Future CO_2 and Climate on Agriculture
Brian Joyce et al.	Climate Change Impacts on Water for Agriculture in California: A Case Study in the Sacramento Valley
Josue Medellin et al.	Climate Warming and Water Supply Management in California
Department of Water Resources	Progress on Incorporating Climate Change into Management of California's Water Resources*
Andrew Paul Gutierrez	Analysis of Climate Effects on Agricultural Systems
Timothy Cavagnaro et al.	Climate Change: Challenges and Solutions for California Agricultural Landscapes
James Lenihan et al.	The Response of Vegetation Distribution, Ecosystem Productivity, and Fire in California to Future Climate Scenarios Simulated by the MC1 Dynamic Vegetation Model
Anthony Westerling and Benjamin Bryant	Climate Change and Wildfire in and Around California: Fire Modeling and Loss Modeling
Jeremy Fried et al.	Predicting the Effect of Climate Change on Wildfire Severity and Outcomes in California: A Preliminary Analysis
Max Moritz and Scott Stephens	Fire and Sustainability: Considerations for California's Altered Future Climate
John Battles et al.	Climate Change Impact on Forest Resources
Deborah Drechsler et al.	Public Health-Related Impacts of Climate Change for California
Amy Lynd Luers and Suzanne Moser	Preparing for the Impacts of Climate Change in California: Opportunities and Constraints for Adaptation
Technical Notes	
Sebastian Vicuña et al.	Climate Change Impacts on High Elevation Hydropower Generation in California's Sierra Nevada: A Case Study in the Upper American River
Guido Franco and Alan Sanstad	Climate Change and Electricity Demand in California
Sebastian Vicuña	Predictions of Climate Change Impacts on California Water Resources Using CalSim-II: A Technical Note

* The Department of Water Resources (DWR) coordinated the peer-review process for this paper. It will be available from DWR.

4.0 Introduction

It is now apparent that the increasing atmospheric concentration of GHGs, resulting from human activities, is changing the climate in ways that pose serious risks to California's health, economy, and environment. However, the most severe impacts that are expected with greater temperature rises could be avoided if the rate of GHG emissions is reduced. To help identify the potentially avoidable climate impacts in California, this paper summarizes some of the impacts expected under lower, medium, and higher ranges of projected warmings, as determined by different GHG emissions scenarios and different global climate models.

Linking temperature changes with particular levels of GHG emissions is a useful way to gauge the level of emissions reductions needed to avoid serious climate change impacts. However, current understanding of the climate system permits only limited precision in linking specific temperature changes to specific emission scenarios. Among a collection of more than a dozen national and international global climate models, *all* project increased temperatures as a result of higher emissions of GHG. However, the models differ in their sensitivity to changes in atmospheric GHG concentrations. For example, temperature rises between 1.5°C to 4.5°C (2.7°F to 8.1°F) have been projected for a doubling of CO_2 concentration above pre-industrial levels (IPCC 2001). The range in temperature response is the result of differences in the way that the models represent certain processes of the climate system, such as the way that they simulate clouds and radiation (Stephens 2005).

Society can neither control, nor at present precisely determine, the sensitivity of the earth's climate system to rising GHG concentrations. As a result, society must consider the implications of a range of climate sensitivities when evaluating the risks of climate change and devising policies to manage the one factor we can control: our own GHG emissions.

This paper summarizes the findings of the California Climate Change Center Scenarios Project ("the Project") and compares these new projections with those reported in an earlier study produced by many of the same researchers (Hayhoe et al. 2004). The projections in this summary are based upon three GHG scenarios—a lower emissions, medium-high emissions, and higher emissions scenario. The effect of different estimates of the sensitivity of the climate system to GHG forcing is explored by comparing the temperature projections from three different global climate models—each containing somewhat different representations of some crucial physical processes that result in different levels of climate sensitivity.

The following sections describe the emission scenarios and climate projections, and report on the projected impacts of the specific climate projections across six sectors: coasts, water resources, agriculture, forests/fire, public health, and electricity. The paper concludes with a discussion of the implications of these projections for mitigation and adaptation, and points out some outstanding problems that require further information or research.

5.0 Climate Change Scenarios

5.1. Emission Scenarios

The Intergovernmental Panel on Climate Change's (IPCC's) *Special Report on Emissions Scenarios* (SRES) developed a set of possible future emissions scenarios based on different assumptions about global development paths (Nakicenovic et al. 2000). This report contrasts the results from recent analyses for California of three SRES emissions scenarios—a lower emissions scenario (B1), a medium-high emissions scenario (A2), and a higher emissions scenario (A1fi) (Figure 1):

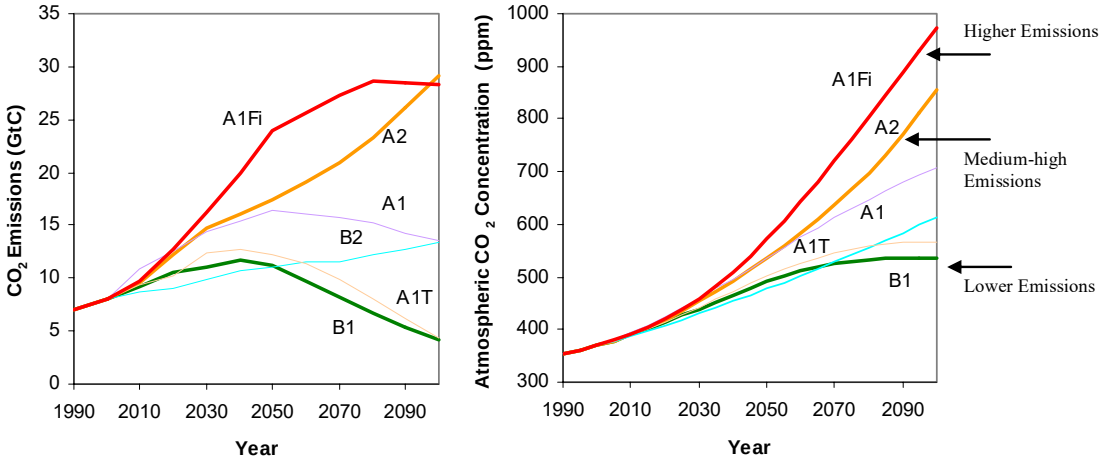


Figure 1. IPCC SRES Emission Scenarios

Six IPCC SRES Emissions Scenarios are presented here. The bold lines represent the three scenarios used in the analysis presented here (B1, A2, A1fi), the other lines represent IPCC scenarios not used in this study, yet presented here to illustrate how the trajectories selected for this study fit within the family of curves developed by the IPCC (Nakicenovic et al. 2000). The trajectories in this figure do not exactly match those in official IPCC documents (Nakicenovic et al. 2000) because the results we report here are based on revised emissions projections subsequently made available by IPCC; these are available at http://sres.ciesin.columbia.edu/. In addition, the authors used a new version of MAGICC available from www.cgd.ucar.edu/cas/wigley/magicc/index.html. However, the differences between this figure and similar figures provided by the IPCC are minor, and do not affect the discussion in this paper.

- The lower emissions scenario (B1) characterizes a world with population growth similar to the highest emissions scenarios, but with rapid changes toward a service and information economy and with the introduction of clean and resource-efficient technologies. The B1 scenario has CO_2 emissions peaking just below 10 gigatonnes per year (Gt/yr) in mid-century before dropping below the current-day level of 7 Gt/yr by 2100. Under the B1 scenario, the CO_2 concentration would double, relative to its pre-industrial level, by the end of this century.
- The medium-high emissions scenario (A2) projects continuous population growth, with slower economic growth and technological change than in the other scenarios. For the medium-high emissions scenario (A2), CO_2 emissions continue to climb throughout the century, reaching almost 30 Gt/yr, about four times the present rate of emissions. By the end of the century CO_2 concentration would reach more than triple its pre-industrial level.
- The higher emissions scenario (A1fi) represents a world of rapid fossil-fuel-intensive economic growth, global population that peaks mid-century then declines, and the introduction of new and more efficient technologies towards the end of the century. The higher emissions scenario (A1fi) rises faster than the A2 scenario, reaching about 25 Gt/yr, more than three times the present rate of emissions, by 2050. The A1fi scenario concludes the century with approximately the same annual emissions as the A2 scenario. However, the A2 and A1fi scenarios differ in two ways that have important implications for the projected changes. First, the emissions pathways of A1fi and A2 diverge by mid-century, with A1fi rising rapidly and then flattening out toward the end of the century. Second, the total cumulative emissions in the A1fi scenario are almost 20% higher at the end of century than in the A2 scenario.

To capture a range of uncertainty among climate models, this chapter reports on projections from three state-of-the-art global climate models (GCMs) that capture a range of climate sensitivities:

- The Parallel Climate Model (PCM1) from the National Center for Atmospheric Research (NCAR) and the U.S. Department of Energy (DOE) groups (Washington et al. 2000), a low-sensitivity model, with a climate sensitivity of approximately 1.8°C (3.2°F)[1]
- The Geophysical Fluids Dynamic Laboratory (GFDL) CM2.1 (NOAA Geophysical Dynamics Laboratory, Princeton New Jersey) model (Delworth et al. 2005), a medium-sensitivity model with climate sensitivity of approximately 3°C (5.4°F)
- The U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3) (Pope et al. 2000), with a slightly higher climate sensitivity of 3.3°C (5.9°F)

Each of the three GCMs produced a reasonably good simulation of key features of California's observed climate and representations of tropical Pacific ENSO variability.

[1] *Climate sensitivity* is defined as the change in temperature resulting from a doubling of CO_2 concentration above pre-industrial levels.

The models were also chosen for having available simulation datasets at monthly and daily time scales in order to carry out the impact studies undertaken in the scenarios analysis.

Global climate models calculate weather, ocean, and land surface variables over a discrete global grid too coarse to adequately depict the complex structure of temperature and precipitation that characterizes the California setting. The results presented here rely principally on a statistical technique using properties of observed data (Wood et al. 2002), that was employed to correct model biases and "downscale" the model data to a finer level of detail—a grid of approximately 12 kilometers (km) (7 miles). This downscaling technique, which was employed in previous climate change assessments, was used to satisfy study requirements for impact studies, including modeling the water and energy balance. To derive land surface hydrological variables consistent with the downscaled forcing data, a macroscale, distributed, physically based hydrologic model—the variable infiltration capacity (VIC) model (Liang et al. 1994; Liang et al. 1996)—was used.

5.2. Climate Projections

5.2.1. Temperature

Temperatures in California are projected to rise significantly over the twenty-first century. As shown in Table 1 and Figure 2, magnitudes of the warming vary because of the uncertainties in the climate sensitivity, as expressed by differences between models and in the emission scenarios. The rises (2000 to 2100) vary from approximately 1.7°C–3.0°C (3.0°F–5.4°F) in the lower range of projected warming, 3.1°C–4.3°C (5.5°F–7.8°F) in the medium range, and 4.4°C–5.8°C (8.0°F–10.4°F) in the higher range (Cayan et al. 2006a). To comprehend the magnitude of these projected temperature changes, over the next century the lower range of projected temperature rise is slightly larger than the difference in annual mean temperature between Monterey and Salinas, and the upper range of project warming is greater than the temperature difference between San Francisco and San Jose, respectively.[2]

[2] The difference in annual mean temperatures between Monterey (65.3ºF or 18.5ºC) and Salinas (67.8ºF or 19.9ºC) is 2.5ºF (1.4ºC) and the difference between San Francisco Mission Dolores (63.6ºF or 17.6ºC) and San Jose (71.0ºF or 22ºC) is 7.4ºF (4.4ºC).

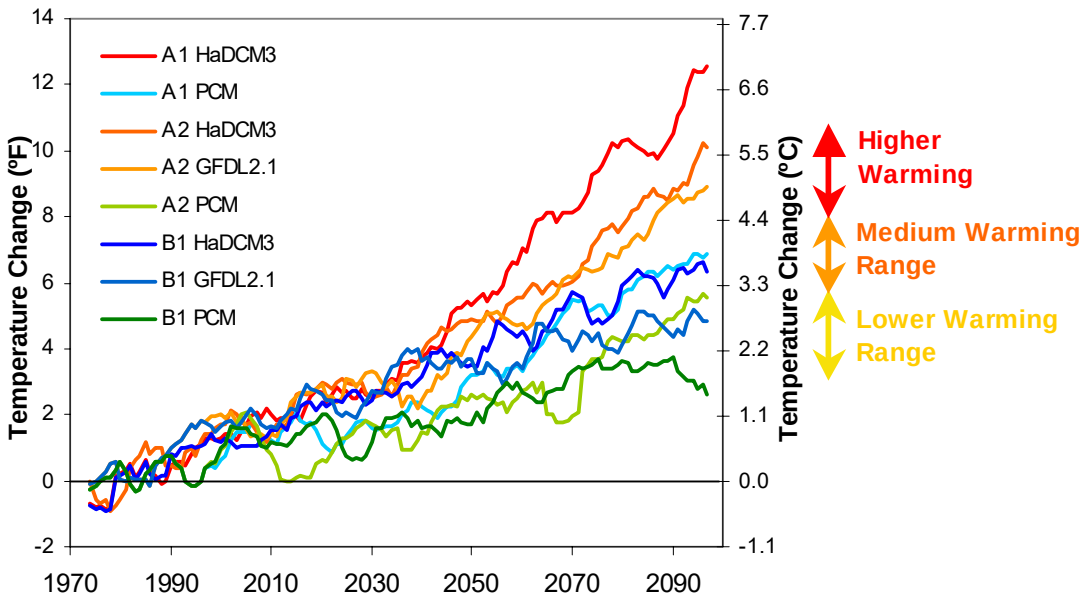


Figure 2. Change in California annual mean temperature

Change in California annual mean temperature (7-year running mean) (°F/°C) by year, from 1970–2099, relative to 1961–1990 average.

An important aspect of the model results is that all of the GHG scenario simulation, (except the low-emission scenario simulated by the low response model) exhibit higher warming in summer than in winter. In the medium-high emission (A2) scenario with the low sensitivity and medium sensitivity models, temperature increases by the end of the twenty-first century are 1.5°C–3.5°C (2.7°F–6.3°F), greater in summer than in winter (Cayan et al. 2006a). This result has important implications for impacts such as ecosystems, agriculture, water and energy demand, and the occurrence of heat waves, which have public health consequences.

5.2.2. Precipitation

There is no clear trend in precipitation projections for California over the next century. However, from the recent IPCC model projections—including several models that were not selected for the present study—there are considerable differences, from wetter to drier, between models and between emissions scenarios. The center of this distribution of simulations yields relatively little change, with a tendency for a slight decrease in precipitation, as is the case for the GFDL and the HadCM3 simulations (Cayan et al. 2006a).

Table 1. Potential warming ranges for California

	GCMs	Lower °C (°F)	Medium °C (°F)	Higher °C (°F)
Projected End of Century Range of Warming*		1.7°C–3°C (3.0°F–5.4°F)	3.1°C–4.4°C (5.5°F–7.8°F)	4.4°C–5.8°C (8.0°F–10.4°F)
Lower GHG Emissions B1	PCM	1.7 (3.0)		
	GFDL	2.2 (4.0)		
	HadCM3		3.1 (5.6)	
Medium-High GHG Emissions A2	PCM	2.6 (4.7)		
	GFDL		3.9 (7.0)	
	HadCM3			4.5 (8.1)
Higher GHG Emissions A1fi	PCM		3.3 (6.0)	
	HadCM3			5.8 (10.4)

*The temperature ranges were defined here for illustration only. The division was made simply by dividing evenly (low, medium, high) range of change in California's average annual temperatures as projected by the three GCM and emissions scenarios reported on in this summary (1.7°C–5.8°C **(**3.0°F–10.4°F**)**). The projected warming ranges presented here are for 2070–2099 relative to 1971–2000. However, some of the impacts summarized in this report used a different historical climatological baseline of 1961–1990. The difference between the 1961–1990 and 1971–2000 baselines leads to a small difference in projected temperature rise for the different scenarios and models. The difference in baselines amounts to approximately a 0.2°C (0.36°F) difference in the full range of projected end-of-century temperature rise.

There is no evidence from the projections indicating that the Mediterranean seasonal precipitation regime in California will change. All of the simulations examined here indicate that the very dominant portion of precipitation continues to be derived during winter from North Pacific storms. Summer precipitation changes only incrementally, and actually decreases in some of the simulations, so there is little evidence for a stronger monsoon influence. For the scenarios reported here, each of the model runs is characterized by large interannual to decadal fluctuations of precipitation, but not much change in annual precipitation over the 2000–2100 period. Little change in variability over the period of the model runs is evident in the simulations. The frequency of warm tropical events (El Niños) remains about the same as was exhibited in the historical simulations. As in observations, GCM El Niño events are related to anomalous precipitation patterns near the California region (Cayan et al. 2006a).

6.0 Coastal Sea Level

Coastal observations and global model projections indicate that California's open coast and estuaries will experience rising sea levels during the next century. Sea level rise already has affected much of the coast in Southern California, Central California, and the San Francisco Bay and estuary. These historical trends, quantified from a small set of California tide gages, have approached 2 mm/year (0.08 in/yr), which are rates very similar to those estimated for global mean sea level. So far, there is little evidence that the rate of rise has accelerated, and indeed the rate of rise at California tide gages has actually flattened since about 1980. However, projections indicate that substantial sea level rise, even faster than the historical rates, could occur during the next century.

As discussed in Cayan et al. (2006b), recent climate change simulations project significant global sea level rise during the next century, as the result of thermal expansion as the oceans warm and as runoff from melting land-based snow and ice accelerates. Sea level rise projected from the models increases in proportion to the amount of global warming. By the 2070–2099 period, sea level rise projections range from 13–62 cm (5.1–24.4 in) higher than the 2000 level for simulations following the lower emissions scenario (B1), from 18–76 cm (7.1–29.9 in) for the medium-high emission scenario (A2), and from 21–89 cm (8.5–35.2 in) for the higher emissions scenario(A1fi). These are illustrated in Figure 3, together with the last century of observed sea level at the San Francisco tide gage.

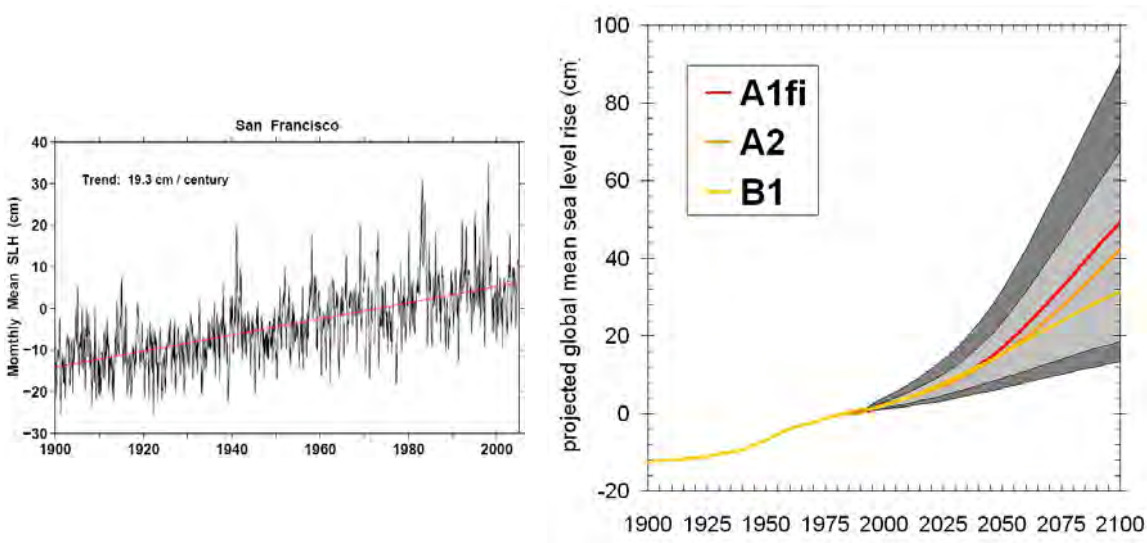


Figure 3. Observed change in sea level rise in San Francisco and projections of global mean sea level rise

Projected sea level rise from climate model estimates for three GHG emissions scenarios, A1fi (higher emissions), A2 (medium-high emissions), and B1 (lower emissions). San Francisco observed sea level, with trend of 19.3 cm/century (7.6 in/century), is shown for comparison. (Cayan et al. 2006b). In the graph on the right, light gray and dark gray represent uncertainty from thermal expansion and ice melt, respectively.

In addition to relatively steady long-term trends and astronomical tides, sea levels along the California coast undergo inter-annual and weather scale fluctuations that carry sea level elevations above and below the predicted tides and trends. These slower sea level rises are crucial because they boost the sea level excursions associated with the shorter term tidal, weather, and climate fluctuations. The most impressive examples of high sea level episodes in recent decades occurred during the winters of the massive El Niño events of 1982–1983 and 1997–1998 (Flick 1998). Thus, much of the potential damage from rising sea levels will occur during the occasions when high water stands due to tides, weather and climate anomalies are made higher (or more frequent) by the gradually rising mean sea levels. Importantly, GCMs include El Niños and La Niñas, as well as longer-lasting Pacific decadal variability, both in historical simulations as well as in projections that are being used to investigate twenty-first century climate changes.

Cayan et al. (2006b) considered two climate models and three emission scenarios to provide a set of future weather and short-period climate fluctuations, and a range of potential long-term sea level rises. Moderate to very large sea level rises were projected. The middle to higher end of this range would substantially exceed the historical rate of sea level rise (15–20 cm (5.9–7.8 in) per century) observed at San Francisco and San Diego during the past 100 years. Using a model of the combined contributions of tides, weather, climate, and long-term global warming on hourly sea levels, the potential for sea level rise impacts was assessed from the occurrence of hourly extremes. Considering a range of scenarios, and a range of possible sea level trends (Figure 4), Cayan et al. (2006b) find that, if warming is near the low end of the temperature range of projections so that sea level rise trends are also near the low end, then the occurrence of extremely high sea level events will increase, but not greatly, and sea level extremes under the various emissions scenarios (B1, A2, A1fi) are not much different from each other. On the other hand, if warming is greater, then sea level rise trends are at the higher end in each scenario, causing extreme events and their duration to increase markedly, especially for the medium-high and higher GHG emissions scenarios (A2, A1fi). Because of uncertainties in the climate sensitivity, it is not clear how rapidly sea levels will rise, even under the lowest emission scenarios. However, the California coast has already experienced rises of sea level that approach 15–20 cm (6–8 in) over the last century, so it seems prudent to consider scenarios where projected rise rates equal or exceed these historical sea level rise rates.

Coastal sea level extremes are also exacerbated by other processes, such as heavy surf from wind-driven waves, and these effects tend to be active during the same storms that causing anomalously high sea levels. Near San Francisco and Crescent City, when sea level fluctuations, above tide predicted levels, reach anomalies that exceed the 99th percentile of their measurements, the average in peak wave height at nearby wave-measuring buoys maintained by NOAA climbs to about double its ambient level. Because wave energy is proportional to the *square* of the wave height, the wave height increase during anomalous sea level episodes is equivalent to a coincident increase in wave energy by a factor of four. This observational evidence indicates that when anomalous sea level is highest, wave energy has an increased likelihood of reaching very high levels. When waves and anomalously high sea level coincide with high tides, the

chances for coastal damage are heightened. Continuing increases in mean sea level due to global change makes this problem even more severe.

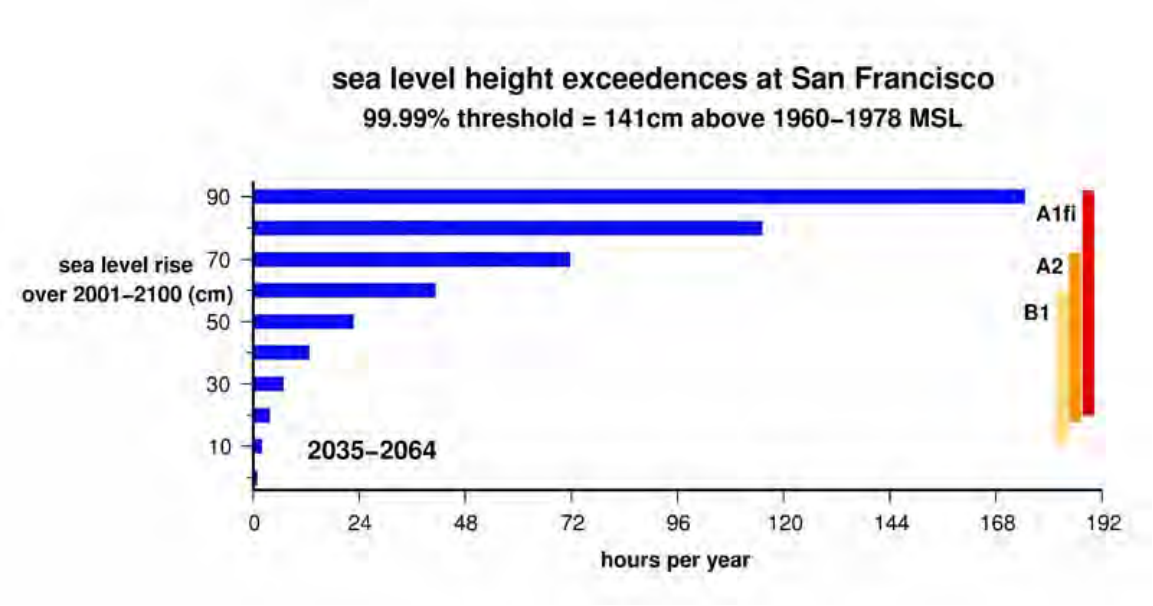


Figure 4. Projected number of hours per year, when San Francisco sea level height (SLH) exceeds 99.99% of its historical threshold

Projected number of hours per year, averaged over 2035–2064, when San Francisco sea level height exceeds historical (1960–19780 99.99 percentile observed threshold. Estimates are calculated from GFDL model weather and ENSO variability superimposed on predicted tides and a range of long term sea level rise as approximated by linear trends, from 0 to 90 cm over 2000–2100. Range of trends that have been estimated from climate models is indicated for three different GHG emission scenarios (Cayan et al. 2006b).

Sea level rise also threatens the Sacramento / San Joaquin Delta of the San Francisco Bay estuary. Historically, major floods have produced breaches in levees that protect low-lying, subsiding island tracts in the Delta and riverine and estuarine margins elsewhere, despite many engineered changes to the rivers. As sea levels rise, flood stages in the Delta would be expected to rise also, putting increasingly more pressure on Delta levees. The threats from sea level rise are particularly significant, because as Mount and Twiss (2005) have noted, the forces that rising sea / river levels bring to Delta levees increase as the *square* of the rises, rather than ”just“ linearly with the rises. Furthermore, the combination of flood and high sea-level stands are particularly dangerous in the Delta, where it is the combination of sea level and river stages that determine the water height. Storms are primary causes of the highest water levels both from barometric and wind effects on the sea levels and from the (freshwater) floods that they can generate. A count of the number of projected extremely high sea level episodes at San Francisco that coincide with potential storm / flood episodes is depicted in Figure 5 by cases when sea level is unusually high and atmospheric surface pressure is unusually low. This simulation indicates that, at least during the earlier decades of the next century, the largest increases in the frequency of extremely high sea level episodes as sea levels rise will coincide with periods of enhanced storm-flood risks.

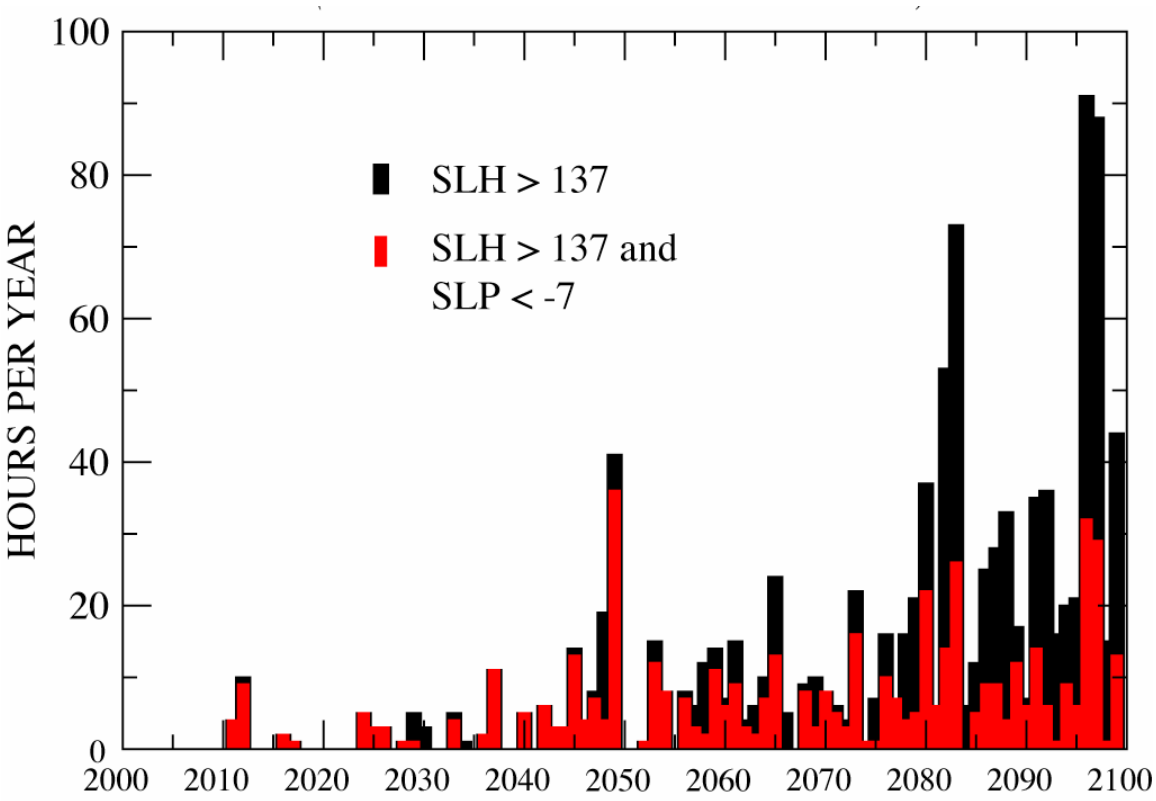


Figure 5. Projected total exceedances of San Francisco hourly sea level height

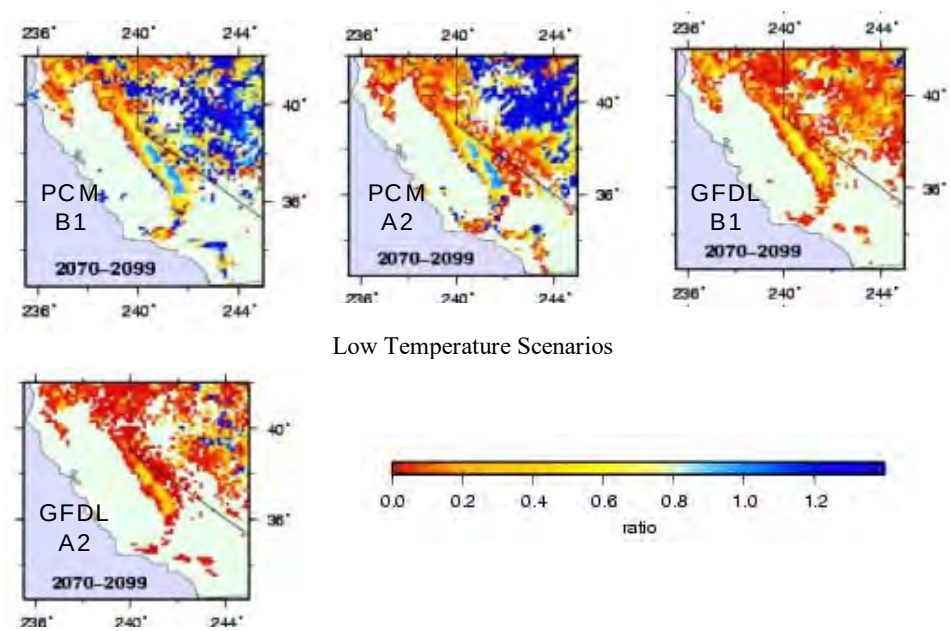
Projected total exceedances of San Francisco hourly sea level height above historical 99.99 percentile (black), and number that are coincident with sea level pressure (SLP) anomalies less than -7 mb. This figure was generated using projected sea level from GFDL model weather and Nino3.4 SST with a linear trend of 30 cm over 2000–2100 (Cayan et al. 2006b).

7.0 Water Resources

Although most climate model simulations project relatively moderate changes in precipitation over this century, rising temperatures are expected to lead to diminishing snow accumulation in mountainous watersheds, including the Sierra Nevada. Warmer conditions during the last few decades across the western United States have already produced a shift toward more precipitation falling as rain instead of snow (Knowles et al. 2005), and snowpacks over the region have been melting earlier in the spring (Mote et al. 2005; Stewart et al. 2005). Delays in snow accumulation and earlier snowmelt will have cascading affects on water supplies, natural ecosystems, and winter recreation.

7.1. Snowpack

The Variable Infiltration Capacity (VIC) distributed land surface hydrology model was used to simulate snowpack throughout the century (Cayan et al. 2006a). Projected reductions in snowpack increase with temperature, with the larger losses of spring snowpack in the higher range of projected warming (Figure 6). Each of the simulations shows losses of spring snow accumulation, largely over the Sierra Nevada, become progressively larger over the twenty-first century. In the Sierra Nevada by the 2035–2064 period, snowpack could decrease 12% to 47% from historical levels under the lower range of projected warming, and decrease 26% to 40% in the higher range of projected warming, with precipitation changes playing a partial role in the reductions for the lower temperature cases. By the end of century, snowpack could decrease by as much as 90% in the higher amount of warming—almost double the losses expected under the lower warming cases.



Source (Cayan et al. 2006a)

Figure 6. April 1 snow water equivalent 2070–2090 fraction of 1961–1990.

7.2. Water Supply

Declining snowpack will aggravate the already overstretched water resources in California. The snowpack in the Sierra Nevada provides natural water storage, equal to about half the storage capacity in California's major human-made reservoirs, holding the winter precipitation in the form of snow and releasing it in the spring and early summer as the snow melts. This loss in storage could mean more water shortages in the futures. However, the full effect of this storage loss will depend in part on whether reservoirs can be managed to capture the earlier snowmelt while not losing flood control capacity or, at the higher elevations, hydropower generation capacity.

Two different methods were used to project the effects of the alternative climate scenarios on water supply. One approach used the VIC model to simulate inflows into major reservoirs in the Sacramento Valley as drivers for their respective water resource management models, CALSIM and CALVIN[3] (Chung et al. 2006; Medellin et al. 2006; Vicuña et al. 2006; Vicuña 2006). The second approach used the Water Evaluation and Planning (WEAP) system (Joyce et al. 2006).

These two approaches differ in how they process the climate change scenarios.[4] Under most scenarios, both modeling approaches project streamflows to decrease slightly by mid-century, with more dramatic changes by the end of the century. Flows into the major Sierra Nevada reservoirs could decline between 25%–30% under the medium range of projected warming and the simulated decline in precipitation—almost double the decrease projected under the lower range of projected warming. However one model run produces a slight increase in precipitation and a corresponding rise in projected streamflows.

The Sacramento Four River Index (also called the *Sacramento 40-30-30 Index*) was used to classify the probability of water year types under the different climate change scenarios.[5]

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[3] CALSIM was used to assess hydrologic impacts in the Central Valley; CALVIN also covers the portions of the state outside the Central Valley

[4] CALSIM and CALVIN require as input a given time series of monthly stream flows—both use a modified version of the historical stream flow over the period 1922–1994. Climate change is incorporated into the given historical series by the "perturbation ratio" method: for a given time period of interest (2035–2064 or 2070–2099), a given stream location, and a particular month, one computes the average ratio of the VIC streamflow in that month over the period of interest to the VIC streamflow for the corresponding month over a base period (1961–1990). The monthly ratios are then used to adjust, or "perturb," the monthly stream flows in the historical series 1922–1994. In contrast, the WEAP approach uses raw time series of precipitation and temperature in a watershed hydrology model and directly generates a time series of streamflows. The perturbation approach is tied more closely than the WEAP approach to the historic inter-annual pattern of year-to-year variation in drought and wetness, although both approaches can generate changes in drought persistence.

[5] The Sacramento River Index was developed by the State Water Resources Control Board for regulatory purposes, and requires the forecasting by May of each year of the current year's April–July unimpaired runoff in the Sacramento Valley. When a retrospective analysis is conducted using the historical hydrology, as here, the actual April–July runoff is known, but not the prospective forecast, and therefore the index cannot be calculated in exactly the same way. The research here uses the Brekke et al. (2004) retrospective approximation for calculating the index.

This river index classifies the years into five categories: Wet, Above Normal, Below Normal, Dry, and Critical. Because the River Index pays greater attention to the aggregate stream flow then the timing of flow, it is more influenced by changes in precipitation then temperature. The projections for the less dry model (PCM) indicate that toward the end of the century, under the higher-emissions scenario, up to 50% of the years between 2070–2099 could be critically dry years, as compared to 18% in the historical period (Vicuña 2006; Hayhoe et al. 2004). Under the lower-emissions scenario in the less-dry model, little or no change in the frequency of critically dry years is expected. In contrast, from the projections using the drier models (HadCM3 and GFDL), even under the lower-emissions scenarios the frequency of critically dry years would increase, up to twice as often as historical conditions.

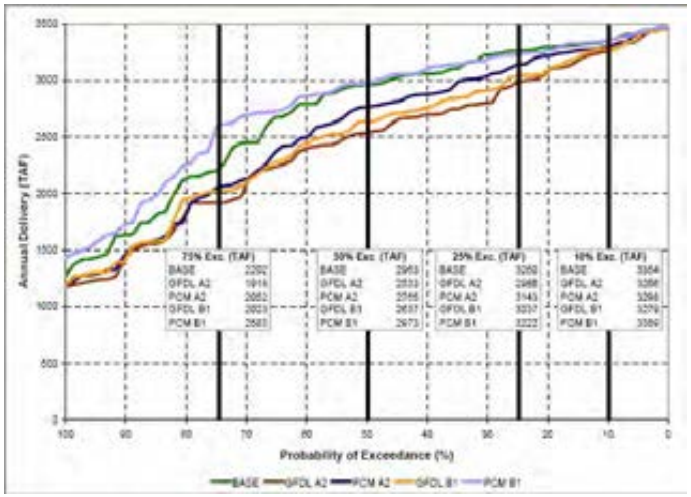
CALSIM was used to assess the consequences of the climate change scenarios on carryover storage at CVP and SWP reservoirs and for deliveries to CVP and SWP (Chung et al. 2006; Vicuña 2006). Toward the end of the century, the change in the volume and timing of runoff reduce the ability of the major projects to deliver water to agricultural users south of the Delta. These deliveries fall by 15%–30% under the lower range of projected warming, and 40%–50% under the medium and higher ranges of projected warming (Vicuña 2006) (Figure 7), with the drier model simulations showing the largest decreases. The projected changes in water supply would be further exacerbated by increased demand due to warmer temperatures. By the end of century, warmer temperatures are expected to increase the crop demand between 2% and 13%, in the lower and medium warming cases, respectively; there could be a similar effect on urban demand for outdoor lawn watering (Baldocchi et al. 2006).

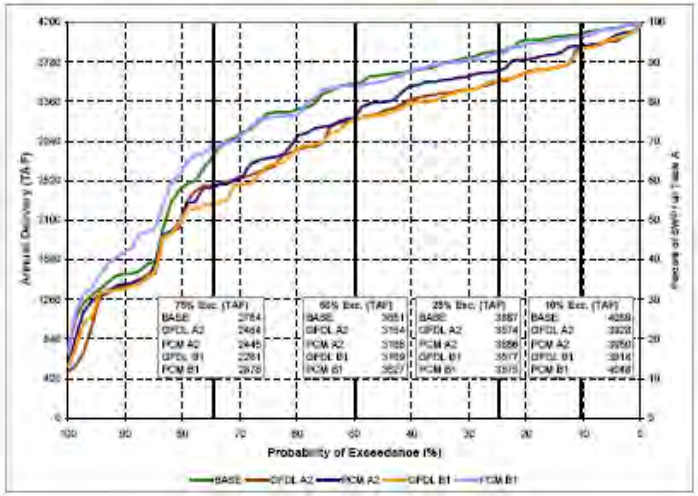
7.3. Winter Recreation

Declines in Sierra snowpack will also have widespread implications for winter tourism. Warming could affect the starting and closing dates of the ski season. Toward the end of the century, in lower temperature scenarios, the ski season at lower and middle elevation settings could shorten by as much as a month, while projected climatic changes under the higher temperature scenario suggest that the minimum snow conditions for ski resort operation might never occur, and resorts would be forced to rely entirely on snowmaking or move their operations (Hayhoe et al. 2004).

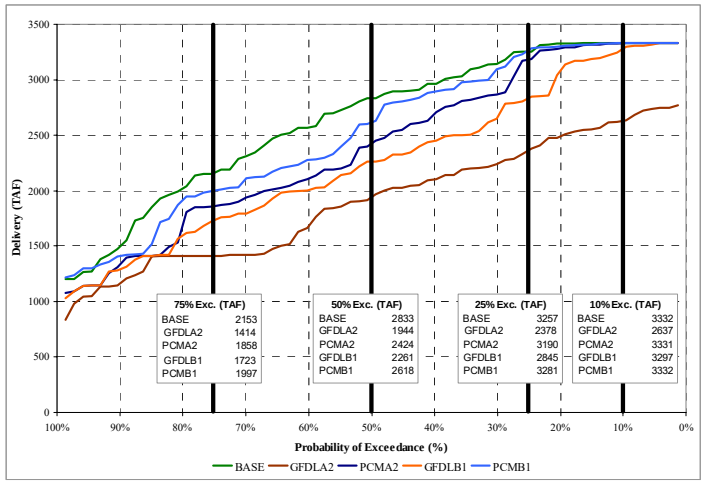
CVP **SPW**

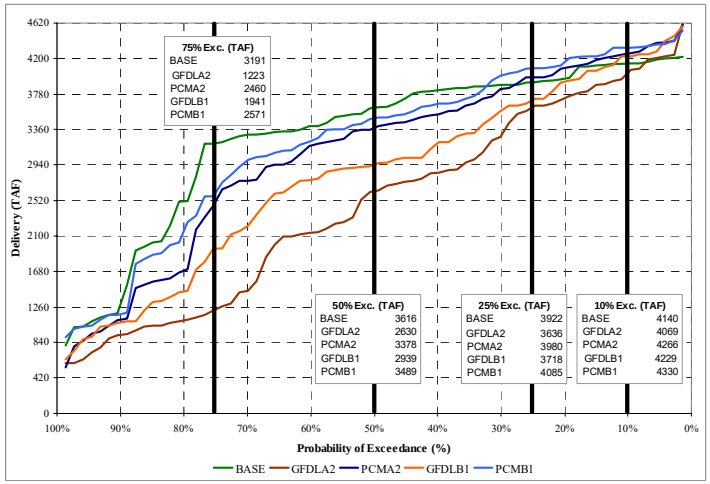
2035-2064





2070-2099





(Chung et al. 2006; Vicuña 2006)

Figure 7. Exceedance probability plot for Central Valley Project and the State Water Project

7.4 Potential Strategies for Reducing the Impacts on Water Resources

To compensate for the loss of natural storage in the snowpack, the existing man-made storage capacity will have to be managed more effectively, and also augmented. Modern probabilistic seasonal and short-term hydrology forecasting methods and more sophisticated decision algorithms could help reservoir managers better balance the competing demands of storage for water supply, hydropower, and flood control (Yao and Georgakakos 2001).[6] Besides this, it is likely that some form of additional storage will eventually be needed, whether above ground or below ground in the form of enhanced conjunctive use. More generally, it is likely that a portfolio of adaptation responses will be needed, including more conservation and increased efficiency in water use. The transmission systems for moving water around the state will also need to be both firmed up (to protect against seismic risks in the Delta, for example) and also enhanced to provide greater flexibility and connectivity in meeting water users' demands.

[6] A demonstration project is underway with funding from the CALFED Bay-Delta Program, the National Oceanic Atmospheric Administration (NOAA), and the Public Interest Energy Research Program (PIER). If that project is successful, it will pave the way for the operational use of these new management tools.

8.0 Agriculture

Agriculture, along with forestry, is the sector of the California economy that is most likely to be affected by a change in climate. California agriculture is a $68 billion industry.[7] California is the largest agricultural producer in the nation and accounts for 13% of all U.S. agricultural sales, including half of the nation's total fruits and vegetables. Regional analyses of climate trends over agricultural regions of California suggest that climate change is already in motion. Over the period 1951 to 2000, the growing season has lengthened by about a day per decade, and warming temperatures have resulted in an increase of 30 to 70 growing degree days per decade, with much of the increase occurring in the spring (Feng and Hu (2004). Climate change affects agriculture directly through increasing temperatures and rising CO_2 concentrations, and indirectly through changes in water availability and pests.

8.1. Temperature

Temperature influences crop growth through its impact on photosynthesis and respiration, as well as on growing season length and water use. Temperature also serves as a controlling factor for developmental processes, such as flowering and fruit maturation, which may be threatened if lengthening of the growing season introduces asynchrony between the timing of flowering and the life cycle of important insect pollinators.

Crop growth models show that a warming from a low to a higher temperature generally raises yield at first, but then becomes harmful (Doering et al. 2002). Possible effects of excessively high temperature include: decreased fruit size and quality for stone fruits, premature ripening and possible quality reduction for grapes, reduced fruit yield for tomatoes, increased incidence of tipburn for lettuce, and similar forms of burn for other crops. For example, rising temperatures are likely to produce adverse effects on quantity and quality for a number of California's agricultural products. For example, milk production has been found to decline when temperatures rise above 25°C (77°F), and Hayhoe et al. (2004) projected that in California milk production could decline up to 20% if temperatures rise to the higher warming range. Hayhoe et al. (2004) also projected a decline in wine grape quality as a result of increasing temperatures, where grapes in the major wine growing regions were expected to shift from optimal quality to marginal or impaired as temperatures rise to the higher warming range. Similarly, Baldocchi and Wong (2006) found that as temperatures rise from to the lower and medium warming ranges the number of chill hours declines, threatening the future viability of many species of fruit trees in the state.[8]

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[7] This is the 1998 figure for the total sales of agricultural and processing products in California (Kuminoff et al. 2001).

[8] Tree crops have become an increasingly prominent part of Central Valley agriculture over the three decades; the economic cost associated with the loss of a tree crop due to extreme weather conditions is likely to be significantly larger than that associated with the loss an annual field crop.

8.2. Carbon Dioxide (CO_2)

From a variety of studies in the literature, photosynthesis increases when a plant is exposed to a doubling of CO_2. However, whether this translates into increased yield of economically valuable plant product is uncertain and highly variable. Also, elevated CO_2 levels are associated with decreased concentrations of mineral nutrients in plant tissues, especially a decrease in plant nitrogen, which plays a central role in plant metabolism. Some crops may benefit in quality from an increase in CO_2; for example the fruit flavor of strawberries improves. Some crops are harmed by an increase in CO_2—for example grain protein in crops decreases and, in the case of wheat, breadmaking quality decreases (Cavagnaro et al. 2006).

8.3. Pests and Weeds

Growth rates of weeds, insect pests, and pathogens are also likely to increase with elevated temperatures, and their ranges may expand. A relatively new area of research involves the use of physiologically based dynamic models to fully understand the effects of weather (e.g., temperature, rainfall, solar radiation) on species dynamics. Gutierrez et al. (2006) used a dynamic model to estimate the potential impacts of a pest (pink bollworm, PBW) on cotton cultivation in the state. At the present time this pest is of importance only in the southern desert valleys (e.g., the Imperial and Coachella valleys), because winter frost restricts PBW's invasion to the million acres of cotton grown in the San Joaquin Valley. However, if winter temperatures rise by 2°C to 2.5°C (3.6°F to 4.5°F), as projected under the medium- to higher ranges of projected warming, the distribution of PBW would likely expand northward (Figure 8).

8.4. Potential Strategies for Reducing the Impact on Agriculture

Because of the greater priority being given to urban users in the event of water shortage, the agricultural sector is likely to bear a disproportionate share of water scarcity due to any climate-induced reduction in surface water supply. Farmers will likely respond by increasing their pumping of groundwater where this is available, shifting to higher value/less water-using crops, adopting higher efficiency methods of irrigation, and fallowing some farmland. Over time, new seed varieties could be developed that are better adapted to the changed climate and pest conditions, and entirely new crops may be found to meet pharmaceutical or energy supply needs. However, some of these adaptations may require publicly supported research and development if they are to materialize.

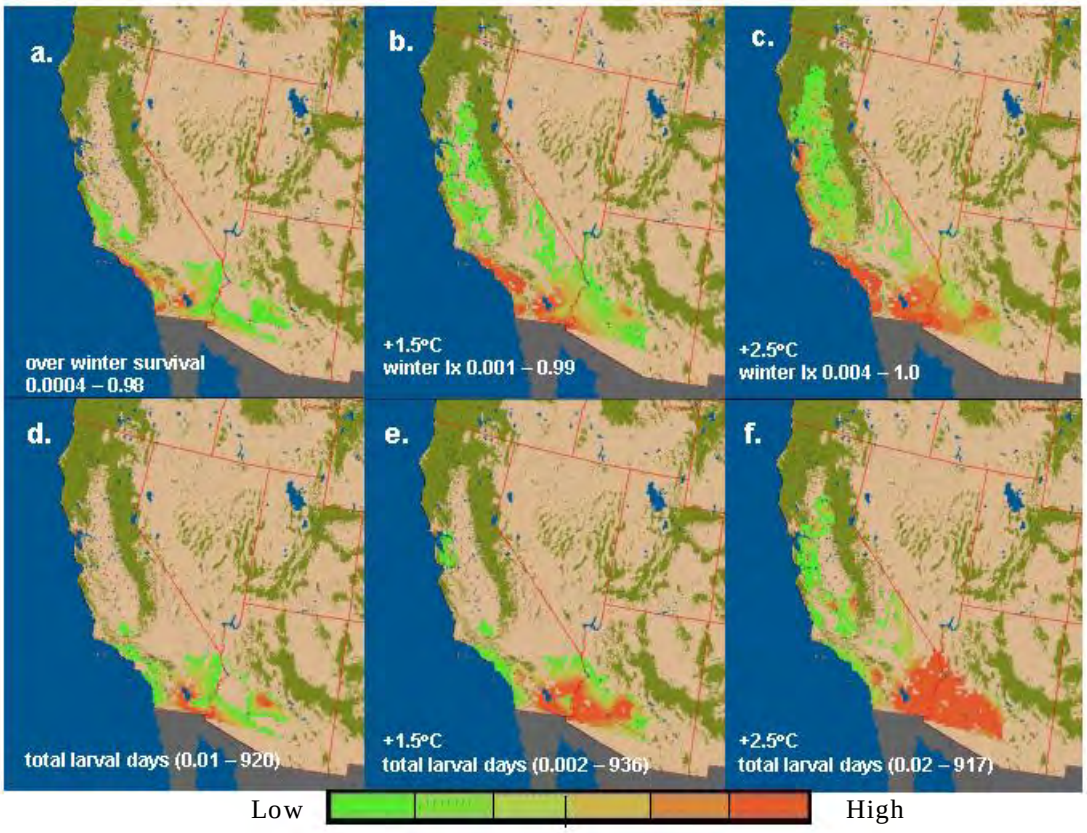


Figure 8. Cotton/pink bollworm (PBW): Predicting areas of favorableness

The effects on winter survival (a-c) and total seasonal pest PBW larval densities (larval days, d-e) under current weather (a,d) and with 1.5ºC (2.7ºF) (b,e) and 2.5ºC (4.5ºF) (c,f) increases in daily temperatures respectively (Gutierrez et al. 2006).

9.0 Forests and Natural Landscapes

Climate changes and increased CO_2 concentrations are expected to alter the extent and character of forests and other ecosystems (Field et al. 1999; McCarty et al. 2001; Aber et al. 2001). The distribution of species is expected to shift; the risk of climate-related disturbance such as wildfires, disease, and drought is expected to rise; and forest productivity is projected to increase or decrease—depending on species and region. In California, these ecological changes could have significant implications for both market (e.g., timber industry, fire suppression and damages costs, public health) and non-market (e.g., ecosystem services) values.

9.1. Natural Landscapes

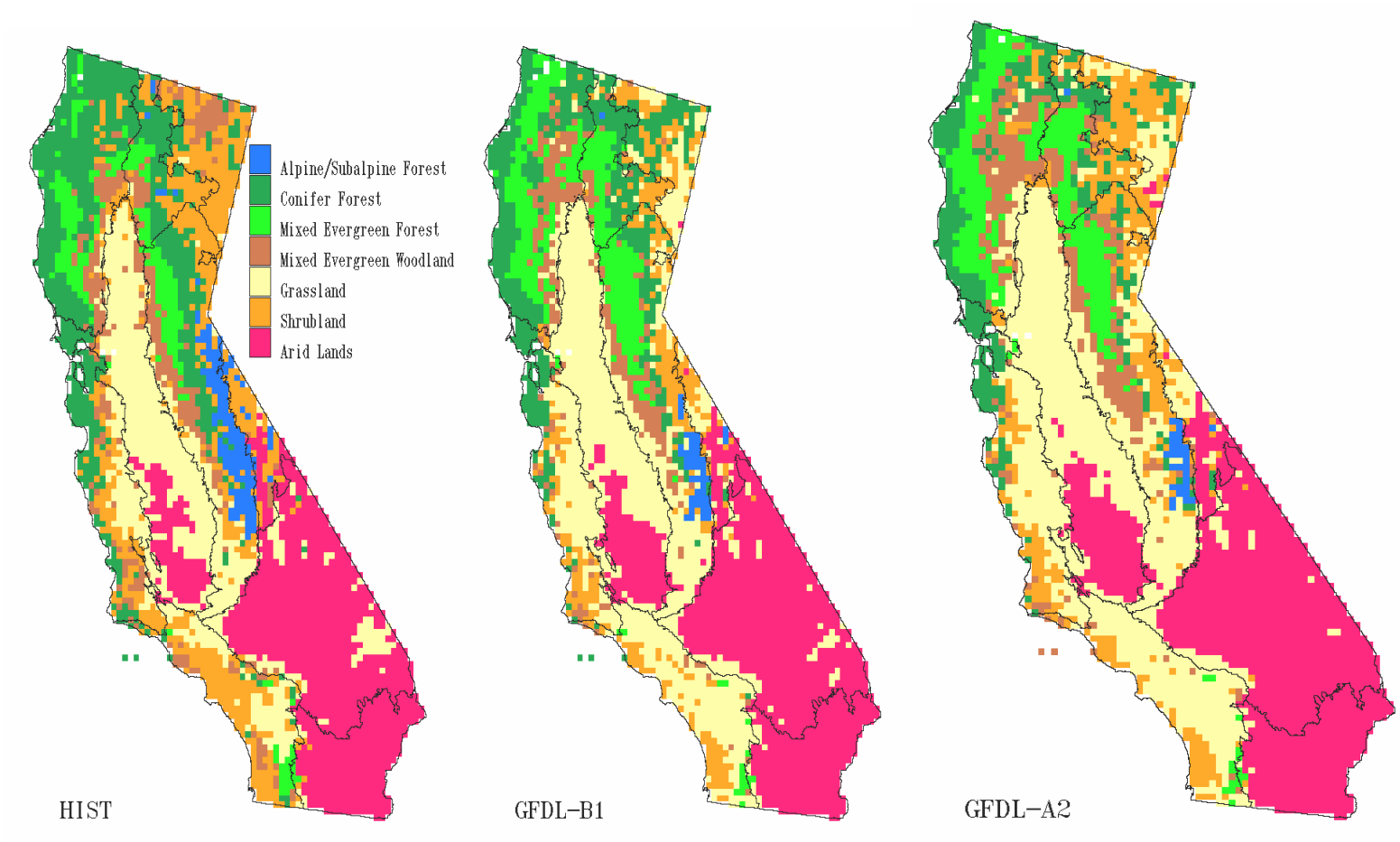
Lenihan et al. (2006) used the MC1 Dynamic Vegetation Model to simulate the response of vegetation distribution and ecosystem productivity to observed historical climate and to project the response to several scenarios of potential future climate change for California (Lenihan et al. 2006; Hayhoe et al. 2004). MC1 simulates lifeform mixtures and vegetation types; ecosystem fluxes of carbon, nitrogen, and water; and fire disturbance. The MC1 projections indicate that the ecosystems most susceptible to temperature rise are the alpine and subalpine forest cover. In addition, changes in fire frequency are expected to contribute to an increase in the expanse of grasslands, largely at the expense of woodland and shrubland ecosystems (Figure 9).

9.2. Wildfires

Fire is an important natural disturbance within many California ecosystems that promotes vegetation and wildlife diversity, releases nutrients and eliminates heavy fuel accumulations that can lead to catastrophic burns. The changing climate could alter fire regimes in ways that could have social, economic, and ecological consequences (McKenzie et al. 2004; Fried et al. 2004; Brown et al. 2004).

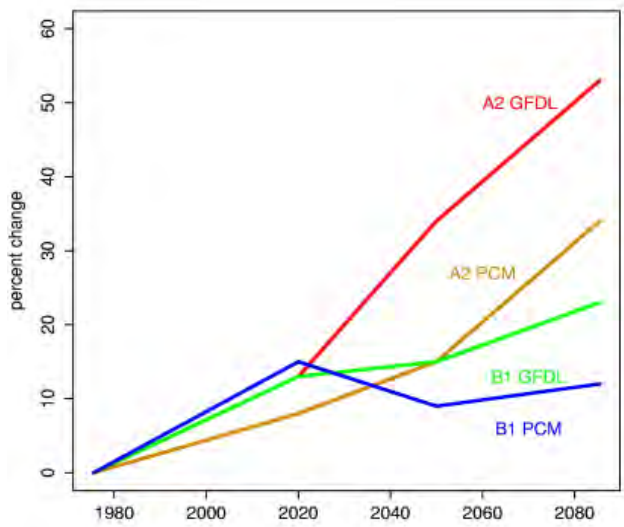
Westerling and Bryant (2006) estimated future statewide wildfire risk from a statistical model based on temperature, precipitation, and simulated hydrologic variables. These are conservative estimates because they do not include effects of extreme fire weather, but implications are nonetheless quite alarming. Projections made for the probabilities of “large fires”—defined as fires that exceed an arbitrary threshold of 200 hectares (approximately 500 acres)—indicate that the risk of large wildfires statewide would rise almost 35% by mid-century and 55% by the end of the century under a medium-high emissions scenario, almost twice that expected under lower emissions scenarios (Figure 10). Estimates of increased damage costs from the increases in fire season severity (Westerling and Bryant 2006) are on the order of 30% above current average annual damage costs.

A second study explored, through a case study in Amador and El Dorado Counties, the effects of projected climate change on fire behavior, fire suppression effort, and wildfire outcomes (Fried et al. 2006). Climate and site-specific data were used in California Department of Forestry and Fire Protection (CDF) standard models to predict wildfire behavior attributes such as rate of spread and burning intensity. The predicted wildfire



(Lenihan et al. 2006)

Figure 9. Vegetation distribution under historical conditions and multiple climate change scenarios at end of century



(Source: Westerling and Bryant 2006)

Figure 10. Percent change in the expected minimum number of large fires per year in California

outcomes were aggregated using the California Fire Economics Simulator version 2 (Fried and Gilless 1999), a stochastic computer model developed for CDF's fire protection planning program. The study found an increase in the projected area burned (10%–20%) and number of escaped fires (10%–40%) by the end of century, under the drier climate scenarios (GFDL). However, the less dry model showed little change.

Neither of these approaches for modeling the effects of climate change on wildfires considers the effects of the potential changes in wind conditions that may result from a changing climate, because the winds produced by GCMs are too coarse to be useful over most of the complex terrain in the California region. However, the strength and direction of winds can greatly influence fire behavior (Fried et al. 2004). Although initial studies suggest that future climate change may decrease early fall Santa Ana Wind conditions in some regions (Miller and Schlegel 2006), further research is needed to more thoroughly characterize potential changes in wind conditions and their possible effects on wildfires in the state.

9.3. Pests and Pathogens

Pests and disease have historically had a significant effect on California forests. The changing climate may exacerbate these effects, by expanding the range and frequency of pest outbreaks. For example, the introduced pathogen, pine pitch canker (*Fusarium subglutinans* f. sp. *pini*), once limited to coastal areas of California has expanded to the El Dorado National Forest in the Sierra Nevada. Rising winter temperature in the Sierra Nevada would make conditions more favorable for pitch canker, and could result in increased disease severity and economic loss (Battles et al. 2006).

9.4. Forest Productivity

Past studies project increases in forest productivity with continued climatic change (Mendelsohn 2003; Lenihan et al. 2003). However increasing evidence suggests that given the uncertainties concerning how trees will respond to elevated CO_2 concentrations (Körner et al. 2006), and the increased risk and susceptibility to catastrophic loss, the implications for the forest productivity and the timber industry may be less optimistic.

The recent assessment by Battles et al. (2006) of the expected impacts of climate change on the California forest sector used an industry standard planning tool to forecast 30-year tree growth and timber yields for forest stands in El Dorado County under a high and medium level of projected warming. Conifer tree growth was reduced under all climate change scenarios. In the medium level of projected warming, productivity in mature mixed-species stands was reduced by 20% by the end of the century. The reductions in yield were more severe (30%) for pine plantations.[9] Projections further indicate that the reduced growth rates could lead to substantial decreases in tree survival rates.

9.5. Potential Strategies for Reducing Impacts on Wildfire Risk and Forestry

Existing fire management strategies will be severely challenged by the interacting effects of expected changes in population and land use, and the projected changes in wildfire frequency and severity resulting from climate change. However, there are actions that can be taken in the near-term to improve our ability to live within California's fire-prone landscapes, while maintaining the functioning and structure of the ecosystems upon which we depend. For example, Moritz and Stephens (2006) suggest: (1) the adoption of a risk-based framework for fire management; (2) the reintroduction of fire to fire-prone ecosystems; (3) the creation of flexible policies that differentiate between the diverse ecosystems in California; and (4) a reevaluation of building and land use planning in the wildland-urban interface.

Battles et al. (2006) point to a number of strategies to offset declining forest yields. For example, silvicultural treatments could be designed to compensate growth losses to climate change with improvements in stand conditions. Planting mixtures of species, maintaining several age classes, reducing tree density, and pruning trees at strategic intervals are examples of cultural practices that could improve timber yields. Retaining a mixture of species and ages in the mixed conifer forests may alleviate some of the risks associated with the projected climatic changes. Single-species stands are at most risk. Spatially mixed forests limit the spread of both pathogens and insects. Decreasing tree densities reduce fuel loads and competition, and promote structures that are more resilient to catastrophic events like fire and epidemics.

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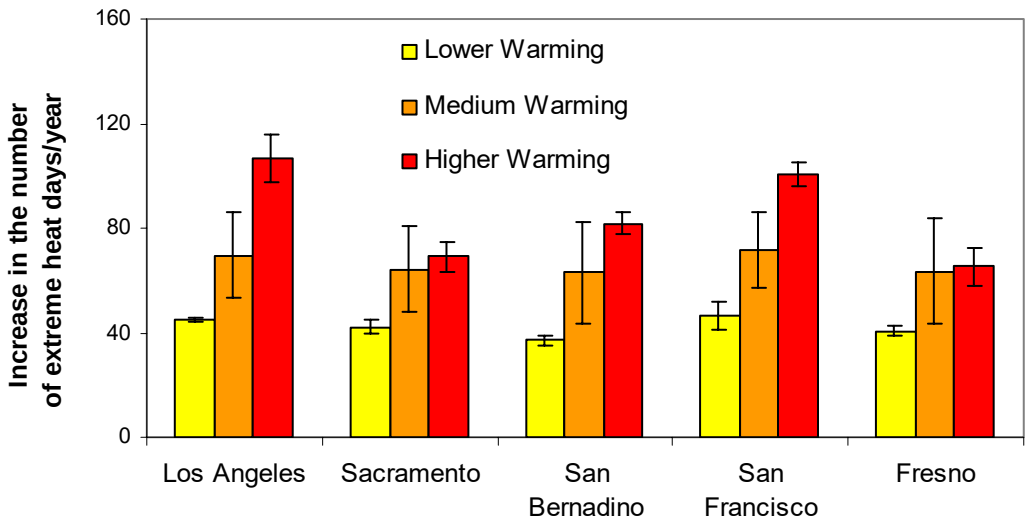
[9] The projections do not consider possible changes in vegetation distribution over the time period. However, Lenihan et al. (2006) analysis suggests that the composition for the study site considered in this study is expected to change very little over the next century.

10.0 Public Health

Climate change will affect the health of Californians by increasing the frequency, duration, and intensity of conditions conducive to air pollution formation, oppressive heat, and wildfires. The primary concern is not the change in average climate, but rather the projected increase in extreme conditions that are responsible for the most serious health consequences. In addition, climate change has the potential to influence asthma symptoms and the incidence of infectious disease.

10.1. Heat-related Deaths

Analyses of various climate change scenarios indicate that the future will have a greater number of extremely hot days and fewer extremely cold days, which may lead to two to six times as many heat-related deaths for the five cities studied (Drechsler et al. 2006). For the higher range of projected warming, the number of days over 31˚C (90˚F) in Los Angeles and over 35˚C (95˚F) in Sacramento will increase by up to 100 days by the end of the century—a striking increase over historical rates of occurrence, and almost twice the increase projected under the low-temperature path (Drechsler et al. 2006) (Figure 11).



(Source: Drechsler et al. 2006)

Figure 11. Projected increase in the number of extreme heat days relative to 1961–1990. *Extreme heat* is defined as the average temperature that is exceeded less than 10% of the days during the historical period (1961–1990), or approximately 36 days a year.

Individuals likely to be most affected include the elderly, the already ill, and the economically disadvantaged (CDC 2005a,b; Kilbourne 2002; Kaiser et al. 2001). Other identified risk factors for temperature-related health effects include social isolation, not leaving the home daily, and for heat-related death, living on the upper floors of multi-story buildings (Naughton et al. 2002). The number of deaths attributed to heat have declined over the past 30 years in the United States, primarily due to the increasing

number of households with central air conditioning, which appears to be the strongest protective factor (Davis et al. 2003; Donaldson et al. 2003). Kilbourne (2002) suggested that municipal housing codes be modified to require functional air conditioners in rental housing, in addition to existing requirements for heat. The U.S. Department of Commerce expects that air conditioning will be universal in the United States by 2050 (McGheehin and Mirabelli 2001), which will increase demand for electricity for residential cooling—especially on peak demand summer days in the future. In 2100, California will need at least 10% more electricity, compared to today's total generation capacity, for air conditioning alone on peak demand summer days (Miller et al. 2005). Ongoing studies are investigating the contribution of air pollution increases to deaths attributed to heat and refining the air conditioning demand estimates.

10.2. Air Pollution-related Death and Disease

Californians experience the worst air quality in the nation, with over 90% living in areas that violate either the state ambient air quality standard for ozone or particulate matter (PM) (CARB 2005a). The annual health impacts of these standard violations include 8800 premature deaths (3000–15,000 probable range), or 4% of all death; 9500 (4600–14,000) hospitalizations and emergency room visits; 2,800,000 (2,400,000–3,200,000) lost work days; and 4,700,000 (1,200,000–8,600,000) school absence days (CARB and OEHHA 2002, 2005; CARB 2005b). An annual value of $2.2 billion ($1.5–2.8 billion) is associated with hospitalizations and the treatment of major and minor illnesses related to air pollution exposure in California (CARB 2005b). In addition, the value of premature deaths resulting from exposure to air pollution in excess of the state's PM and ozone standards is $69 billion ($34–133 billion) (CARB 2005b). Current motor vehicle and industry control programs cost about $10 billion per year.[10] Ozone (from the precursors methane and nitrogen oxides, NO_X) and PM (especially elemental carbon), and to a lesser extent carbon monoxide and volatile organic compounds (VOCs), contribute to climate change (IPCC 2001).

Two recent reports from the National Research Council of the National Academies note that higher temperatures lead to increased emissions and formation of air pollution (NRC 2001, 2004). Maximum ozone levels are about double the current air quality standards and climate change will slow progress toward attainment by increasing emissions, accelerating chemical processes, and increasing summertime stagnation episodes. Model estimates of the effect of altered climate applied to current (2005) pollutant emission patterns show that temperature alone may alter emissions. For the medium-high emissions scenario, summer-time on-road VOC emissions from motor vehicles for the 2005 baseline are estimated to increase by 4% to 5% using temperature

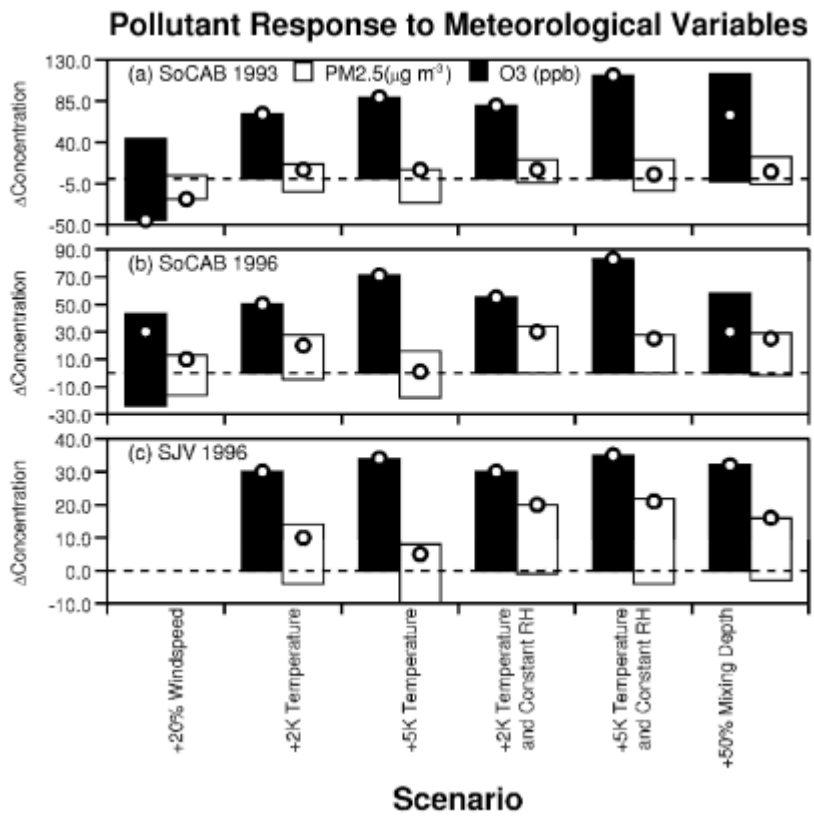
[10] The nationwide annual cost for air pollution control in 2000 was estimated to be $44 billion in 1986 dollars (USEPA 1991). Between 1986 and 2000, nationwide control costs grew about 3.85% annually. Assuming that control costs continued to grow at the same rate from 2000 to 2004, the annual control cost in 2004 is estimated to be about $53 billion in 1986 dollars. Using the Consumer Price Index (CPI), the nationwide annual cost of air pollution control is estimated to be $88 billion in 2004 dollars (the 2005 CPI is not yet available). Assuming California accounts for 12% of this expenditure (proportional to its population), the annual cost of air pollution control for California is about $10 billion.

projections for mid-century and by 13% to 16% for end-of-century temperature projections (Drechsler et al. 2006). These estimates also suggest small decreases in NO_X (Drechsler et al. 2006). Estimates for the low-emissions scenario are similar for mid-century and less than half for 2100. The medium-high emissions scenario results in a positive feedback loop for GHG emissions from on-road motor vehicles, with 4% to 5% increase in methane and 8% to 9% increases in CO_2 by 2100. These emissions estimates are strictly a test of sensitivity to temperature, as they do not take into account future changes in motorist behavior (e.g., increased air conditioning usage or increased miles driven), future growth in the number of vehicles or changes in the fleet mix, future emission controls, or possible technological advances in vehicle design. Constable et al. (1999) estimate that a doubled CO_2 atmosphere will result in a doubling of national biogenic VOC emissions. While California power plants are well controlled, higher temperatures lead to increased NO_X emissions (3% per ˚F, or 1.8% per ˚C) due to increased air conditioning usage (Drechsler et al. 2006).

A sensitivity study of three air pollution episodes in the South Coast Air Basin and San Joaquin Valley (Kleeman and Cayan 2006) found that increased temperatures favor the formation of ozone but discourage the formation of ammonium nitrate (a major component of PM). The decrease in PM caused by increased temperatures will be offset by other factors, most notably the increase in background ozone concentrations. The IPCC (2001) estimates that global background ozone concentrations could increase to 40–80 ppb by the year 2100 (up to double the current background value), largely due to emissions outside of California. Background ozone strongly contributes to the nighttime formation of particulate nitrate through the production of N_2O_5 in the upper atmosphere during the evening hours. A preliminary study by Kleeman and Cayan (2006) suggests that if global background ozone levels double, there would be an increase in $PM_{2.5}$ concentrations in California (Figure 12), despite the corresponding increase in temperature. Increased humidity also favors the formation of ozone and ammonium nitrate. Increased wind speed reduces ozone and PM concentrations by enhancing dilution of precursor emissions. Increased mixing depth also reduces PM concentrations, but leads to an increase in surface ozone concentrations because less NO_X is available to titrate the ozone that is produced aloft and mixed to the surface. The converse would be true for lowered wind speeds and mixing heights.

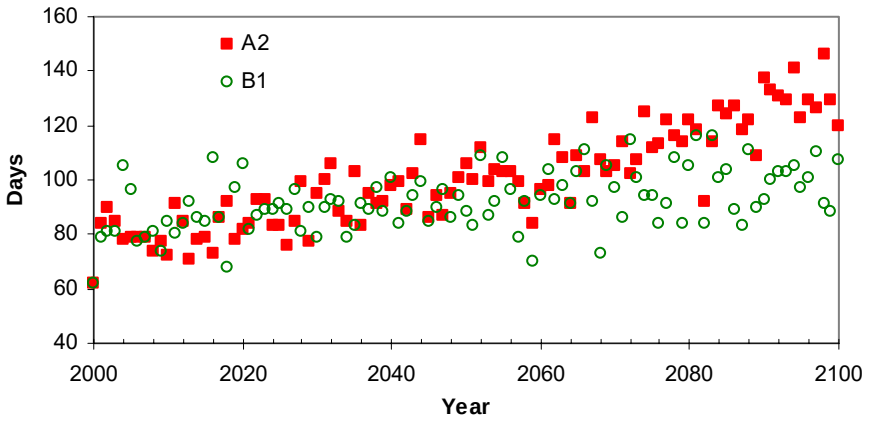
Statistically downscaled climate data from two simulations of one global climate model (GFDL) using two global emissions scenarios (a medium-high (A2) and a lower (B1) scenario), indicates that the number of days meteorologically conducive to pollutant formation could rise by 75% to 85% in the high ozone areas of Los Angeles (Riverside) (Figure 13) and the San Joaquin Valley (Visalia, the high ozone area downwind of Fresno) by the end of the century under a medium-high emissions scenario, but only 25% to 35% under the lower emissions path (Kleeman and Cayan 2006). In addition, global background ozone (primarily formed from the GHG methane and NO_X from fuel combustion) is projected to increase by 4-10 ppb (low scenario) to more than 20 ppb (high scenario) at 2100 (Prather et al. 2003). If background ozone increases by the amount projected for the high scenario, the state 8-hour-average ozone air quality standard of 70 ppb would be impossible to attain in much of California, even with near-zero local emissions. The future trend for PM is not as clear, because increasing

temperatures reduce some particle types while others show no change or increase slightly. Rainy days, wildfires, global dust storms, humidity, and other factors also affect PM, and are the subject of ongoing study (Kleeman and Cayan 2006).



(Source: Kleeman and Cayan 2006)

Figure 12. Summary of pollutant response to meteorological perturbations when background ozone concentrations are doubled to 60 ppb during pollution episodes that occurred in: (a) Southern California on September 9, 1993; (b) Southern California on September 25, 1996; and (c) the San Joaquin Valley on January 6, 1996. The bars represent the range of concentration change at any location in the modeling domain in response to the indicated perturbation. The circles represent the concentration change at the location of the maximum concentration for each pollutant.



(Source: Kleeman and Cayan 2006)

Figure 13. Projected days at Riverside meteorologically conducive to exceedances of the 1-hour California ambient air quality standard for ozone of 0.09 ppm.

10.2.1. Wildfires

Wildfires affect public safety and have the potential to significantly impact public health through their smoke. For example, a survey of 26% of all tribal households on the Hoopa Valley National Indian Reservation in northern California showed a 52% increase in medical visits for respiratory problems during a large fire in 1999, compared to the same period of 1998. More than 60% of those surveyed reported an increase in respiratory symptoms during the smoke episode, and 20% continued to report increased respiratory symptoms two weeks after the smoke cleared (Mott et al. 2002). The projected increases in fire season severity could lead (Westerling and Bryant 2006) to more "bad air" days. However, quantitative estimation of the impacts of future wildfire events is extremely difficult. The impacts of any fire are unique to that event, and are influenced not only by the magnitude, intensity, and duration of the fire, but also the proximity of the smoke plume to a population.

10.3. Asthma

Another concern of climate change is the effect on asthma prevalence and attacks. This impact is difficult to predict for several reasons. The most common asthma triggers are dust mites and molds, both of which are higher indoors than outdoors. Both require a relatively humid environment for survival. Consequently, if the climate becomes drier, or drought periods increase, these triggers will become less important. However, both will respond to higher humidity with increased growth, and these triggers may become more significant. Many asthmatics are allergic to various plant pollens. Plants and trees typically have pollination seasons that last a few weeks per year. To the extent that pollen seasons lengthen or become more intense in response to climate change, increased asthma exacerbation could result.

10.4. Infectious Disease

Climate change also has the potential to influence the incidence of infectious disease spread by mosquitoes, ticks, fleas, rodents, and food (Colwell and Patz 1998). More study is needed, because research to date has focused on short-term changes in weather patterns (primarily in ambient temperature and rainfall), rather than long-term changes.

10.5. Potential Strategies for Reducing Public Health Impacts

Some of the public health impacts can be reduced through adaptation measures, but costs are significant and special attention will need to be given to those most vulnerable to the health effects. For example, building climate change considerations into efforts to attain the health-based air quality standards will be necessary in the long-term if the standards are to be met. In addition, heat emergency action plans can help reduce those affected by extreme heat waves (Bernard and McGeehin 2004). Chicago and Milwaukee have developed effective heat emergency plans that could serve as models for California. In both cities, heat-related death rates were considerably lower during the 1999 heat wave, during which the action plans developed in response to the 1995 heat wave were activated (Naughton et al. 2002; Weisskopf et al. 2002). However, Bernard and McGeehin (2004) reviewed heat emergency plans from 18 cities, and found that many plans were inadequate, and that many other at-risk cities had no heat emergency action plans. These findings point to the urgency of developing heat emergency action plans for California before the need arises, and the inclusion of objective criteria for assessing the effectiveness of the plans.

11.0 Electricity Generation and Demand

Changes in temperature and other meteorological variables will affect both the generation of and demand for electricity. The demand for natural gas to warm our homes and buildings will also be affected, most likely resulting in reduced demand in the winter. This section summarizes what is known about the potential effects of climate change on electricity in California and presents some new results for the climate scenarios discussed in previous sections.

11.1. Electricity Generation: Hydropower

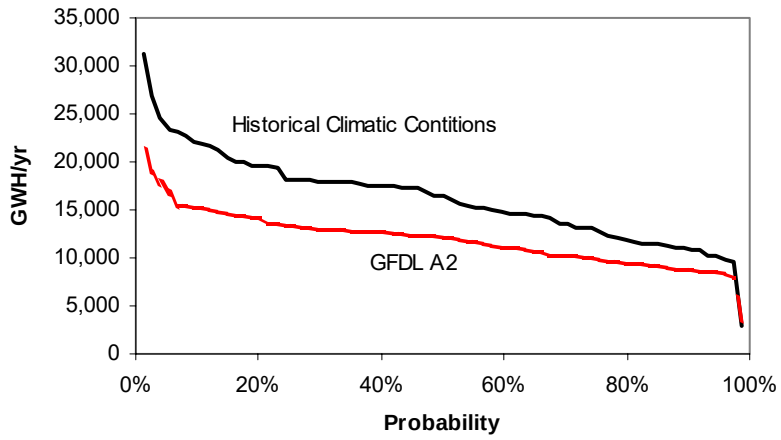
Changes in precipitation levels, should they occur, and changes in the patterns and timing of snowmelt would alter the amount of electricity that hydroelectric facilities could generate. It would also affect seasonal availability, with less water available for hydroelectric generation in the late spring and summer months, when demand is the highest. In addition, there is a high likelihood that changes in precipitation and runoff patterns would lead to changes in broader water policies and end-use priorities, such as water supply and flood control, which could place further limitations on hydroelectric production. Currently, hydropower generation contributes about 15% of California's in-state electricity production, with a range from 9% to 30%, due to variations in climatic conditions. Because it is used predominantly during on-peak periods, hydropower's value outweighs its simple energy contribution. In addition, the state also receives a significant amount of surplus power hydroelectric facilities from the Pacific Northwest, which will also be affected by climate change.

Two recent studies project losses in annual hydropower generation on the order of 10% to 30% by the end of this century, if precipitation levels in California decline (Lund et al. 2003; Vanrheenen et al. 2004). An important caveat about these studies is that they only addressed generation associated with relatively low elevation units, representing about 44% of the total generation capacity from hydropower facilities in the state.

For this study an economic-engineering optimization model of the state water system (CALVIN) was run to estimate the potential impacts of climate change on water resources assuming hypothesized year 2050 level of development with the climate conditions estimated for the end of the century (2070–2099) by the GFDL model for the A2 emissions scenario. As with previous studies, this study indicates that reductions of hydropower generation for relatively low elevation units on the order of 30% would occur, which is a response to a reduction of about 28% in streamflows. Figure 14 presents the frequency distribution of hydropower generation from the major water supply reservoirs modeled in CALVIN. As a point of reference, in the 1990 to 2002 period, California generated from 20,000 gigawatt-hours (GWh) to 51,000 GWh in a given year (Medellin et al. 2006).

Another recent study prepared by the California Department of Water Resources (DWR) used climate projections for the middle of this century (Chung et al. 2006). The DWR modeled the State Water and Central Valley Projects which, as indicated above, represent about 27% of the state's hydroelectric capacity. This study indicates that reductions in electricity generation of approximately 7% would occur for most of lower

and medium range of projected warming. However, for the PCM B1 scenario, the least dry scenario, DWR estimated an increase in generation on the order of 4%.



(Source: Medellin et al. 2006)

Figure 14. Probability of producing at a minimum level of generation in a year in major water supply reservoirs modeled in CALVIN: period centered in 2050.

All the studies reported so far address potential impacts on hydropower units that are located in relatively low elevations and served by a large reservoir storage capacity. These can be used to partially offset the trend to an early melting of the snow stored in the Sierra Nevada. Hydropower units in relatively medium and low elevations have little reservoir storage capacity and rely more heavily on the accumulated snow as a natural reservoir. A substantial fraction of the mountain snowpack that supplies water to these units in the spring and summer is located above 1200 meters (3900 feet). This zone is the most vulnerable area to higher temperatures and is expected to experience the most dramatic spring snow losses (Knowles and Cayan 2004). At the present time, the quantitative evaluation of the potential impacts on the medium and high elevation units remains is an unexplored area of study. However, a recent exploratory study of a system owned and operated by the Sacramento Municipal Utility District (SMUD) in the Upper American River Watershed indicates that, as with lower elevation hydro units, electricity generation would go down in response to lower precipitation levels but the existing reservoir system would be able to store enough water to allow generation of electricity in the hot summer months when it is most needed (Vicuña et al. 2006). This occurs despite earlier streamflow runoff caused by climate change. It is unclear how this and other similar systems would respond under scenarios with increased precipitation levels. The most important variables that will determine impacts are storage capacity of the system relative to the volume of stream inflows and the timing of runoff as it compares to the pattern and timing of energy demand.

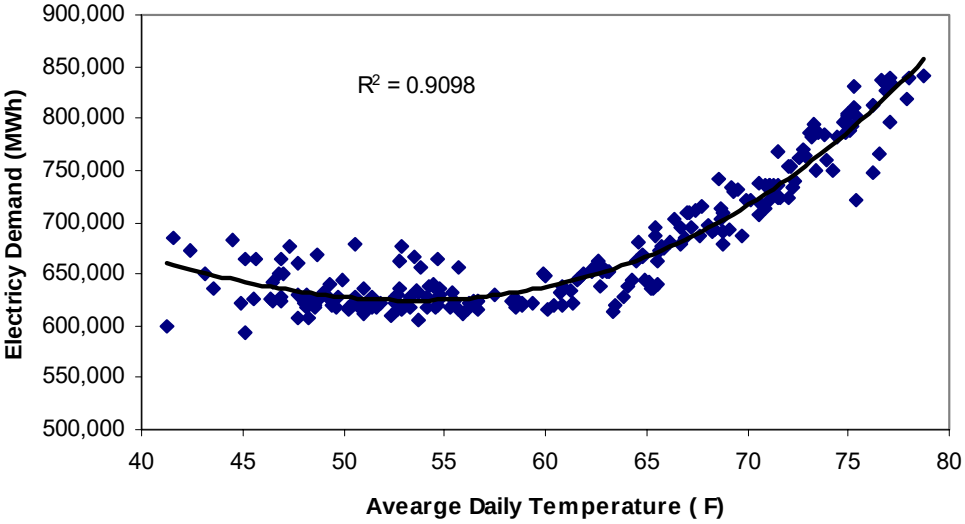
It is important to emphasize that even relatively small changes in in-state hydropower generation result in substantial extra expenditures for energy generation, because this "free" generation must be purchased from other sources. For example, assuming a decrease of 10% from the current average in-state generation level from this renewable energy source, and assuming a price of about 10 cents per kilowatt-hour, this decrease would result in an additional $350 million per year in net expenditures to purchase sufficient electricity to replace the electricity that otherwise would be generated using hydroelectric resources.

11.2. Electricity Demand

One of the few papers that have been published on the potential effect of climate change on electricity demand in California, (Baxter and Calandri 1992) indicates significant increases in electricity requirements. This study was guided by energy forecast models that were developed for or by the Energy Commission to estimate electricity demand taking into account increased population and economic activity. Under their worst-case scenario (a 1.9ºC (3.4ºF) increase), electricity requirements in 2010 would increase by about 7,500 GWh, and would require an additional peak capacity of 2,400 MW. This trend would represent an increase of about 2.6% and 3.7% in energy and peak generation capacity, respectively, from their 2010 base case.

Since it is impossible to know how the energy system and socioeconomic conditions in the state will evolve in the next 100 years, the study described below investigates how future climate projections would affect electricity demand assuming the current infrastructure and demographics. In practice, higher temperatures will increase the penetration of air conditioning units for cooling, but, more important, this approach fails to consider the trend toward more development in the interior parts of California that experience higher temperatures. For these reasons, actual impacts could be higher than what is reported in this section.

Figure 15 shows daily demand of electricity for the area serviced by the California Independent System Operator (CalISO) in 2004 as a function of the simple average of daily temperatures in San Jose, Sacramento, Fresno, and Los Angeles. Figure 15 only includes demand during weekdays, and excludes holidays.

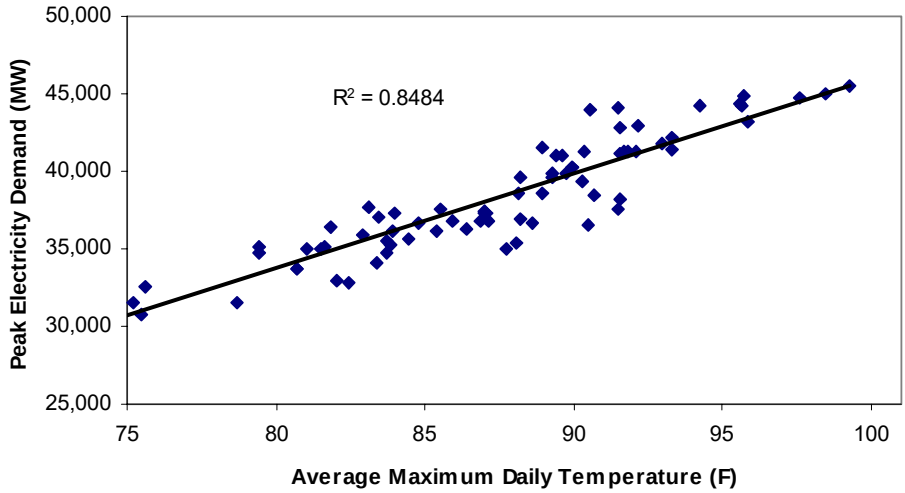


(Source: Franco and Sanstad 2006)

Figure 15. Electricity demand in the CalISO area as function of average temperatures: 2004

Peak electricity demand occurs mostly in the summer months, and it is a strong function of maximum daily temperatures. Figure 16 presents the daily peak energy demand in the CalISO region as function of the average daily maximum temperature measured in San Jose, Sacramento, Fresno, and Los Angeles. It only includes non-holiday weekdays. Electricity consumption during weekends and holidays tends to be lower.

Franco and Sanstad (2006) used these relationships between demand and temperature, to estimate the impact of higher temperatures on annual electricity and peak summer demands (see Table 2). Estimated changes in electricity demand were determined from multiple temperature projections as reported by Cayan et al. (2006a) for grid points close in the cities listed in the previous paragraphs. To calculate changes in peak demand, they used averaged maximum annual temperatures for the periods listed in Table 2.



(Source: Franco and Sanstad 2006)

Figure 16. Peak electricity demand in the CalISO area as a function of maximum daily temperature: June-September 2004

Table 2. Estimated incremental changes in annual electricity and peak load demands for lower, higher, and medium range of projected warming relative to 1961 to 1990 base period

Time Period	Projected Warming Range	Change in Annual Electricity Demand (%)	Change in Peak Demand (%)	Climate Model	Emission Scenario
2005–2034	Low	0.9	1.4	PCM	Low (B1)
		2.5	1.5	GFDL	Low (B1)
		1.2	1.0	PCM	Medium-High (A2)
	Medium	2.9	3.6	GFDL	Medium-High (A2)
	High	3.4	4.8	HadCM3	Higher (A1fI)
2070–2099	Low	3.1	4.1	PCM	Low (B1)
		5.8	7.3	GFDL	Low (B1)
		5.3	5.6	PCM	Medium-High (A2)
	Medium	11.0	12.1	GFDL	Medium-High (A2)
	High	20.3	19.3	HadCM3	Higher (A1fI)

Annual expenditures of electricity demand in California represent about $28 billion (U.S. EIA 2005). Therefore, even the relatively small increases in energy demand shown in Table 2 would result in substantial extra financial expenditures for energy services in the state. For example, assuming a linear increase in electricity expenditures from the recent

historical period, a 3% increase in electricity demand by 2020 would translate to about $1.2 billion nominal dollars a year in additional electricity expenditures.

11.3. Potential Strategies for Reducing Impacts on Electricity Sector

The impacts of climate change on the electricity system will depend in part on how the electricity system evolves in the future. For example, an increased penetration of photovoltaic (PV) systems would reduce the impacts of peak demand because this energy source closely matches the diurnal demand for electricity (Borenstein 2005), but other technologies could also be used to satisfy an increased demand. Energy efficiency programs will reduce electricity demand counteracting some of the negative effects of increased ambient air temperatures. Finally, reducing the heat island effect with the use of more reflective surfaces (e.g., for roofs and pavement) and planting trees that provide shade to homes and buildings will also allow the state to better cope with the expected temperature increases.

12.0 Implications for Mitigation and Adaptation

Continued climate change would have widespread impacts on California's economy, ecosystems, and the health of its citizens. The analyses summarized in Figure 17, however, suggest that many of the more severe impacts projected under the medium and higher warming ranges could be avoided by following the lower emissions pathway. However, if the actual climate sensitivity to GHGs reaches the level of the more sensitive global climate models employed here, an even lower emissions path than the B1 scenario may be required to avoid the medium warming range. How much would GHG emissions have to be reduced to stay below the lower emissions pathway (B1) and insure against temperatures rising to the medium and higher warming ranges presented in this study? The Governor's Executive Order #S-3-05 calls for an 80% reduction in GHG emissions below 1990 levels by 2050. If the industrialized world were to follow California's lead, and assuming the industrializing nations followed the B1 pathway, global emissions would remain below the lower emissions scenario (B1),[11] increasing the likelihood that California and the world would be on track to avoid the more severe impacts by preventing temperatures from rising to the medium warming range.[12] This estimate of the impact of an 80% reduction by the industrialized world has on global emissions depends crucially on the development patterns of the developing world. The SRES B1 scenario assumes development proceeds with a "high level of environmental and social consciousness" with a transition to "alternative energy systems" (Nakicenovic et al. 2000). Emission reductions targets such as the one set by the Governor's Executive Order could spur the innovation necessary to lead the world to a transition to alternative energy systems.

However, even if global emissions stay below the lower emissions scenario (B1), some impacts from climate change are inevitable. Evidence indicates that even if actions could be taken to immediately curtail GHG emissions, the potency of GHGs that have already built up, their long atmospheric lifetimes, and the inertia of the Earth's climate system could result in average global temperatures rising an additional 0.6°C (1.1°F) (Wigley 2005; Meehl et al. 2005). As a result, some impacts from climate change, in California and across the globe, are now unavoidable. Consequently, although it is not the solution to global warming, it is becoming clear that adaptation is an essential complementary strategy to manage some of the projected impacts of climate change.

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[11]This was calculated as follows: (1) Organisation for Economic Co-operation and Development (OECD) population and total emissions were based on SRES B1 IMAGINE runs (Nakicenovic et al. 2000). OECD total emission in 1990 were 2.83 GtC; (2) Eighty percent below this value is 566 MtC; (3) Total global emissions was calculated by adding the 566 MtC to the total emissions for non-OECD countries, as projected by SRES B1. This value is approximately 10 GtC; (4) This 10 GtC/yr was compared to the global emission projected in the B1 scenario (approximately 11 GtC/yr).

[12] As illustrated in Figure 1, beyond 2050, global emissions will need to decrease substantially below 10 GtC/yr to stay on the B1 pathway out to the end of the century. The SRES B1 pathway assumes global emissions decrease to 4.23 GtC/yr by 2100. However, stabilizing atmospheric concentrations will require even lower emissions as natural uptake is estimated between 0.7–2.9 GtC/yr (IPCC 2001).

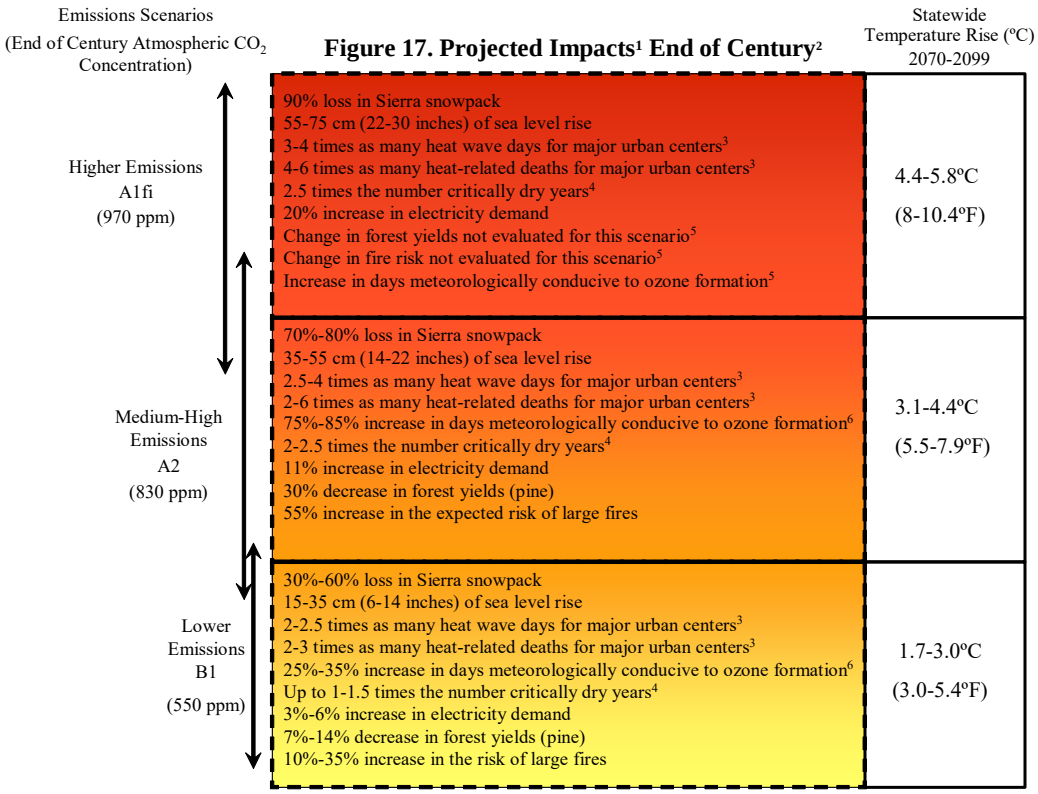

Figure 17. Projected impacts[1] end of 21st century.[2] Impacts presented relative to 1971–2000.

[1] The impacts summarized in this figure reflect projections from different models, based on the current scientific understanding of the relevant social and biophysical processes. Because our scientific understanding is still developing in some key processes that would affect the sectors studied, we provide here some guidance to our levels of confidence of these projections. We assign high confidence to the direction of change in all of impacts described in Figure 17. However, in some sectors we have less confidence in the magnitude of change, because the projections are based on specific assumptions about future development patterns or societal response to projected changes. For example, changes in the number of heat-related deaths could decrease if different assumptions were made about the effectiveness of adaptation measures such as air conditioner use. Furthermore, neither the projection for heat-related deaths nor the projected increases in energy demand take into account population growth, and thus the magnitude of the impact may be significantly higher than the projections presented here. Similarly, the projections for wildfire risk may be conservative, in that they assume constant population and existing vegetation, land-use, and management patterns.

[2] The projected warming ranges presented here are for 2070–2099, relative to 1971–2000. However, some of the impacts summarized in this report used a different historical climatological baseline of 1961–1990. The difference between the 1961–1990 and 1971–2000 baselines leads to a small difference in projected temperature rise for the different scenarios and models. The difference in baselines amounts to approximately a 0.2°C (0.36°F) difference in the full range of projected end-of-century temperature rise.

[3] Los Angeles, San Bernardino / Riverside, San Francisco, Sacramento, and Fresno.

[4] Measures for the San Joaquin and Sacramento basins.

[5] Impacts expected to be more severe as temperatures rise. However, the higher range of projected warming was not assessed for the project.

[6] For high ozone locations in Los Angeles (Riverside) and the San Joaquin Valley (Visalia).

While there are many opportunities for California to increase its capacity to cope with the projected changes, these often can be costly and require time and planning. Furthermore, there are critical limits to adaptation, especially in addressing the threats of abrupt climate changes or in dealing with those impacts on natural, unmanaged species and ecosystems, which may not be able to keep up with the increasingly rapid and severe climate changes expected if emissions go unabated. In addition, managing the impacts of climate change may be particularly challenging when different kinds of changes are experienced together. For example, how would California manage in years where it was subjected simultaneously to an extreme heat wave, an energy blackout, and widespread wildfires, during an extended drought? While at present we are unable to predict the probability and all of the consequences of such an event, in preparing for change we must consider the potential compounding effects of multiple impacts.

Finally, the ability to cope and adapt is differentiated across populations, economic sectors, and regions within the state. As a result, without appropriate mitigating actions, climate change will likely aggravate existing equity issues within California and the rest of the United States. For example, the most vulnerable populations to the health impacts of climate change are children, elderly people, and the poor—the same groups that already face the greatest health and environmental risks.

In order to realize the state's adaptive and mitigative response potential, the state will need to continue to generate public discussion, build awareness, and foster the political will necessary to manage climate change.

13.0 The Need for Climate Change Information for California

There are key unknowns in the cascade of effects of climate change that inhibit better planning and policy actions. For example, better monitoring is needed of California's climate and climate-sensitive sectors to detect and understand a complex chain of impacts. In particular, more work is needed on ecological impacts both in terrestrial and aquatic systems, in the development of more detailed, probabilistic climate projections for the state, and to determine how climate changes and environmentally related policies might impact the California economy, recreation, and tourism. A more comprehensive analysis of the effects of climate change on energy supply and demand, within and outside of California, is needed. The effect of climate change on water resources, including more quantitative understanding of water supply and water demand for the rich complex of agricultural and natural ecosystems in the state is still not well understood. A geographically detailed analysis of the impacts of sea level rise on the California coast and the San Francisco Bay and Delta will be needed to assess potential impacts and conduct planning on local and regional scales. The impact of climate and climate change on temperature-related deaths, air pollutant emissions and quality impacts, and other aspects of human health will require more data and further study. Population growth, urbanization, and technological innovation are among a number of important factors that directly affect these areas. Given the serious potential consequences of climate change on the state's resources, the research community should continue to produce the tools, methods, and information that will be needed to develop robust coping or adaptation strategies in California.

Moreover, additional information is needed to help identify and understand the social and institutional constraints to managing climate change. The international and some national research efforts increasingly have turned away from simple impact assessments towards a "vulnerability" assessment approach that focus on identifying what makes certain populations and sectors susceptible to impacts of climate change. The vulnerability framework considers climate change within the context of multiple interacting stresses—such as population growth, land-use change, and institutional change. California's climate research should begin to include this research framework to identify the most vulnerable populations and regions of the sate, and develop strategies to build their resilience to climate variability and change, and related stresses.

14.0 References

Aber, J., R. P. Neilson, et al. 2001. ”Forest processes and global environmental change: Predicting the effects of individual and multiple stressors.” *BioScience* 51(9): 735–751.

Baxter, Lester W., and Kevin Calandri. 1992. “Global warming and electricity demand: A study of California.” *Energy Policy* March: 233–244.

Baldocchi, D., A. Gutierrez, M. Hanemann, L. Dale, and W. Schlenker. 2006. An assessment of impacts of future CO_2 and climate on agriculture. (www.climatechange.ca.gov/).

Battles, J., T. Robards, A. Das, K. Waring, J. K. Gilles, F. Schurr, J. LeBlanc, G. Biging, and C. Simon. 2006. Climate change impact on forest resources. (www.climatechange.ca.gov/).

Bernard, S., and M. McGeehan. 2004. “Municipal heat wave response plans.” *American Journal of Public Health* 94: 1520–1522.

Brekke, L. D., N. L. Miller, K. E. Bashford, N. W. T. Quinn, and J. A. Dracup. 2004. ”Climate change impacts uncertainty for water resources in the San Joaquin River Basin, California.” *J. American Water Resources Association* 40(1): 149–164.

Brown, S., T. Pearson, et al. 2004. Baseline Greenhouse Gas Emissions for Forest, Range, and Agricultural Lands In California. Sacramento, California Energy Commission: 1–91.

Borenstein, S. 2005. ”Valuing the Time-Varying Electricity Production of Solar Photovoltaic Cells.” CSEM Working Papers. The University of California Energy Institute (UCEI). March.

CARB (California Air Resources Board). 2005a. *The California Almanac of Emissions and Air Quality: 2005 Edition.* www.arb.ca.gov/aqd/almanac/almanac05/almanac05.htm.

CARB (California Air Resources Board). 2005b. *Draft Emission Reduction Plan for Ports and International Goods Movement in California.* www.arb.ca.gov/planning/gmerp/gmerp.htm. December 1.

CARB and OEHHA.(California Air Resources Board and Office of Environmental Health Hazard Assessment. 2002. *Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates.* www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm. May 3.

CARB and OEHHA (California Air Resources Board and Office of Environmental Health Hazard Assessment). 2005. *Revised Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Ozone.* www.arb.ca.gov/research/aaqs/ozone-rs/rev-staff/rev-staff.htm. October.

Cavagnaro, T., L. Jackson, and K. Scow. 2006. *Climate change: Challenges and solutions for California agricultural landscapes.* (www.climatechange.ca.gov/).

Cayan, D., E. Maurer, M. Dettinger, M. Tyree, K. Hayhoe, C. Bonfils, P. Duffy, and B. Santer. 2006a. *Climate scenarios for California.* (www.climatechange.ca.gov/).

Cayan. D., P. Bromirski, K. Hayhoe, M. Tyree, M. Dettinger, and R. Flick. 2006b. *Projecting future sea level.* (www.climatechange.ca.gov/).

CDC (Centers for Disease Control and Protection). 2005a. "Hypothermia-related deaths – United States, 2003–2004." *Morbidity and Mortality Weekly Report* 54: 173–175.

CDC. 2005b. "Heat-related mortality–Arizona, 1993–2002, and United States, 1979–2002." *Morbidity and Mortality Weekly Report* 54: 628–630.

Chung et al. 2006. *Progress on Incorporating Climate Change into Management of California's Water Resources.* California Department of Water Resources.

Colwell, R., and J. Patz. 1998. *Climate, Infectious Disease and Health: An Interdisciplinary Perspective.* American Academy of Microbiology.

Constable, J., A. Guenther, D. Schimel, and R. Monson. 1999. "Modeling changes in VOC emission in response to climate change in the continental United States." *Global Change Biology* 5: 791–806.

Davis, R., P. Knappenberger, P. Michaels, and W. Novicoff. 2003. "Changing heat-related mortality in the United States." *Environmental Health Perspectives* 111: 1712–1718.

Delworth, T. et al. 2005. "GFDL's CM2 global coupled climate models - Part 1: Formulation and simulation characteristics." Accepted for publication in the *Journal of Climate,* April 2005.

Doering, O. C. et al. 2002. *Effects of Climate Change and Variability on Agricultural Production Systems.* Kluwer Academic Publishers. Boston.

Donaldson, G., W. Keatinge, and S. Nayha. 2003. "Changes in summer temperature and heat-related mortality since 1971 in North Carolina, South Finland, and Southern England." *Environmental Research* 91: 1–7.

Dreschler, D. M., N. Motallebi, M. Kleeman, D. Cayan, K. Hayhoe, L. S. Kalkstein, N. Miller, S. Sheridan, and J. Jin. 2006. *Public health-related impacts of climate change.* (www.climatechange.ca.gov/).

Feng S., and Q. Hu. 2004. "Changes in agro-meteorological indicators in the contiguous United States: 1951–2000." *Theoretical and Applied Climatology* 78: 247–264.

Field, C., G. C. Daily, et al. 1999. *Confronting Climate Change in California Ecological Impacts on the Golden State.* The Union of Concerned Scientists and The Ecological Society of America.

Flick, R. E. 1998. "Comparison of California tides, storm surges, and mean sea level during the El Niño winters of 1982–1983 and 1997–1998." *Shore and Beach* 66(3):7–11.

Franco, G., and A. Sanstad. 2006. *Electricity Demand and Climate Change in California.* (www.climatechange.ca.gov/).

Fried, J. S., M. S. Torn, et al. 2004. "The impact of climate change on wildfire severity: A regional forecast for Northern California." *Climatic Change* 64: 169–191.

Fried et al. 2006. *Predicting the effect of climate change on wildfire severity and outcomes in California: A preliminary analysis.* (www.climatechange.ca.gov/).

Fried, J. S., and J. K. Gilless. 1999. *CFES2: The California Fire Economics Simulator Version 2 User's Guide.* University of California, Division of Agriculture and Natural Resources Publication 21580. 92 pp.

Gutierrez, A. P. 2006. *Analysis of climate effects on agricultural systems.* (www.climatechange.ca.gov/).

Hayhoe, K., D. Cayan, et al. 2004. "Emissions pathways, climate change, and impacts on California." *PNAS* 101(34): 12422–12427.

IPCC. 2001. *IPCC Third Assessment Report, Climate Change 2001: The Scientific Basis.* Intergovernmental Panel on Climate Change.

Joyce, B., et al. 2006. *Climate change impacts on water for agriculture in California: A case study in the Sacramento Valley.* (www.climatechange.ca.gov/).

Kaiser, R., C. Rubin, A. Henderson, M. Wolfe, S. Kieszak, C. Parrott, and M. Adcock. 2001. "Heat-related death and mental illness during the 1999 Cincinnati heat wave." *The American Journal of Forensic Medicine and Pathology* 22: 303–307.

Kilbourne E. M. 2002. "Heat-related illness: Current status of prevention efforts." *American Journal of Preventative Medicine* 22: 328–329.

Kleeman, M., and Dan Cayan. 2006. *Impact of Climate Change on Meteorology and Regional Air Quality In California.* Interim Report to ARB. January

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2005. "Trends in Snowfall versus Rainfall in the Western United States." *J. Climate,* in review.

Knowles, N., and D. R. Cayan. 2004. "Elevational dependence of projected hydrologic changes in the San Francisco estuary and watershed." *Climatic Change* 62: 319–336.

Körner, C., R. Asshoff, O. Bignucolo, S. Hättenschwiler, S. G. Keel, S. Peláez-Riedl, S. Pepin, R. Siegwolf, and G. Zotz. 2005. "Carbon Flux and Growth in Mature Deciduous Forest Trees Exposed to Elevated CO_2." *Science* 309:1360–1362.

Kuminoff, N. V., A. D. Sokolow and D. A. Sumner. 2001. Farmland Conversion: Perceptions and Realities. Agricultural Issues Center, Issues Brief No 16.

Lenihan, J. M., R. Drapek, et al. 2003. "Climate change effects on vegetation distribution, Carbon, and Fire in California." *Ecological Applications* 13(6): 1667–1681.

Lenihan et al. 2006. *The response of vegetation distribution, ecosystem productivity, and fire in California to future climate scenarios simulated by the MC1 dynamic vegetation model.* (www.climatechange.ca.gov/).

Liang, X., D. P. Lettenmaier, E. Wood, and S. J. Burges. 1994. "A simple hydrologically based model of land surface water and energy fluxes for general circulation models." *Journal of Geophysical Research* 99: 14,415–414,428.

Liang, X., D. P. Lettenmaier, and E. F. Wood. 1996. "One-dimensional statistical dynamic representation of subgrid spatial variability of precipitation in the two-layer variable infiltration capacity model." *Journal of Geophysical Research* 101: 21,403–421,422.

Lund, J. R., et al. Climate Warming & California's Water Future. 2003. California Energy Commission: Sacramento. 1–251. This is appendix VII in www.energy.ca.gov/pier/final_project_reports/500-03-058cf.html.

McCarty, J. P. 2001. "Ecological Consequences of Recent Climate Change." *Conservation Biology* 15: 320–331.

McGeehin, M. A., and M. Mirabelli. 2001. "The Potential Impacts of Climate Variability and Change on Temperature-Related Morbidity and Mortality in the United States." *Environmental Health Perspectives* 109 (Supplement 2): 185–189.

McKenzie, D., Z. Gedalof, D. L. Peterson, P. Mote. 2004. "Climatic change, wildfire, and conservation." *Conservation Biology* 18: 890–902.

Medellin, J., J. Harou, M. Olivares, J. Lund, R. Howitt, S. Tanaka, M. Jenkins, and T. Zhu. 2006. *Climate warming and water supply management in California.* (www.climatechange.ca.gov/).

Meehl, G. A. et al. 2005. "How much more Global Warming and Sea Level Rise." *Science* 307: 1769–1772.

Mendelsohn, R. 2003. A California model of climate change impacts on timber markets. Appendix XII in *Global climate change and California: Potential implications for ecosystems, health, and the economy.* www.energy.ca.gov/pier/final_project_reports/500-03-058cf.html. 26 pages.

Miller, N. L., J. Jin, K. Hayhoe, M. Auffhammer, and A. Sanstad. 2005. *Heat Extremes and Energy Demand.* Presented at Second Annual Climate Change Research Conference, Sacramento, California. September 15.

Miller, N. L., and N. J. Schlegel. 2006. *Climate Change Science Report to the Governor: Climate Change Projected Santa Ana Fire Weather Occurrence.* (www.climatechange.ca.gov/).

Moritz, M., and S. Stephens. 2006. *Fire and Sustainability: Considerations for California's Altered Future Climate.* (www.climatechange.ca.gov/).

Mote P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. "Declining snowpack in western North America." *Bulletin of the American Meteorological Society* 86: 39–49.

Mott, J., P. Meyer, D. Mannino, S. Redd, E. Smith, C. Gotway-Crawford, and E. Chase. 2002. "Wildland forest fire smoke: Health effects and intervention evaluation, Hoopa, California, 1999." *Western Journal of Medicine* 176: 157–165.

Mount, J., and R. Twiss. 2005. "Subsidence, sea level rise, and seismicity in the Sacramento-San Joaquin Delta." *San Francisco Estuary and Watershed Science* 3(1): 1–18.

Nakicenovic, N. et al. 2000. *Special Report on Emissions Scenarios.* Intergovernmental Panel on Climate Change.

Naughton, M., A. Henderson, M. Mirabelli, R. Kaiser, J. Wilhelm, S. Kieszak, C. Rubin, and M. McGeehin. 2002. "Heat-related mortality during a 1999 heat wave in Chicago." *American Journal of Preventive Medicine* 22: 221–227.

NRC (National Research Council of the National Academies). 2001. *Global Air Quality: An Imperative for Long-Term Observational Strategies.* National Academy Press, Washington, D.C., pp. 10–13. www.nap.edu/books/0309074142/html/.

NRC (National Research Council of the National Academies). 2004. *Air Quality Management in the United States.* National Academy Press, Washington, D.C. pp. 16, 277–278. www.nap.edu/books/0309089328/html.

Pope, V. D., M. L. Gallani, P. R. Rowntree, and R. A. Stratton. 2000. "The impact of new physical parametrizations in the Hadley Centre climate model: HadAM3. *Climate Dynamics* 16: 123–146.

Prather, M. et al. 2003. "Fresh air in the 21st century?" *Geophys. Res. Lett.* 30(2): 1100. doi:10.1029/2002GL016285.

Stephens, G. L. 2005. "Cloud Feedbacks in the Climate System: A Critical Review." *Journal of Climate* American Meteorological Society. 18: 237–273.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. "Changes toward earlier streamflow timing across Western North America." *Journal of Climate* 18: 1136–1155.

U. S. Energy Information Administration, U. S. Dept. of Energy, State Energy Price and Expenditure Series. 2005.

USEPA (U.S. Environmental Protection Agency). 1991. *Environmental Investments: The Cost of a Clean Environment: A Summary, Report of the Administrator.* Island Press, Washington, D.C. December.

Vanrheenen, N. T. et al. "Potential implications of PCM climate change scenarios for Sacramento-San Joaquin river basin hydrology and water resources." *Climatic Change* 2004. 62: 257–281.

Vicuña 2006. *Predictions of Climate Change Impacts on California Water Resources Using CalSim-II: A Technical Note.* (www.climatechange.ca.gov/).

Vicuña et al. 2006. *Climate change impacts on high elevation hydropower generation in California's Sierra Nevada: A case study in the Upper American River.* (www.climatechange.ca.gov/).

Washington, W. M., J. W. Weatherly, G. A. Meehl, A. J. Semtner, T. W. Bettge, A. P. Craig, W. G. Strand, J. Arblaster, V. B. Wayland, R. James, and Y. Zhang. 2000. "Parallel climate model (PCM) control and 1% per year CO_2 simulations with a 2/3 degree ocean model and a 27 km dynamical sea ice model." *Clim. Dyn.* 16: 755–774.

Weiskopf, M., H. Anderson, S. Foldy, L. Hanrahan, K. Blair, T. Torok, and P. Rumm. 2002. "Heat wave morbidity and mortality, Milwaukee, Wis. 1999 vs 1995: An improved response?" *American Journal of Public Health* 92: 830–833.

Westerling, A., and B. Bryant. 2006. *Climate change and wildfire in and around California: Fire modeling and loss modeling.* (www.climatechange.ca.gov/).

Wigley, T. M. L. 2005. "The Climate Change Commitment." *Science* 307: 1766–1769.

Wood, A. W., E. P. Maurer, et al. 2002. "Long-range experimental hydrologic forecasting for the eastern United States." *Journal of Geophysical Research-Atmospheres* 107(D20): 4429.

Yao, H., and A. Georgakakos. 2001. "Assessment of Folsom Lake response to historical and potential future climate scenarios 2. Reservoir management." *Journal of Hydrology* 249(1–4): 176–196.

APPEAL EXHIBIT K

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COMMENTARY

The Innovation

The rising threats of wildland-urban interface fires in the era of climate change: The Los Angeles 2025 fires

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Received: January 13, 2025; Accepted: February 1, 2025; Published Online: February 4, 2025; https://doi.org/10.1016/j.xinn.2025.100835

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Citation: Qiu M., Chen D., Kelp M., et al., (2025). The rising threats of wildland-urban interface fires in the era of climate change: The Los Angeles 2025 fires. The Innovation 6(5), 100835.

The Los Angeles metropolitan area, home to over 18 million residents, has been surrounded by multiple fast-growing fires since January 7, 2025. As of January 23, these fires are estimated to have burned over 50,000 acres of land and destroyed at least 16,000 structures. Over 180,000 people have been ordered to evacuate, and at least 27 people are reported to have died in these fires. Preliminary estimates suggest that the economic loss of the Los Angeles 2025 fires could exceed 250 billion US dollars. Figure 1 shows the main areas affected by the current wildfires, a comparison with previous major wildfires, and their impacts on air quality.

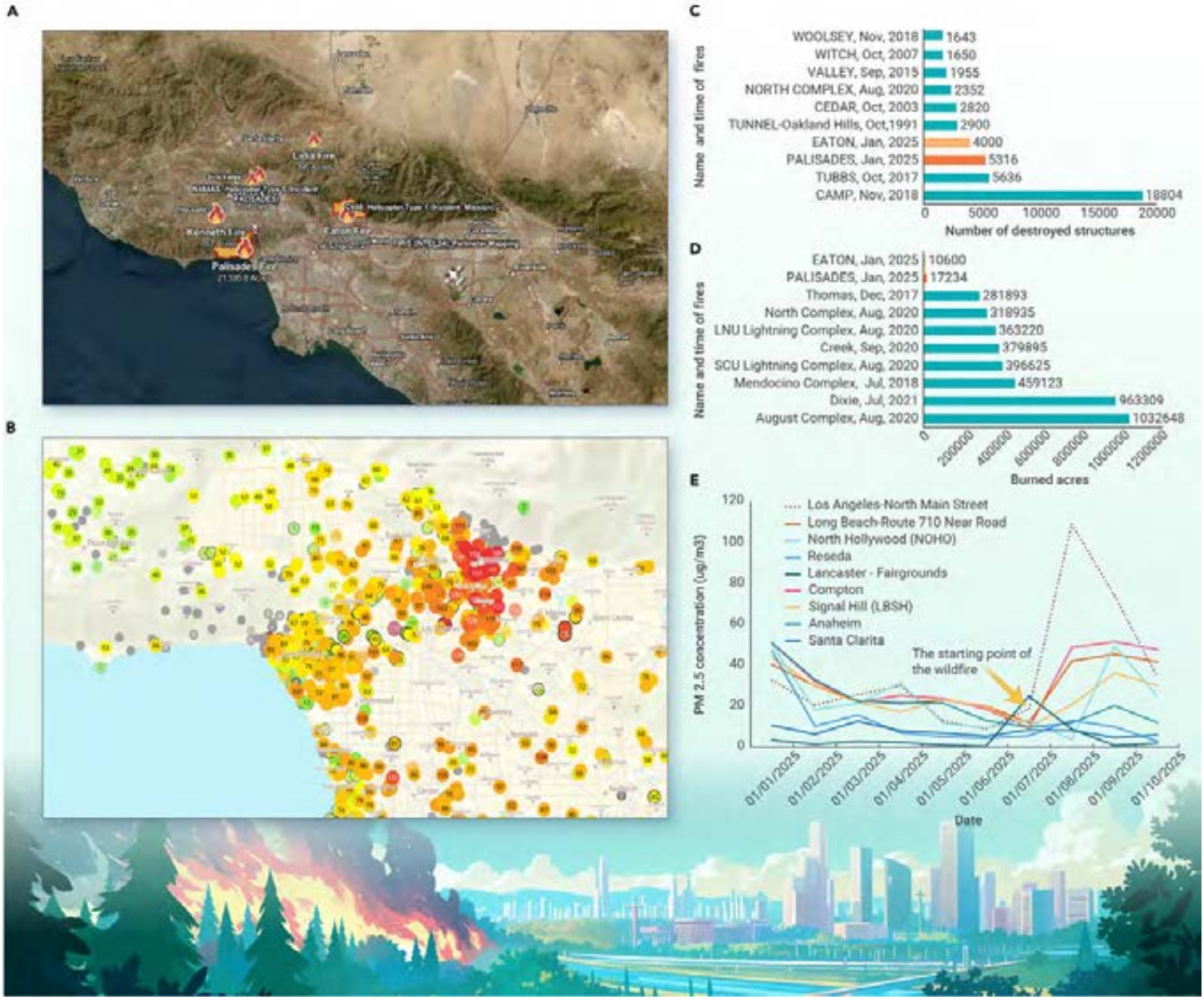

Figure 1. 2025 Los Angeles wildfires and impacts (A) Burned areas as of January 13 (data source: CalFire). (B) 7-day average PM2.5 air quality index in the Los Angeles metropolitan area from January 5 to 11 (data source: PurpleAir). (C) Comparison with the eight most destructive wildfires in California's history. (D) Comparison with the eight wildfires with the largest burned area in California's history (estimates as of January 23). (E) PM2.5 concentrations (mg/m^3) measured at monitoring sites in Los Angeles (data source: https://www.epa.gov/outdoor-air-quality-data/download-daily-data).

These fires are only the latest examples of record-breaking fires in the western US and fire-prone regions worldwide. What sets the 2025 Los Angeles fires apart, however, is their proximity to densely populated urban areas. These fires are occurring in areas extremely close to where people live—areas that are also known as the wildland-urban interface (WUI). Because of the fire point locations, these WUI fires are particularly damaging to nearby property and communities, making it difficult for people to evacuate effectively. As of January 23, the Los Angeles fires are already ranked as some of the most destructive fires in terms of the number of structures destroyed in California's history, despite its smaller burned area compared to past fires (Figures 1C and 1D).

WUI fires are increasing throughout the US, mainly driven by two reasons. First, the WUI is expanding as land-use planning has pushed houses closer to forested areas. The number of houses within wildfire boundaries in the US has doubled since the 1990s.[1] In California alone, the number of WUI houses increased by 244,000 in 2020 compared to 2010. Both Pacific Palisades and Altadena—two of the most heavily impacted communities during the 2025 Los Angeles fires—are located in the WUI, according to the US Forest Service. WUI expansions have also increased fire ignition risks from human activities. Second, the warming climate has significantly increased fuel aridity and fire weather risks, which in turn have increased the likelihood of fires in the western US. The 2025 Los Angeles fires are fueled by extreme wind conditions, with wind speeds exceeding 100 miles per hour in certain areas. These strong and dry winds, known as Santa Ana Winds in Southern California, originate from inland areas and often occur in autumn and winter. While these wind patterns are a natural phenomenon in Southern California, they increasingly overlap with hot and dry weather conditions due to climate change, and this dangerous combination creates the perfect conditions for wildfires to spread.[2]

Wildfires also create substantial damage beyond the immediate fire perimeters. Smoke generated by fires can travel far distances and negatively influence physical and mental health outcomes (Figures 1B and 1E). WUI fires might be particularly damaging to human health, as combustions of building materials release large quantities of smoke with high amounts of toxic elements (e.g., heavy metals) to population centers downwind. Beyond the direct effects on air quality, health, and economic losses, wildfires also release large quantities of greenhouse gases, which further amplify the existing climate feedback, accelerate global warming, and lead to more frequent extreme weather events in the future.

Southern California is not the only place in the world that is experiencing rising threats from WUI fires. In the summer of 2024 alone, two devastating fires also occurred in Portugal and Greece. The Greece wildfires occurred only 22 miles from its capital city, Athens. Global landscape fires (which include wildfires, agricultural fires, and prescribed burning) are estimated to lead to over 1.5 million deaths each year and are projected to continue to rise in future climate.[3] While the global mortality estimates associated with WUI fires remain unclear, the health impacts of WUI fires have emerged as an important concern given the rapid increase in burned areas of WUI fires despite a decline in total fire-burned areas.[4]

Mitigating the threats of WUI fires (and wildfires in general) requires ambitious, innovative, and comprehensive changes in a variety of public policies related to infrastructure, air quality, public health, land management, public awareness, and insurance markets. However, existing policies either do not account for the changing wildfire risks or were designed under outdated fire regimes. For example, air pollution from wildfires is often exempted from air quality regulations under the Clean Air Act, as these events are viewed as beyond the control of local jurisdictions. However, with the increasing contributions of wildfires to ambient air pollution, air quality regulations that consider wildfire pollution impacts and measures to protect public health during wildfire episodes may become necessary. Leading climate change impact assessment tools, such as those models that are used to calculate the monetary benefits of carbon emissions reductions, rarely account for the damages from climate-induced wildfires, despite a recent study finding that this damage is likely among the most costly consequences of a warming climate in the US.[5] Energy infrastructures are also widely unprepared for the rising wildfire risks—utility companies in California have already spent billions of dollars to upgrade the energy infrastructure due to the increasing wildfire risks, with the cost inequitably distributed across consumers.

These challenges highlight the urgency of global climate actions to reduce greenhouse gas emissions to limit future warming levels and ultimately control wildfire risks. At the same time, policymakers should prioritize designing and implementing adaptation strategies to increase the community's resilience to WUI fires and better protect property and human health. These strategies may include expanding fuel treatment measures (such as mechanical thinning and prescribed fires) in WUI, mitigating potential fire risk factors (such as aged power infrastructure), building defensible spaces, house hardening, and improving indoor filtration to protect health when fire and smoke do occur.

REFERENCES

1. Radeloff, V.C., Mockrin, M.H., Helmers, D. et al. (2023). Rising wildfire risk to houses in the United States, especially in grasslands and shrublands. Science 382:702–707. DOI:https://doi.org/10.1126/science.ade9223.
2. Goss, M., Swain, D.L., Abatzoglou, J.T. et al. (2020). Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. Environ. Res. Lett. 15:094016. DOI:https://doi.org/10.1088/1748-9326/ab83a7.
3. Xu, R., Ye, T., Huang, W. et al. (2024). Global, regional, and national mortality burden attributable to air pollution from landscape fires: a health impact assessment study. Lancet 404:2447–2459. DOI:https://doi.org/10.1016/S0140-6736(24)02251-7.
4. Tang, W., He, C., Emmons, L. et al. (2024). Global expansion of wildland-urban interface (WUI) and WUI fires: insights from a multiyear worldwide unified database (WUWUI). Environ. Res. Lett. 19:044028. DOI:https://doi.org/10.1088/1748-9326/ad31da.
5. Qiu, M., Li, J., Gould, C. et al. (2024). Mortality burden from wildfire smoke under climate change (National Bureau of Economic Research), p. w32307. DOI:https://doi.org/10.3386/w32307.

ACKNOWLEDGMENTS

G.H. acknowledges support from NASA (#80NSSC23K0028), NSF (#2101044), and the Stony Brook OVPR Seed Grant. M.D.Y. acknowledges support from NIH (#R01ES036566). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.

APPEAL EXHIBIT L

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Global expansion of wildland-urban interface (WUI) and WUI fires: insights from a multiyear worldwide unified database (WUWUI)

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IOP Publishing Environ. Res. Lett. 19 (2024) 044028 https://doi.org/10.1088/1748-9326/ad31da

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RECEIVED
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REVISED
26 February 2024

ACCEPTED FOR PUBLICATION
8 March 2024

PUBLISHED
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LETTER

Global expansion of wildland-urban interface (WUI) and WUI fires: insights from a multiyear worldwide unified database (WUWUI)

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Keywords: wildland-urban interface, fire, burned area, future projection, MODIS, fire counts, CESM2

Supplementary material for this article is available online

Abstract

Fires in the wildland-urban interface (WUI) are an important issue globally. To understand the change of WUI, we develop a 9 km worldwide unified wildland-urban interface database for 2001–2020 with Random Forest models and satellite data. We find that WUI has been increasing in all populated continents from 2001 to 2020 and the global relative increase is 24%, with the largest relative increase (∼59%) over Africa. Global total fire counts decrease by 10% from 2005 to 2020, whereas the WUI fraction of fire counts increases by 23%. The global total burned area decreases by 22% from 2005 to 2020, whereas the WUI fraction of burned area increases by 35%. These are mainly due to the expansion of WUI area. On all the populated continents, the WUI fractions of fire counts are higher than the WUI fractions of burned area, implying that WUI fires tend to have smaller sizes than wildland fires. We also project future WUI changes for the years 2030 and 2040, together with the projection of future fire burned area under different shared socioeconomic pathways (SSP) scenarios in the Community Earth System Model version 2 (CESM2). The projected global WUI fraction (excluding Antarctica and the oceans) is 5.9% in 2040 compared to 4.8% in 2020. The global WUI fraction of burned area is projected to increase from now to 2040 under most scenarios analyzed in this study, unless the WUI area stays at the 2020 level together with the projected burned area under SSP4-4.5. This study is a first step to understanding the changes of WUI fires at the global scale and demonstrates a growing importance of WUI fires. The global multi-year WUI and WUI fire datasets developed in this study can facilitate future work quantifying the impacts of WUI fires on air quality and climate.

1. Introduction

The wildland-urban interface (WUI) is the geographic area where anthropogenic urban land use and wildland vegetation come into contact or intermingle (e.g. chAs-Amil *et al* 2013, Modugno *et al* 2016, Masoudvaziri *et al* 2021). The technical definition of WUI has not been unequivocally determined (Stewart *et al* 2009, Mell *et al* 2010, Platt 2010). Different definitions have been used in different countries/regions (e.g Theobald and Romme 2007, Galiana-Martina *et al* 2011, Herrero-Corral *et al* 2012, Chas-Amil *et al* 2013, Price and Bradstock 2014, Thomas and Butry 2014, Modugno *et al* 2016, Johnston and Flannigan 2017, Miranda *et al* 2020, Sarricolea *et al* 2020). A widely used WUI definition is the USA Federal Register definition (USDA and USDI 2001), which includes Intermix and Interface. Intermix refers to areas with ⩾6.18 houses per km^2 and ⩾50% cover of wildland vegetation; while Interface refers to areas with ⩾6.18 houses per km^2 and <50% cover of vegetation located <2.4 km from an area ⩾5 km^2 in size that is ⩾75% vegetated. The USA Federal Register definition does not consider industrial structures and infrastructure while some other WUI definitions include all artificial surfaces (e.g. Modugno *et al* 2016, Johnston and Flannigan 2017).

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The concept of WUI has existed for decades in the fire management community (e.g. Davis 1990, Ewert 1993, Stewart *et al* 2007, Jaffe *et al* 2020). However, our understanding of WUI fires and their impacts on atmospheric chemistry and air quality is limited compared to that of wildland fires. Fires in WUI are an important issue and require more research and better understanding for a few reasons. (1) In WUI, there are more human ignitions compared to wildland (Price *et al* 2014, Radeloff *et al* 2018). (2) WUI fires are closer to humans and properties and can cause significant destruction and economic losses. As an example, the 2003 Cedar Fire in California destroyed more than 3000 homes (Manzello *et al* 2014). (3) WUI fires can have severe impacts on air quality and public health due to emissions of some toxic species. As an example, the emission factor of dioxins is around five orders of magnitude greater for urban fuels compared with biomass (Holder *et al* 2023). (4) WUI fires will become even more important in the future. For instance, previous studies indicated WUI is expanding in some countries or regions (e.g. Liu *et al* 2015, Radeloff *et al* 2018). Fire activities are also projected to increase due to climate change (e.g. Pechony and Shindell 2010, Flannigan *et al* 2013, Veira *et al* 2016, Abatzoglou *et al* 2019, Di Virgilio *et al* 2019, Tang *et al* 2023). Moreover, WUI expansion and fire activity increase can have a combined effect that is greater than the sum of their individual effects if WUI expands into regions of higher wildfire risk than the existing WUI (Liu *et al* 2015).

WUI fire studies have focused on just a few countries and regions in the past, even though WUI fire is a global issue (Bento-Gonçalves *et al* 2020). Recently, a global WUI map has been developed for the year 2020 at a 10 m spatial resolution (Schug *et al* 2023a, 2023b; hereafter the Schug-WUI map) to study the global distribution of WUI and WUI fires. The Schug-WUI map uses the USA Federal Register definition and is developed based on remote sensing-derived datasets (Zanaga *et al* 2021, Pesaresi and Politis 2022). However, the Schug-WUI map is only available for one specific year. To understand the changes in WUI and WUI fires, we develop a multiyear worldwide unified wildland-urban interface (WUWUI) database for 2001–2020 (Tang *et al* 2024) by leveraging Random Forest models, the Schug-WUI map, and other satellite and socioeconomic data (the WUWUI dataset can be accessed through https://zenodo.org/records/10703310). The WUWUI database provides a globally consistent picture for applications such as consistently tracking the change of global WUI, understanding WUI fires at the global scale, and intercomparing temporal evolution of WUI and WUI fires among different regions. The WUWUI dataset developed here is not intended to replace, but to complement, the existing WUI datasets. WUI maps developed specifically for regions of interest with high spatial resolution are needed when focusing on a specific region or local details. In addition, we project future WUI changes for the years 2030 and 2040, and analyze them together with projected future fire burned area under different shared socioeconomic pathways (SSP) scenarios in the Community Earth System Model version 2 (CESM2).

2. Data and methods

2.1. Data used to develop the WUWUI database

Several MODIS satellite products and population density data (summarized in table 1) are used as input predictors for the Random Forest models (table 1). These variables are chosen to include relevant information to WUI or can reflect the features of WUI, and meanwhile avoid redundant information. For the land cover type data, we calculate the fractions of each land cover type as predictors within 9 km × 9 km grids, and the mean distance between urban pixels within each grid as another predictor. For the other MODIS variables above, we calculate the means and standard deviations of each variable as predictors within each 9 km × 9 km grid (figure S1). To reflect impacts of potential spatial connections between neighboring grids, we also use the values of the aforementioned variables from the surrounding area as additional predictors for a given grid. I.e. in addition to calculating the aforementioned variables within the 9 km × 9 km, we also calculated the same variables within an 18 km × 18 km grid centered with the 9 km × 9 km grid. (figure S1).

2.2. Random forest models

We use the Schug-WUI map for 2020 (Schug *et al* 2023b) as the 'truth' map, and MODIS satellite products and population data as predictors to train a series of Random Forest models for individual continents. The WUWUI map is developed at the 9 km × 9 km (1/12 degree latitude × 1/12 degree longitude) resolution as a tradeoff between spatial resolution, performance of the Random Forest models, and usefulness for applications (e.g. typical global climate and air quality modeling). Based on our tests, at the 4 km resolution, the model performance is not as good as it is at 9 km resolution, whereas at 12 km resolution, the model performance is close to 9 km resolution. Therefore, we decide to use 9 km resolution to perform analyses. Therefore, the Schug-WUI map and predictors are all aggregated to 9 km × 9 km resolution to develop Random Forest models which predict WUI area fraction in each 9 km × 9 km grid. 75% (25%) of the data for each continent are randomly selected as a training (test) set. We use the Grid Search algorithm to optimize a few other relevant model hyper-parameters (e.g. tree numbers, the number of predictor variables to select at random for each decision split, and the threshold for the minimum size of a leaf node) to achieve the best model performance. The finally selected values for

Table 1. Satellite and population data used as input for the Random Forest models.

Data product	Versions	Spatial resolution	Temporal resolution	Variables from satellite products used	Derived variables used in the Random Forest model
MODIS/Terra + Aqua Land Cover Type Yearly	MCD12Q1 v6.1 (Friedl and Sulla-Menashe 2019)	500 m	Yearly	LC_Type1	landcover_fraction_in_the_grid_Barren, landcover_fraction_in_the_grid_Forests, landcover_fraction_in_the_grid_Savannas, landcover_fraction_in_the_grid_Urban, landcover_fraction_in_the_grid_Wetlands, landcover_fraction_in_the_grid_Croplands, landcover_fraction_in_the_grid_Grasslands, landcover_fraction_in_the_grid_Shrublands, landcover_fraction_in_the_grid_Water, urban_pixel_mean_distance_in_the_grid, urban_pixel_total_distance_in_the_grid, landcover_fraction_in_the_surrounding_grid_Barren, landcover_fraction_in_the_surrounding_grid_Forests, landcover_fraction_in_the_surrounding_grid_Savannas, landcover_fraction_in_the_surrounding_grid_Urban, landcover_fraction_in_the_surrounding_grid_Wetlands, landcover_fraction_in_the_surrounding_grid_Croplands, landcover_fraction_in_the_surrounding_grid_Grasslands, landcover_fraction_in_the_surrounding_grid_Shrublands, landcover_fraction_in_the_surrounding_grid_Water, urban_pixel_mean_distance_in_the_surrounding_grid, urban_pixel_total_distance_in_the_surrounding_grid
MODIS/Terra + Aqua Albedo Daily	MCD43A3 v6.1 (Schaaf and Wang 2015)	500 m	Daily data averaged for summer mean	Albedo_WSA_Band2, Albedo_WSA_Band5	mean_of_Albedo_Band2_in_the_grid, standard_deviation_of_Albedo_Band2_in_the_grid, mean_of_Albedo_Band5_in_the_grid, standard_deviation_of_Albedo_Band5_in_the_grid

(Continued.)

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Table 1. (Continued.)

Data product	Versions	Spatial resolution	Temporal resolution	Variables from satellite products used	Derived variables used in the Random Forest model
MODIS/Terra Vegetation Indices 16-Day	MOD13Q1 v6.1 (Didan 2015)	250 m	16 days data averaged for summer mean	250 m 16 d NDVI	mean_of_summer_time_NDVI_in_the_grid, standard_deviation_of_summer_time_NDVI_in_the_grid
MODIS/Terra Vegetation Continuous Fields Yearly	MOD44B v6.1 (DiMiceli *et al* 2015)	250 m	Yearly	Percent_Tree_Cover, Percent_NonTree_Vegetation, Percent_NonVegetated	mean_of_Percent_Tree_Cover_in_the_grid, standard_deviation_of_Percent_Tree_Cover_in_the_grid, mean_of_Percent_NonTree_Vegetation_in_the_grid, standard_deviation_of_NonTree_Vegetation_in_the_grid, mean_of_Percent_NonVegetated_in_the_grid, standard_deviation_of_Percent_NonVegetated_in_the_grid, mean_of_Percent_Tree_Cover_in_the_surrounding_grid, standard_deviation_of_Percent_Tree_Cover_in_the_surrounding_grid, mean_of_Percent_NonTree_Vegetation_in_the_surrounding_grid, standard_deviation_of_NonTree_Vegetation_in_the_surrounding_grid, mean_of_Percent_NonVegetated_in_the_surrounding_grid, standard_deviation_of_Percent_NonVegetated_in_the_surrounding_grid
Population density	GHS-POP (Schiavina *et al* 2022)	1 km	Yearly	Population density	Mean_Population_Density_in_the_grid

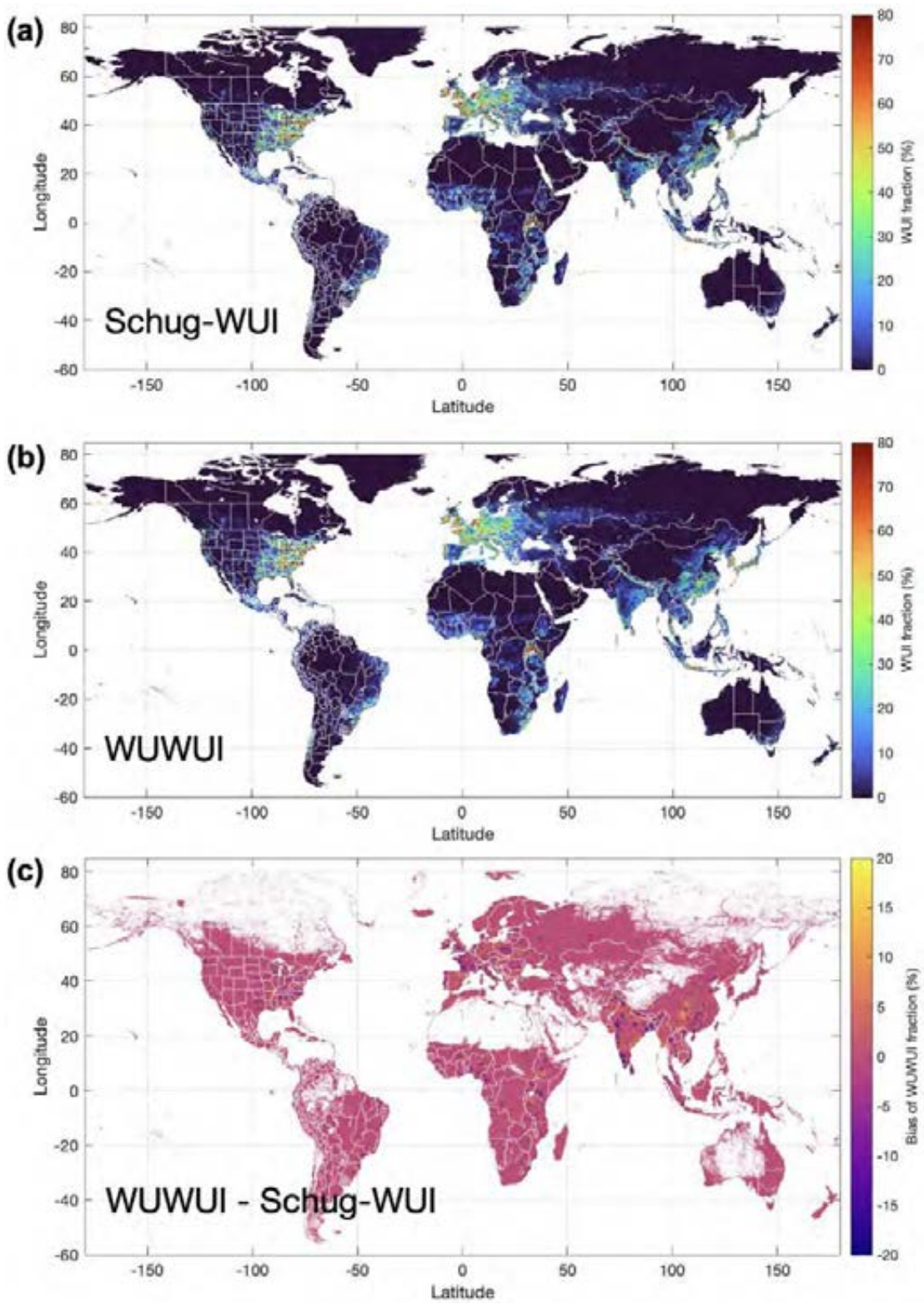

Figure 1. (a) Wildland-urban interface (WUI) fraction (%) in 2020 from the Schug-WUI map for 2020 (Schug *et al* 2023b) and (b) worldwide unified wildland-urban interface (WUWUI) data. (c) Difference (%) between (a) and (b) calculated by WUI fraction from WUWUI minus WUI fraction from the Schug-WUI map. Grids in which WUI fraction is extremely low (<0.01%) in both WUWUI and Schug-WUI map are not shown.

these parameters are 100, 44, and 3, respectively. The performance of the Random Forest models can be found in table S1. A comparison between WUWUI and Schug-WUI maps in 2020 is shown in figure 1. Overall, the Random Forest models perform well in all the six continents and the WUWUI and Schug-WUI maps agree well for the year 2020. We then use the models to predict WUI area fraction for the years of 2001, 2005, 2010, 2015, and 2020. The developed WUWUI maps are shown in figures 1 and 2.

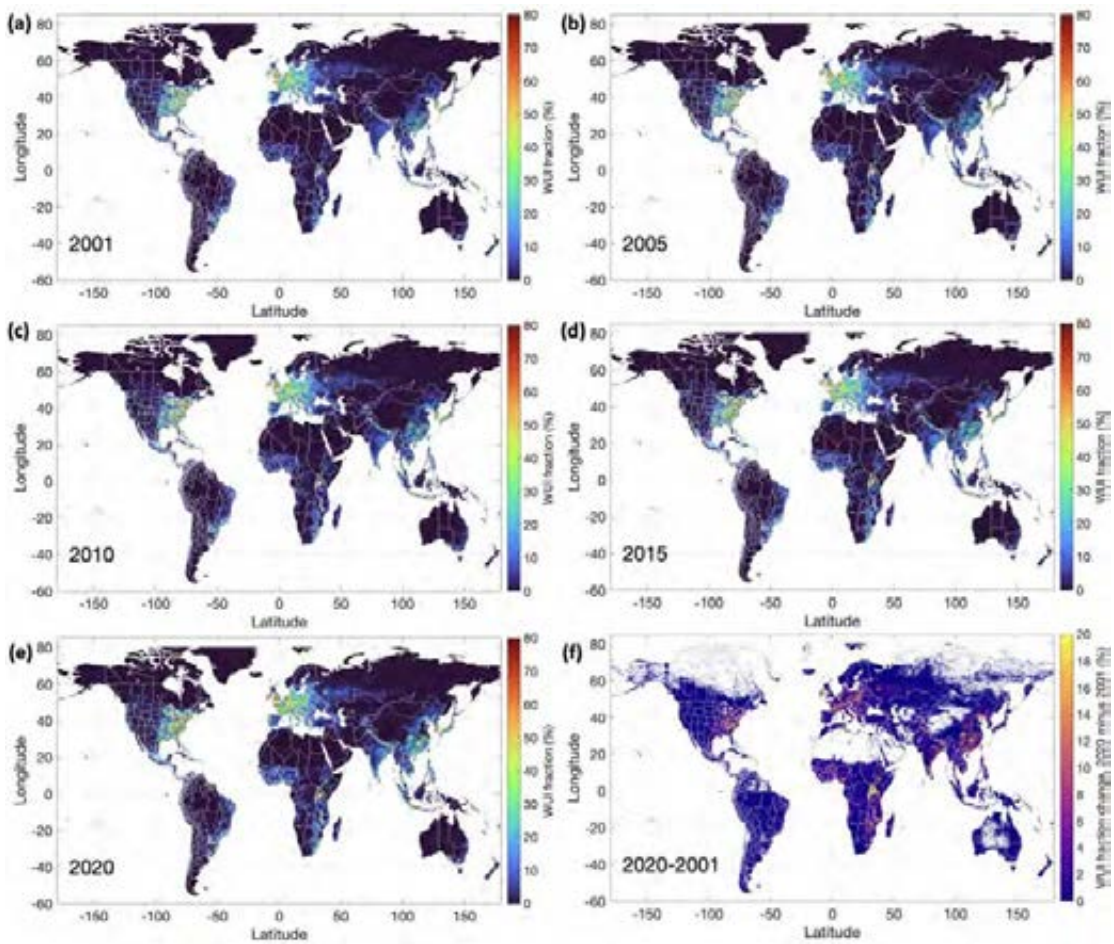

Figure 2. Wildland-urban interface (WUI) fraction (%) in (a) 2001, (b) 2005, (c) 2010, (d) 2015, and (e) 2020 from WUWUI data. (f) Wildland-urban interface (WUI) fractional (%) change from 2001 to 2020, calculated by WUI fraction in 2020 minus WUI fraction in 2001. Grids in which WUI fraction is extremely low (<0.01%) in both 2001 and 2020 are not shown.

2.3. Fire count and burned area data from MODIS

We compare the 2005, 2010, 2015, and 2020 WUWUI maps with MODIS active fire count products (NASA/University of Maryland 2002, Davies *et al* 2009) and burned area products (MODIS/Terra + Aqua Burned Area Monthly L3 Global 500 m; MCD64A1 v061; Giglio *et al* 2021) to quantify the evolution of WUI fires. Unlike WUI, fire detections and burned area have large interannual variability (e.g. Tang *et al* 2023). To address interannual variability and emphasize the trends, we use 3 year averages centered on the years of WUI data for fire counts and burned area to represent the mean fire activity. 2001 is not included due to MODIS data availability. Total fire count and burned area are calculated for each 9 km × 9 km grid. The fire counts (burned area) within WUI for a given grid is calculated by multiplying the total fire counts (burned area) within the entire grid by the WUI fraction of that grid. This calculation implicitly assumes the distribution of fire count and burned area within a grid is independent from the WUI distribution in the grid. This method is adequately accurate at 9 km based on our sensitivity analysis (see the discussion and figure S2 in the supplement for details).

2.4. Future projection of fire burned area in CESM2

The SSPs were established to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation (O'Neill *et al* 2017, Riahi *et al* 2017), which has been used in the IPCC-6 report. SSP1-2.6 (sustainable development) is the low end of the range of future forcing pathways in SSP. SSP2-4.5 is a scenario that represents the middle part of the range of future forcing pathways. SSP5-8.5 is the unmitigated baseline scenario, representing the high end of the range of future pathways.

CESM2 is a widely-used state-of-the-art community Earth system model that has components of ocean, atmosphere, land, sea-ice, land-ice, river, and wave models (Danabasoglu *et al* 2020). The fire scheme in CESM2 provides estimates of fire burned area. The modeled burned area in CESM2 is affected by climate and weather conditions, vegetation composition and structure, and human activities. In general, burned area estimation in fire models is subject

to uncertainties such as uncertainties from population density and land use and land cover change (Li *et al* 2019). Nevertheless, fire simulation in CESM2 still outperforms several other fire models in a previous comparison (Li *et al* 2019). The fire simulation in CESM2 falls in the range of observation-based fire emission inventories (Tang *et al* 2023).

The horizontal resolution for modeled burned area is 1.25° × 0.9° (longitude × latitude). The burned area data from CESM2 under the scenarios SSP1-2.6, SSP2-4.5, and SSP5-8.5 for 2020, 2030, and 2040 are used. More details on these simulations can be found in Tang *et al* (2023). Following the analyses with burned area data from MODIS, we use 3 year averages centered on the years of WUI data of fire counts and burned area.

2.5. Future projection of WUI

The WUI changes at continental scale fit well with linear trends from 2001 to 2020 (R^2 for the linear regressions vary from 0.97 to 0.99; figure S3). Therefore, we use the linear trends to project WUI fractions for 2030 and 2040 by continent. We first show the linear-projection-based results as a possible scenario for the future, assuming the WUI fractions will grow at the same rate from 2020 to 2040 as it was in the past 20 years.

Even though the WUI change in the past 20 years follows very well the linear trends, the WUI change in the future is still uncertain. To address this uncertainty, we assess 3 WUI change scenarios: (1) the WUI fraction is projected to increase from 2020 to 2040 following the same linear trend as 2001–2020; (2) the WUI fraction is projected to increase from 2020 to 2030 following the same trend as 2001–2020, and then stay at the 2030 level; (3) the WUI fraction at 2030 and 2040 will be the same as 2020. These three WUI change scenarios cover a range of possible different WUI conditions in the near future.

After projecting WUI to 2030 and 2040, we then calculate the projected fraction of burned area within WUI. The WUI fraction of burned area is calculated by multiplying the projected total burned area within a grid with the projected WUI fraction of the grid at the resolution of 1.25° × 0.9°. To reduce the uncertainty from the coarse spatial resolution of CESM model results, we apply scaling factors to correct the systematic bias due to coarse resolution (See Supplement for details).

3. Evaluation of WUWUI

We evaluate the WUWUI map against the Schug-WUI map for the year 2020, which shows very high spatial consistency (figure 1). The 2001–2020 WUI data for the conterminous United States (CONUS) downloaded from the Forest Service Research Data Archive, United States Department of Agriculture (Radeloff *et al* 2023) (hereafter USDA WUI for short) was developed following the Federal Register definition of WUI (USDA and USDI 2001), which is also used for the Schug-WUI and WUWUI maps. Therefore, here we compare WUWUI with USDA WUI map over CONUS at 9 km × 9 km resolution (figures 3 and S4). The spatial patterns of WUWUI and USDA WUI maps agree well for the years 2010 and 2020 (figure 3), given that the USDA WUI map and WUWUI were developed via different methods. USDA WUI was developed through integrating U.S. Census and USGS National Land Cover Data with geographic information systems, while the Schug-WUI map (basis for WUWUI) uses European Space Agency World Cover dataset (Zanaga *et al* 2021) for land cover and the GHS-POP dataset (Schiavina *et al* 2022) for population. The WUWUI map also agrees well with another global WUI dataset developed in Chen *et al* (2022) for the year 2020 (figure S5).

4. Change of global WUI from 2001 to 2020

The most noticeable increase in the WUI fraction from 2001 to 2020 is seen in the East Africa (figure 2(f)). The global average fraction (excluding the Antarctic and oceans) of WUI increases from 3.9% to 4.8% during 2001–2020 (figure 4(a)). The continental mean fraction of WUI is the largest in Europe (increasing from 12.4% in 2001 to 14% in 2020), followed by North America (increasing from 5.9% in 2001 to 6.5% in 2020). As for the WUI area (figure S6), North America and Asia has the largest WUI area in 2020 (1.43×10^{12} m^2 and 1.43×10^{12} m^2, respectively), followed by Europe (1.37×10^{12} m^2). In 2001, continental averaged fraction of WUI is the lowest in Africa (2.2%), but in 2020, South America has the lowest WUI fraction (2.6%). WUI has been increasing in all continents from 2001 to 2020 with different increase rates (figure 4(a)). The largest absolute increase of the WUI fraction from 2001 to 2020 occurs over Europe (0.08%/year) and Africa (0.07%/year) (figure 4(a)). In terms of the relative change (i.e. difference in the WUI fraction between 2020 and 2001 divided by the WUI fraction in 2001), Africa and Asia have the most significant increase. From 2001 to 2020, the WUI fraction in Africa has increased by 59% compared to the 2001 value.

The rapid increase in the WUI fraction combined with the large area of the Africa continent points toward an urgent need to understand and address WUI expansion and associated issues (e.g. WUI fires) in Africa. Similarly, the WUI fraction (and area) in Asia has increased by 33% in the past 20 years compared to the 2001 value. The lowest relative increase from 2001 to 2020 is seen in North America (∼11%) where the WUI fraction is already relatively high.

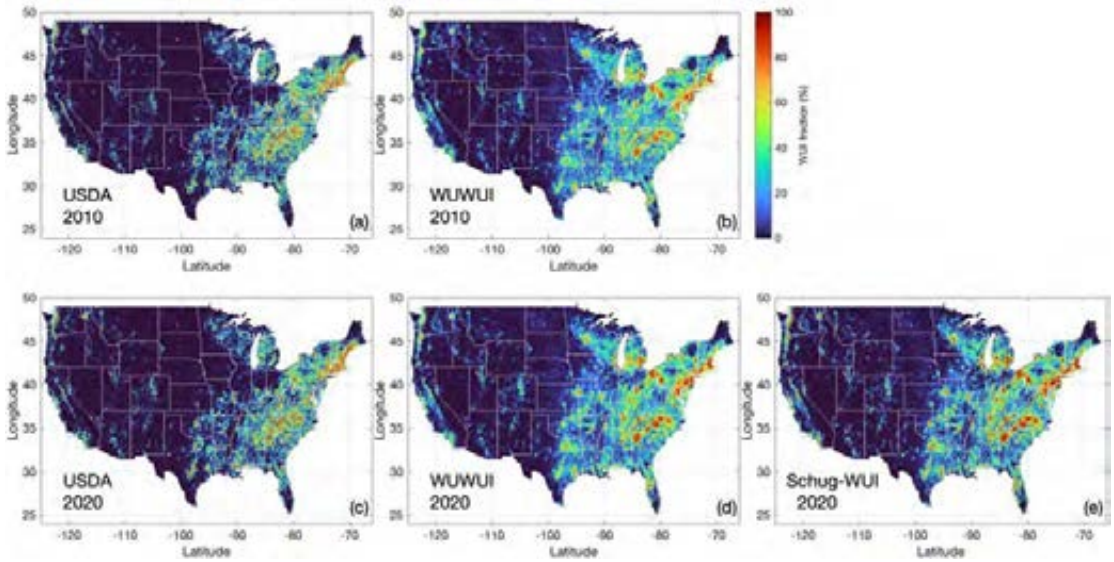

Figure 3. Wildland-urban interface (WUI) fraction (%) in 2010 from (a) USDA WUI map and (b) WUWUI database. Wildland-urban interface (WUI) fraction (%) in 2020 from (c) USDA WUI map (Radeloff *et al* 2022), (d) WUWUI database, and (e) the Schug-WUI map (Schug *et al* 2023b).

5. Changes of global WUI fires from 2005 to 2020

Globally, the WUI fraction of fire counts (figure 4(b); defined as fire counts within WUI divided by total fire counts) and the WUI fraction of burned area (figure 4(c); defined as burned area within WUI divided by total burned area) increase from 2005 to 2020. The global total fire counts and burned area decreased from 2005 to 2020 (figure S7) mainly driven by the decreased wildland fire counts and burned area (figure S9). Similar to the overall global trend, fire count and burned area per unit WUI area also decreased (figure S8), even though the total WUI fire counts and burned area increased (figure S9). Therefore, the increase of WUI fractions of fire counts and burnt area is driven by the expansion of WUI area in the past 20 years.

Specifically, the global total fire counts decrease by 10% from 2005 to 2020, whereas the WUI fraction of fire counts from 2005 to 2020 increases from 3.5% to 4.3% (i.e. relative increase of 23%). The global total burned area decreases by 22% from 2005 to 2020, whereas the WUI fraction of burned area from 2005 to 2020 increases from 1.7% to 2.3% (i.e. relative increase of 35%). The global increase of the relative importance/fraction of WUI fires (in terms of both fire count and burned area) suggests an urgent need to understand and quantify WUI fires and their impacts globally, especially in those understudied regions such as Africa.

Over Africa, the WUI fractions of both fire counts and burned area increase from 2005 to 2020 with absolute increases of 1.1% and 0.65% and relative increases of 41% and 36%, respectively, even though the total fire counts and burned area in Africa decrease from 2005 to 2020 (figure S7). The relative increase of WUI fractions of both fire counts (41%) and burned area (36%) are close to the relative increase of WUI fraction itself (46%) in Africa during 2005–2020. This suggests that the increased WUI fraction of fire activities may be mainly driven by the increase of WUI areas. The fire trends in Africa largely contribute to the global trends as Africa has the highest fire count and burned area (figure S7). Over Europe, the WUI fractions of both fire counts and burned area also increase from 2005 to 2020 with absolute increases of 2.6% and 1.5% and relative increases of 25% and 29%, respectively, even though the total fire counts and burned area in Europe decreased from 2005 to 2020 (figure S7). In Asia and South America, however, the WUI fractions of fire counts and burned area increase from 2005 to 2015 but decrease from 2015 to 2020. The overall trends are still positive. In Oceania, there is no clear trend in either the WUI fractions of fire counts or burned area from 2005 to 2020 (figure S7).

In North America, the WUI fraction of fire counts (8%–9%) is higher than the WUI area fraction (∼6%). This implies that fire risk is relatively high in WUI regions compared to non-WUI regions over North America as fire counts represents fire occurrence. The WUI fraction of fire counts increase from 2005 (8.2%) to 2010 (9.2%) and stays almost constant from 2010 (9.2%) to 2020 (9.1%). However, the WUI fraction of burned area increases during 2010–2020. In 2015, the WUI fraction of burned area is 4.5%, whereas it is 4.9% in 2020. These changes of fire counts and burned area indicate that the WUI fires in North America may become larger and more destructive from 2015 to 2020.

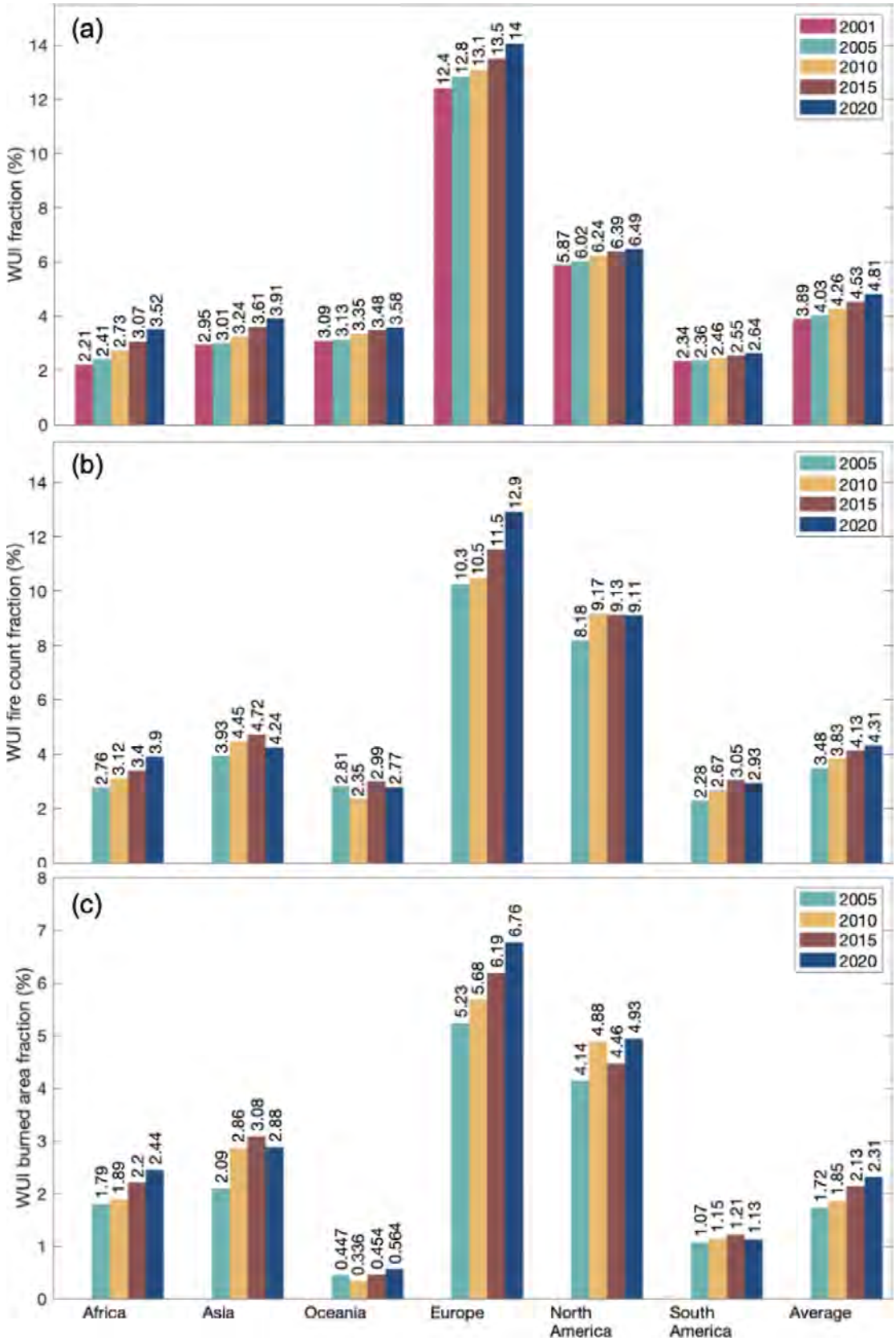

Figure 4. (a) Wildland-urban interface (WUI) fraction (%) in 2001, 2005, 2010, 2015, and 2020 by continents. (b) Fraction of fire counts within WUI (%) in 2005, 2010, 2015, and 2020 by continents. (c) Fraction of burned area within WUI (%) in 2005, 2010, 2015, and 2020 by continents. 2001 is not included in (b) and (c) due to data availability.

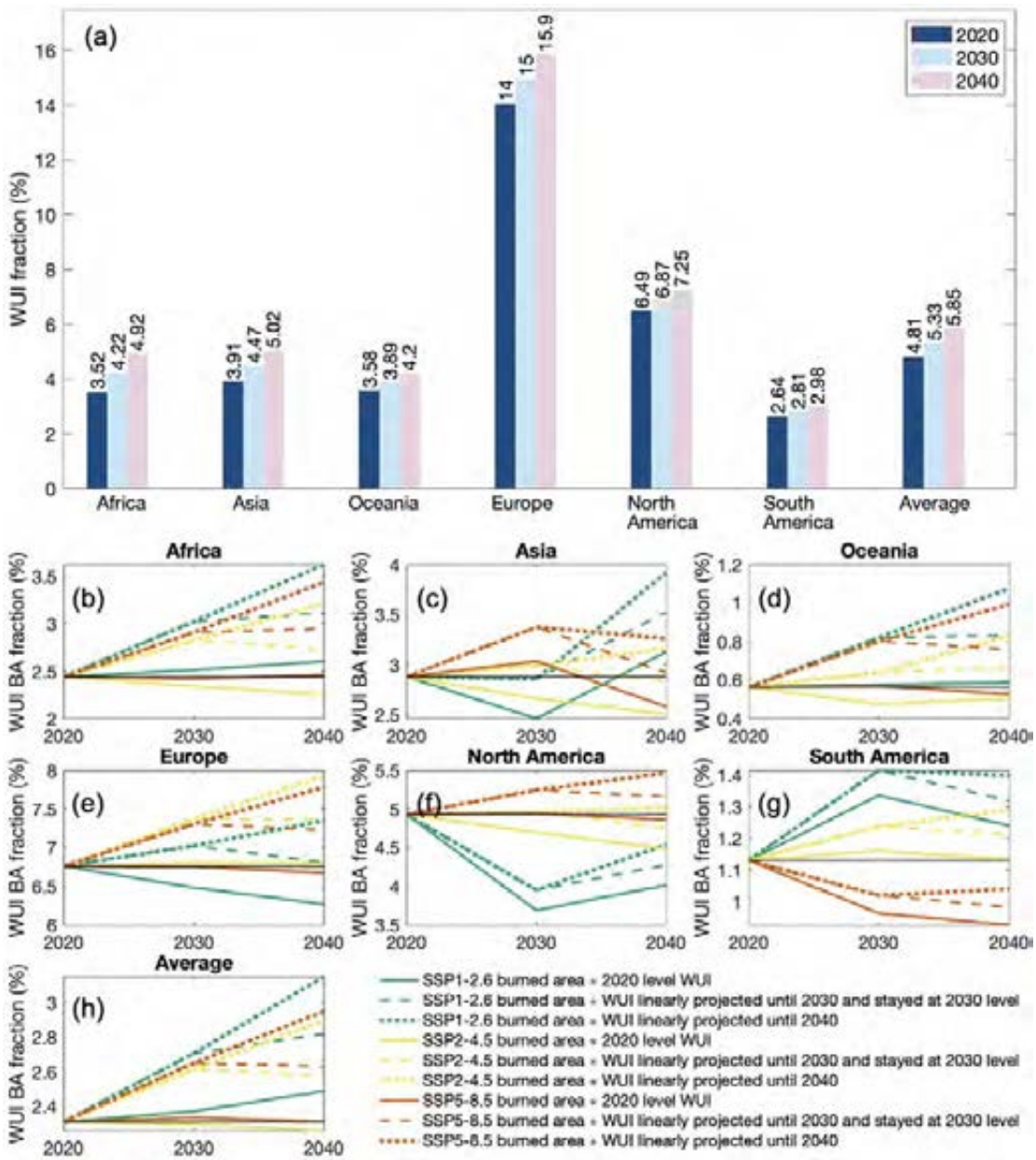

Figure 5. (a) Wildland-urban interface (WUI) fraction (%) in 2020, 2030, and 2040 by continents. (b)–(h) Fraction of burned area within WUI (%) in 2020, 2030, and 2040 under different scenarios. The fraction of burned area within WUI (%) calculated with CESM2 burned area is normalized to the fraction of burned area within WUI (%) in 2020 calculated with MODIS burned area observations (shown in figure 4). An unnormalized version is shown in figure S11.

In all six continents, the WUI fraction of fire counts is higher than that of burned area. Globally, the WUI fraction of burned area (∼2%) is smaller than that of fire count (3%–4%), implying that WUI fires tend to have smaller sizes than wildland fires. This is reasonable as fire management and fire suppression activities can be different in WUI versus wildland (e.g. Stewart *et al* 2007, Jaffe *et al* 2020). WUI fires could also have different duration due to fire management (e.g. Masoudvaziri *et al* 2021) which impacts MODIS detection of active fire counts. The different changes in WUI fractions of fire counts and burned area can reflect changes in human activities and practice. In terms of the WUI fire trends, the relative increase of the WUI fraction of burned area (35%) is larger than that of fire counts (24%) globally, indicating WUI fires may become larger in size in global average sense.

6. Trends of future WUI and WUI fires at continental scale

Following the linear trends, the global average WUI fraction is projected to be 5.3% (5.9%) in 2030 (2040) if the WUI expansion follows the historical trend (figure 5(a)). Europe and North America are projected to still have the highest WUI fractions (15.9% and 7.3% in 2040, respectively). In 2040, the WUI fraction

in Africa (4.9%) is projected to be higher than that in Oceania (4.2%) and close to that in Asia (5.0%).

We combine the three future WUI scenarios with the three future burned area scenarios. The projected burned area is shown in figure S10. Globally (figure 5(h)), the only scenario under which the WUI fraction of burned area is projected to slightly decrease (2.26% in 2040) is the one with future WUI staying at the 2020 level combined with SSP2-4.5 burned area as burned area is projected to decrease under SSP2-4.5 (figure S10). Under all the scenarios with the WUI fraction linearly increasing from 2020 to 2030 or 2040, the WUI fraction of burned area will increase (2.58%–3.15% in 2040). This suggests that WUI fires will likely become more significant in the future. The trends under different scenarios vary across individual continents. In Africa, Europe, and Oceania, the WUI changes tend to play a more important role in determining the trends of future WUI fractions of burned area, whereas in Asia, North America, and South America, the future changes of burned area appear to play a more important role.

7. Conclusions

We developed a 9 km WUWUI database for 2001–2020. We then analyzed the WUI area fraction from WUWUI together with MODIS fire counts and burned area to understand the change of WUI fires. In addition, we analyzed projected changes of WUI fraction and WUI fires in 2030 and 2040. The main conclusions are as follows:

- The global average fraction (excluding the Antarctic and oceans) of WUI is 4%–5% during 2001–2020. The continental average fraction of WUI is the largest in Europe (12%–14%) and the lowest in Oceania (2%–3%).
- WUI area fraction has been increasing in all populated continents from 2001 to 2020 and the global relative increase is 24% (increased from 3.9% in 2001 to 4.8% in 2020). The largest relative increase of WUI from 2001 to 2020 occurs over Africa (59%). The lowest relative increase occurs in North America (11%), where the WUI fraction is already relatively high.
- Global total fire counts and burned area decrease by 10% and 22% from 2005 to 2020, respectively, whereas the WUI fractions of fire counts and burned area increase by 23% and 35%, respectively, mainly due to the WUI area expansion.
- Globally, the WUI fraction is projected to increase from now (4.8%) to 2040 (5.9%). The global WUI fraction of burned area is projected to increase from now to 2040 under most scenarios analyzed in this study. This indicates that WUI and WUI fires would become more important in the future. More research is needed on WUI fires and their impacts on air quality and climate.

This study is a first step to quantify the changes of WUI fires at the global scale, which paves the road for future studies of their impacts on air quality and climate. WUI fires can interact with many key elements such as air quality, urban meteorology, and health/property exposure. Given the global expansion of WUI areas and the increasing importance of WUI fires, understanding WUI fires is becoming crucial in quantifying fire characteristics in the Earth system, interactions between fires and human activities, and fire impacts on air quality and health.

Data availability statement

The WUWUI dataset can be accessed through https://zenodo.org/records/10703310 (Accessed 12 March 2023). The MCD12Q1 data is available at https://lpdaac.usgs.gov/products/mcd12q1v061/ (Accessed 16 November 2023). The MCD43A3 data is available at https://lpdaac.usgs.gov/products/mcd43a3v061/ (Accessed 17 November 2023). The MOD13Q1 data is available at https://lpdaac.usgs.gov/products/mod13q1v061/ (Accessed 17 November 2023). The MOD44B data is available at https://lpdaac.usgs.gov/products/mod44bv061/ (Accessed 31 May 2023). The GHS Population Grid Multitemporal (1975–2030)—OBSOLETE RELEASE data can be accessed through https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_POP_GLOBE_R2022A/ (Accessed 17 November 2023). The MCD64A1 data is available at https://lpdaac.usgs.gov/products/mcd64a1v061/ (Accessed 17 November 2023). The FIRMS fire count data is available at https://firms.modaps.eosdis.nasa.gov/active_fire/ (Accessed 17 November 2023). CESM2 model results can be accessed at https://esgf-node.llnl.gov/projects/cmip6/ (Accessed 17 November 2023).

Acknowledgments

This project is supported by NOAA Atmospheric Chemistry, Carbon Cycle and Climate (AC4) Program (Award Number: NA22OAR4310204). Cenlin He was partially supported by NOAA's Climate Program Office's Modeling, Analysis, Predictions, and Projections Program (MAPP), Grant# NA20OAR4310421. This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977. We thank Schug *et al* for their global WUI map for 2020. We thank Radeloff *et al* for the WUI dataset of conterminous United States (CONUS) downloaded from the Forest Service Research Data Archive, United States Department of Agriculture. We thank the MODIS MCD12Q1, MCD43A3, MOD13Q1, MOD44B, MCD64A1, and active fire teams for the satellite data. We thank GHS-POP team for the population data.

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References

Abatzoglou J T, Williams A P and Barbero R 2019 Global emergence of anthropogenic climate change in fire weather indices *Geophys. Res. Lett.* **46** 326–36

Bento-Gonçalves A and Vieira A 2020 Wildfires in the wildland-urban interface: key concepts and evaluation methodologies *Sci. Total Environ.* **707** 135592

chAs-Amil M L, Touza J and García-Martínez E 2013 Forest fires in the wildland–urban interface: a spatial analysis of forest fragmentation and human impacts *Appl. Geogr.* **43** 127–37

Chen B, Wu S, Jin Y, Song Y, Wu C, Venevsky S, Xu B, Webster C and Gong P 2022 Wildfire risk for global wildland–urban interface (WUI) areas (https://doi.org/10.21203/rs.3.rs-2147308/v1)

Danabasoglu G *et al* 2020 The community earth system model version 2 (CESM2) *J. Adv. Model. Earth Syst.* **12** 1–35

Davies D K, Ilavajhala S, Wong M M and Justice C O 2009 Fire information for resource management system: archiving and distributing MODIS active fire data *IEEE Trans. Geosci. Remote Sens.* **47** 72–79

Davis J B 1990 The wildland-urban interface: paradise or battleground? *J. For.* **88** 26–31

Di Virgilio G, Evans J P, Blake S A P, Armstrong M, Dowdy A J, Sharples J and McRae R 2019 Climate change increases the potential for extreme wildfires *Geophys. Res. Lett.* **46** 8517–26

Didan K 2015 MOD13Q1 MODIS/terra vegetation indices 16-day L3 global 250m SIN grid V006 *NASA EOSDIS Land Processes DAAC* (available at: https://doi.org/10.5067/MODIS/MOD13Q1.006) (Accessed 05 February 2023)

DiMiceli C, Carroll M, Sohlberg R, Kim D, Kelly M and Townshend J 2015 MOD44B MODIS/terra vegetation continuous fields yearly L3 global 250m SIN grid V006 *NASA EOSDIS Land Processes DAAC* (available at: https://doi.org/10.5067/MODIS/MOD44B.006) (Accessed 05 February 2023)

Ewert A W 1993 The wildland-urban interface: introduction and overview *J. Leis. Res.* **25** 1–5

Flannigan M, Cantin A S, De Groot W J, Wotton M, Newbery A and Gowman L M 2013 Global wildland fire season severity in the 21st century *For. Ecol. Manage.* **294** 54–61

Friedl M and Sulla-Menashe D 2019 MCD12Q1 MODIS/terra+aqua land cover type yearly L3 global 500m SIN grid V006 *NASA EOSDIS Land Processes DAAC* (available at: https://doi.org/10.5067/MODIS/MCD12Q1.006) (Accessed 05 February 2023)

Galiana-Martin L, Herrero G and Solana J 2011 A wildland–urban interface typology for forest fire risk management in Mediterranean areas *Landsc. Res.* **36** 151–71

Giglio L, Justice C, Boschetti L and Roy D 2021 MODIS/terra+aqua burned area monthly L3 global 500m SIN grid V061 *NASA EOSDIS Land Processes DAAC* (available at: https://doi.org/10.5067/MODIS/MCD64A1.061) (Accessed 05 August 2023)

Herrero-Corral G, Jappiot M, Bouillon C and Long-Fournel M 2012 Application of a geographical assessment method for the characterization of wildland–urban interfaces in the context of wildfire prevention: a case study in western Madrid *Appl. Geogr.* **35** 60–70

Holder A L, Ahmed A, Vukovich J M, Rao V and Amon C H 2023 Hazardous air pollutant emissions estimates from wildfires in the wildland urban interface *PNAS Nexus* **2** pgad186

Jaffe D A, O'Neill S M, Larkin N K, Holder A L, Peterson D L, Halofsky J E and Rappold A G 2020 Wildfire and prescribed burning impacts on air quality in the United States *J. Air Waste Manage. Assoc.* **70** 583–615

Johnston L M and Flannigan M D 2017 Mapping Canadian wildland fire interface areas *Int. J. Wildland Fire* **27** 1–14

Li F *et al* 2019 Historical (1700–2012) global multi-model estimates of the fire emissions from the Fire Modeling Intercomparison Project (FireMIP) *Atmos. Chem. Phys.* **19** 12545–67

Liu Z, Wimberly M C, Lamsal A, Sohl T L and Hawbaker T J 2015 Climate change and wildfire risk in an expanding wildland–urban interface: a case study from the Colorado front range corridor *Landsc. Ecol.* **30** 1943–57

Manzello S L 2014 Special issue on wildland–urban interface (WUI) fires *Fire Technol.* **50** 7–8

Masoudvaziri N, Bardales F S, Keskin O K, Sarreshtehdari A, Sun K and Elhami-Khorasani N 2021 Streamlined wildland-urban interface fire tracing (SWUIFT): modeling wildfire spread in communities *Environ. Modell. Softw.* **143** 105097

Mell W E, Manzello S L, Maranghides A, Butry D and Rehm R G 2010 The wildland–urban interface fire problem–current approaches and research needs *Int. J. Wildland Fire* **19** 238–51

Miranda A, Carrasco J, González M, Pais C, Lara A, Altamirano A, Weintraub A and Syphard A D 2020 Evidence-based mapping of the wildland-urban interface to better identify human communities threatened by wildfires *Environ. Res. Lett.* **15** 094069

Modugno S, Balzter H, Cole B and Borrelli P 2016 Mapping regional patterns of large forest fires in wildland–urban interface areas in Europe *J. Environ. Manage.* **172** 112–26

NASA/University of Maryland 2002 MODIS hotspot/active fire detections, data set, MODIS rapid response project *NASA/GSFC (producer)* (University of Maryland, Fire Information for Resource Management System (distributors)) (available at: http://maps.geog.umd.edu,)

O'Neill B C *et al* 2017 The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century *Glob. Environ. Change* **42** 169–80

Pechony O and Shindell D 2010 Driving forces of global wildfires over the past millennium and the forthcoming century *Proc. Natl Acad. Sci. USA* **107** 19167–70

Pesaresi M and Politis P 2022 *GHS Built-up Surface Grid, Derived From Sentinel2 and Landsat, Multitemporal (1975–2030)* (European Commission, Joint Research Center)

Platt R V 2010 The wildland–urban interface: evaluating the definition effect *J. For.* **108** 9–15

Price O and Bradstock R 2014 Countervailing effects of urbanization and vegetation extent on fire frequency on the wildland urban interface: disentangling fuel and ignition effects *Landsc. Urban Plan.* **130** 81–88

Radeloff V C *et al* 2018 Rapid growth of the US wildland-urban interface raises wildfire risk *Proc. Natl Acad. Sci.* **115** 3314–9

Radeloff V C, Helmers D P, Mockrin M H, Carlson A R, Hawbaker T J and Martinuzzi S 2022 *The 1990-2020 Wildland-Urban Interface of the Conterminous United States - Geospatial Data* 3rd edn (Forest Service Research Data Archive) (https://doi.org/10.2737/RDS-2015-0012-3)

Radeloff V C, Helmers D P, Mockrin M H, Carlson A R, Hawbaker T J and Martinuzzi S 2023 *The 1990–2020 Wildland-urban Interface of the Conterminous United States–Geospatial Data* 4th edn (Forest Service Research Data Archive) (https://doi.org/10.2737/RDS-2015-0012-4)

Riahi K *et al* 2017 The shared socioeconomic path ways and their energy, land use, and greenhouse gas emissions implications: an overview *Glob. Environ. Change* **42** 153–68

Sarricolea P, Serrano-Notivoli R, Fuentealba M, Hernández-Mora M, De la Barrera F, Smith P and Meseguer-Ruiz Ó 2020 Recent wildfires in Central Chile: detecting links between burned areas and population exposure in the wildland urban interface *Sci. Total Environ.* **706** 135894

Schaaf C and Wang Z 2015 MCD43A3 MODIS/terra+aqua BRDF/albedo daily L3 global—500m V006 *NASA EOSDIS Land Processes DAAC* (available at: https://doi.org/10.5067/MODIS/MCD43A3.006) (Accessed 05 February 2023)

Schiavina M, Freire S and MacManus K 2022 GHS-POP R2022A—GHS population grid multitemporal (1975–2030)—obsolete release (European Commission, Joint Research Centre)

Schug F *et al* 2023a The global wildland–urban interface *Nature* **621** 94–99

Schug F *et al* 2023b Map of the global wildland-urban interface (1.1) *Zenodo* (https://doi.org/10.5281/zenodo.7941460)

Stewart S I, Radeloff V C, Hammer R B and Hawbaker T J 2007 Defining the wildland–urban interface *J. For.* **105** 201–7

Stewart S I, Wilmer B, Hammer R B, Aplet G H, Hawbaker T J, Miller C and Radeloff V C 2009 Wildland-urban interface maps vary with purpose and context *J. For.* **107** 78–83 (available at: www.fs.usda.gov/research/treesearch/34152)

Tang W 2024 Worldwide Unified Wildland-Urban Interface (WUWUI) database (Version v2) *Zenodo* (https://doi.org/10.5281/zenodo.10703310)

Tang W, Tilmes S, Lawrence D M, Li F, He C, Emmons L K, Buchholz R R and Xia L 2023 Impact of solar geoengineering on wildfires in the 21st century in CESM2/WACCM6 *Atmos. Chem. Phys.* **23** 5467–86

Theobald D M and Romme W H 2007 Expansion of the US wildland–urban interface *Landsc. Urban Plan.* **83** 340–54

Thomas D S and Butry D T 2014 Areas of the US wildland–urban interface threatened by wildfire during the 2001–2010 decade *Nat. Hazards* **71** 1561–85

USDA and USDI 2001 Urban wildland interface communities within the vicinity of federal lands that are at high risk from wildfire *Fed. Regist.* **66** 751–77

Veira A, Lasslop G and Kloster S 2016 Wildfires in a warmer climate: emission fluxes, emission heights, and black carbon concentrations in 2090–2099 *J. Geophys. Res. Atmos.* **121** 3195–223

Zanaga D *et al* 2021 ESA WorldCover 10 m 2020 v100 *Zenodo* (available at: https://zenodo.org/record/5571936)

APPEAL EXHIBIT M

Rapid growth of the US wildland-urban interface raises wildfire risk

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Edited by Janet Franklin, University of California, Riverside, CA, and approved February 6, 2018 (received for review October 28, 2017)

The wildland-urban interface (WUI) is the area where houses and wildland vegetation meet or intermingle, and where wildfire problems are most pronounced. Here we report that the WUI in the United States grew rapidly from 1990 to 2010 in terms of both number of new houses (from 30.8 to 43.4 million; 41% growth) and land area (from 581,000 to 770,000 km^2; 33% growth), making it the fastest-growing land use type in the conterminous United States. The vast majority of new WUI areas were the result of new housing (97%), not related to an increase in wildland vegetation. Within the perimeter of recent wildfires (1990–2015), there were 286,000 houses in 2010, compared with 177,000 in 1990. Furthermore, WUI growth often results in more wildfire ignitions, putting more lives and houses at risk. Wildfire problems will not abate if recent housing growth trends continue.

wildfires | housing growth | sprawl | development | fragmentation

The wildland-urban interface (WUI), defined as the area where houses are in or near wildland vegetation, is the area where wildfires pose the greatest risk to people due to the proximity of flammable vegetation (1). Wildfires frequently burn houses in the WUI (2, 3), and are most difficult to fight there. Furthermore, the WUI is where people often ignite wildfires (4), and the vast majority of fires are human-caused (5). While fires are an integral part of many ecosystems and the Earth system as a whole (6), humans have changed fire regimes globally (7) and throughout the United States (5), and climate change will increase fire frequency in the future, including in the WUI (8).

The close proximity of houses and wildland vegetation does more than increase fire risk (9). As houses are built in the WUI, native vegetation is lost and fragmented (10); landscaping introduces nonnative species and soils are disturbed, causing nonnatives to spread (11); pets kill large quantities of wildlife (12); and zoonotic disease, such as Lyme disease, are transmitted (13). Thus, understanding WUI patterns and WUI growth is important with respect to wildfires and many other environmental problems.

The WUI is widespread in the United States (1, 14) and in many other parts of the world (15, 16), including Argentina (17), Australia (18), France (19), and South Africa (20). Furthermore, both the annual area burned (8, 21, 22) and fire suppression costs (23) have rapidly increased in the United States. The area burned annually nearly doubled, from an average of 18,000 km^2/y in 1985–94 to 33,000 km^2 in 2005–14 (22). Concomitantly, federal wildfire suppression expenditures tripled from $0.4 billion/y to $1.4 billion/y (23), and exceeded $2 billion in 2017.

While there is ample evidence that houses in the WUI pose problems, it is not clear how fast the WUI is growing. Overall, the US population grew by 60 million people and 29.2 million homes from 1990 to 2010, but how much of that growth occurred in the WUI is uncertain. Previous assessments of WUI growth (24, 25) analyzed only housing data up to 2000, and did not account for changes in wildland vegetation. Post-2000 housing data are important, because the United States entered a recession after 2008, accompanied by a strong downturn in the housing market. Similarly, without data on vegetation change, the major cause of WUI growth is unclear. Areas where forests are regrowing on abandoned farmland, such as in the New England states (26), could see WUI growth without any additional houses. Fundamentally, two processes can create new WUI: construction of new homes in or near existing wildland vegetation, and an increase in wildland vegetation within and near previously developed areas. The prevalence of each process is unclear.

Knowing how the WUI is growing, and why, is essential when evaluating management and policy responses (3, 8). In the United States, federal wildfire management policy prioritizes fuel treatments and the promotion of fire-adapted communities in the WUI. Local jurisdictions use a variety of land use planning tools to limit the environmental impacts of housing growth in the WUI. The importance of the WUI for the environment and for national policy, accompanied by the lack of information about WUI growth in the most recent decade, highlight the need to both assess WUI growth and identify its causes. Thus, we addressed three major questions: (i) how much has the WUI in the conterminous United States grown from 1990 to 2010; (ii) whether WUI growth is caused mainly by housing growth or by vegetation growth; and (iii) how much WUI growth has occurred within recent wildfire perimeters.

The lack of consistent, fine-resolution longitudinal housing data has been the biggest impediment to a nationwide assessment

Significance

When houses are built close to forests or other types of natural vegetation, they pose two problems related to wildfires. First, there will be more wildfires due to human ignitions. Second, wildfires that occur will pose a greater risk to lives and homes, they will be hard to fight, and letting natural fires burn becomes impossible. We examined the number of houses that have been built since 1990 in the United States in or near natural vegetation, in an area known as the wildland-urban interface (WUI), and found that a large number of houses have been built there. Approximately one in three houses and one in ten hectares are now in the WUI. These WUI growth trends will exacerbate wildfire problems in the future.

Author contributions: V.C.R., M.H.M., P.M.A., A.B.-M., V.B., T.J.H., S.M., A.D.S., and S.I.S. designed research; V.C.R., D.P.H., and H.A.K. performed research; V.C.R., D.P.H., H.A.K., V.B., T.J.H., and S.M. analyzed data; and V.C.R., H.A.K., M.H.M., P.M.A., A.B.-M., T.J.H., S.M., A.D.S., and S.I.S. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1718850115/-/DCSupplemental.

Published online March 12, 2018.

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of WUI growth. The decennial US Census provides fine-resolution housing data for 1990, 2000, and 2010, but the boundaries of the smallest units for which housing units are reported (i.e., census blocks) often shift between decades, precluding direct change analyses (27). We have developed algorithms to convert the decennial Census data at census block resolution into a consistent dataset on housing growth across the conterminous United States (Methods), which we combined with 1992, 2001, and 2011 National Land Cover Data (NLCD) on wildland vegetation: forests (classes 41–43), shrublands (classes 51 and 52), grasslands (class 71), and woody wetlands (class 90). We mapped decadal WUI change from 1990 to 2010 within 2010 census block boundaries, based on the WUI definitions in the Federal Register and our previously developed WUI mapping algorithms (1, 14), and conducted several robustness checks of our new dataset (Supporting Information). Because of concerns about housing growth and wildfire management, we calculated housing growth for 1990–2010 within WUI burned areas identified in Landsat imagery between 1990 and 2015 (22).

We found that the WUI was widespread in 2010, covering 9.5% of the conterminous United States (Fig. 1), and that the WUI grew rapidly from 1990 to 2010 in all its aspects (Fig. 2).

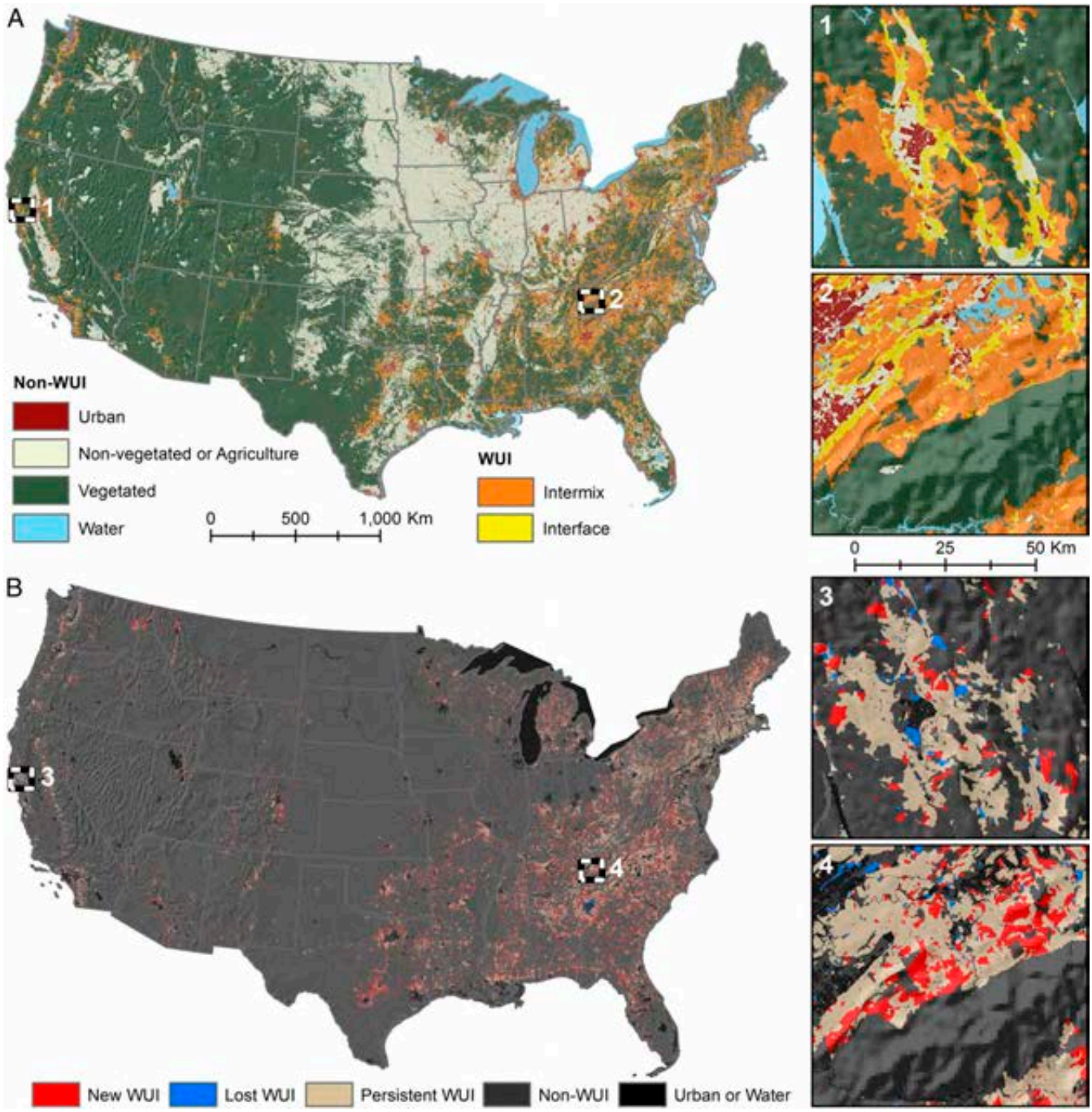

Fig. 1. The WUI in the United States was widespread in 2010 (A), as were changes in WUI area (B), for example, in and around Santa Rosa, California (1, 3), and Gatlinburg, Tennessee (2, 4), areas where wildfires destroyed many homes in 2017 and 2016, respectively.

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The number of housing units ("houses" hereinafter) in the WUI grew fastest, followed by the number of people in the WUI and then WUI area (Fig. 2B and Table S1). New WUI area totaled 189,000 km^2, an area larger than Washington State. At 33%, WUI area growth is faster than that of any of the level I land cover categories included in the NLCD (28). Increases in houses and people were also strong, with 12.7 million more houses and 25 million more people in the WUI in 2010 compared with 1990. The overall combination of more WUI area (7.2% of the conterminous United States in 1990 vs. 9.5% in 2010; Fig. 2C) and higher growth rates for both houses and people in the WUI, compared with the nationwide averages (Table S1), increased the percentage of houses (from 30.3% to 33.2%) and people (from 29.4% to 31.9%) in the WUI from 1990 to 2010 (Fig. 2C). Even though the WUI occupies less than one tenth of the land area of the conterminous United States, 43% of all new houses were built there, and 61% of all new WUI homes were built in areas that were already in the WUI in 1990 (and remained in the WUI in 2010) (Tables S1 and S2).

There are two main types of WUI: intermix WUI, the area where houses and wildland vegetation directly intermingle, and interface WUI, where settled areas abut wildland vegetation (1). We found that intermix WUI was both more extensive and expanded much more rapidly in area (from 5.6% to 7.5% of the conterminous United States from 1990 to 2010) than interface WUI (from 1.6% to 2.0%). However, interface WUI had higher housing growth rates (43% from 1990 to 2010) than intermix WUI (38%) and non-WUI areas (23%; Table S1). In absolute numbers, there were 4.7 million more houses in the intermix WUI and 8.0 million more in the interface WUI in 2010 than in 1990.

Regional differences in WUI growth were striking (Fig. 3). The highest absolute gains in WUI area occurred in the East, whereas high gains in houses and people in the WUI were most common in the South and Southwest. Absolute gains are most relevant for management agencies, because they indicate how much area and how many people and houses may require management actions; however, rapid growth often garners the most attention. Across the United States there is an interesting dichotomy in that states in the East had large absolute gains, but relatively low WUI growth rates, largely because WUI was already so widespread in 1990. In contrast, states in the northern Rockies saw much smaller absolute gains in WUI area and houses, but rapid WUI growth rates.

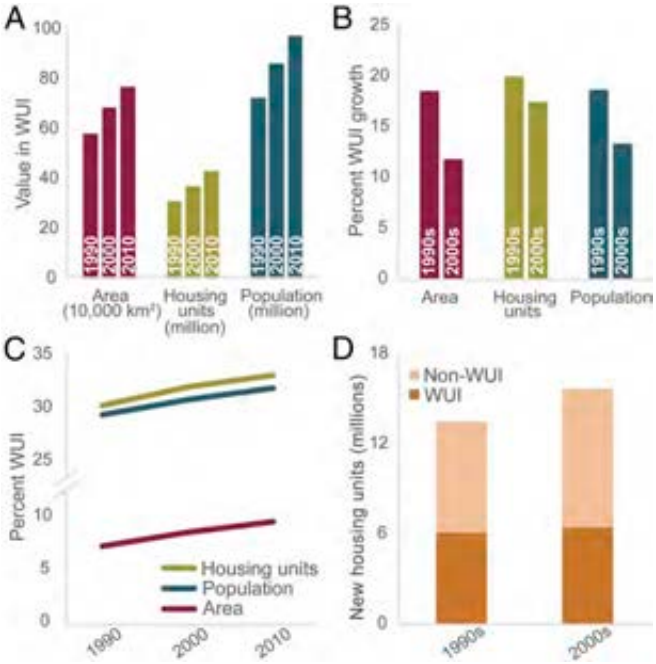

Fig. 2. WUI growth was rapid in terms of the absolute numbers of the area, houses, and people in the WUI in 1990, 2000, and 2010 (A); WUI growth rates during the 1990s and the 2000s (B); the proportion of all houses and people, as well as the land area in the WUI in 1990, 2000, and 2010 (C); and the absolute number of all new housing units within and outside the WUI during the 1990s and 2000s (D).

New WUI areas arise either when new houses are built in or near wildland vegetation or when wildland vegetation regrows in or near settled areas. Between these two possible causes, housing growth was unambiguously the main cause for new WUI areas, with increases in vegetation contributing minimally. Of all new WUI areas, 97% were caused by housing growth in sparsely settled areas, pushing these areas over the threshold of 1 house per 40 acres (6.17 homes/km^2). Only 2% of new WUI area was due to vegetation growth alone, and 1% was due to the combination of both housing and vegetation growth (Table S2). Similarly, new houses were the cause of >80% of WUI growth in all states except Delaware, the District of Columbia, Maryland, and New Jersey (Fig. S1).

Among areas that were WUI in 1990, the vast majority were still WUI in 2010, and both homes and population increased in those areas over that time (Table S2). A small proportion (6%) of the 1990 WUI areas dropped out of the WUI by 2010. Among all WUI changes (i.e., gains and losses combined), 13% of the changes in WUI area and 23% of the changes in WUI houses from 1990 to 2010 were losses. In terms of the causes of WUI area loss, reduced housing density was the most important (65.0%), whereas the loss of vegetation accounted for 32.6%. Housing density may have declined due to actual removal of housing units, or possibly due to enumeration errors in the Census data. Loss of vegetation was the dominant driver of loss of homes from the WUI (65.0%), which occurred largely in densely settled areas where additional housing development, deforestation, or fuel management may have removed wildland vegetation.

The number of houses within burned areas in the different decades is a strong indication of how much WUI growth can exacerbate wildfire problems. In 1990, there were 177,000 houses within the perimeters of the fires that occurred in the subsequent 25 y. By 2010, there were 286,000 housing units in the same fire perimeters, i.e., 109,000 more, which corresponds to 62% growth (far outpacing the average US housing growth rate of 29%). Of these new houses, those built before the wildfires occurred complicated firefighting because more houses had to be protected and more residents had to be evacuated. Similarly, houses built after fires occurred are of concern because new development in areas that burned recently, and thus are known to have a high fire risk, suggests that there is little adaptation to fire risk (2).

Our results provide compelling evidence that the WUI in the United States has grown rapidly, despite the risks that wildfires pose to homes and lives (3) and despite the other environmental problems caused by housing development in or near wildland vegetation (9). Our findings are generally in alignment with previous studies that found rapid previous WUI growth (24) and widespread potential for future WUI growth (25, 29), even though absolute numbers are not comparable because of differences in WUI definitions, datasets, and time periods (30). Furthermore, the WUI is not unique to the United States, but is widespread in many other countries as well (15, 16, 18–20). Rampant WUI growth demonstrates that the social and economic factors that together propel WUI growth are strong. WUI areas are attractive places to live because of affordability and ready access to natural settings and recreation (31). As WUI areas attract new residents, the number of houses per capita often increases as well, due to increasing rates of seasonal homeownership and declining family size (32). Indeed, despite the economic downturn after 2008, the absolute number of

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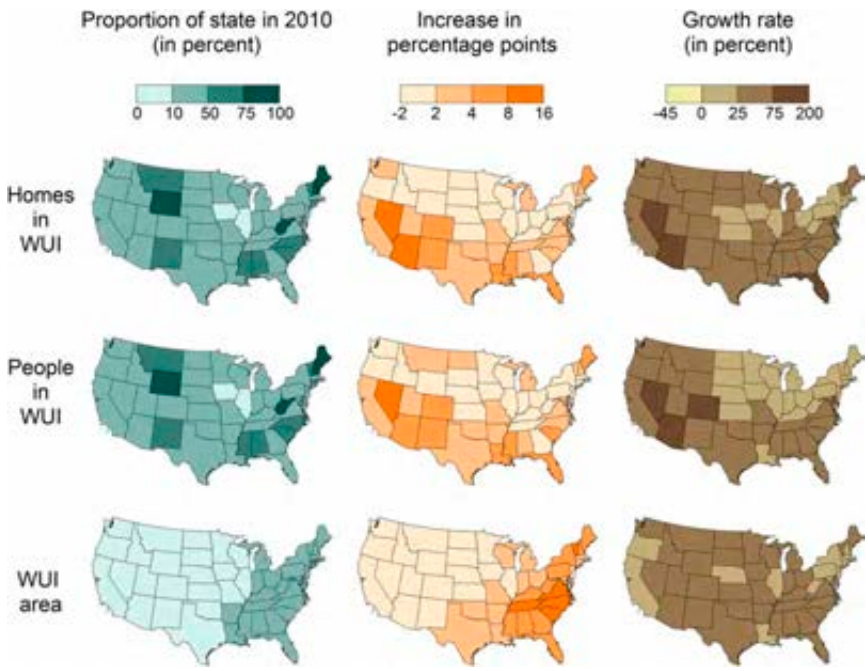

Fig. 3. WUI growth differed greatly among states, especially in the Southwest versus the Southeast, in terms of houses in the WUI, people in the WUI, and WUI area, calculated as the percentage of the state total in 2010, change in the WUI percentage from 1990 to 2010, and the growth rate (in percent) of the WUI from 1990 to 2010. Only the District of Columbia had negative absolute growth in the WUI (homes, people, and area). Fig. S2 summarizes these metrics at the county level.

houses built in the WUI, and in the United States as a whole, was higher between 2000 and 2010 than between 1990 and 2000 (Table S1). Demographic trends do not suggest slower future WUI growth. Furthermore, climate change projections indicate that conditions favorable for wildfires will occur more frequently in the future (8). Thus, increased wildfire ignition rates due to WUI expansion will initiate more wildfires in vegetation that is more susceptible to fire spread, leading to more widespread fires and possibly more severe fire behavior (33). This suggests that WUI growth and climate change together will compound the existing problems with wildfires in the WUI.

As WUI growth continues, there are many management options and policy tools to consider for addressing both wildfire and other environmental problems. Just as WUI-related problems involve actors (e.g., homeowners, community leaders) at many levels, so too must their solutions involve actors at multiple levels (i.e., local, regional, state, and national) (3, 8). Homeowners can reduce their individual fire risk by removing vegetation directly adjacent to their house (i.e., the home ignition zone; refs. 3 and 34), changing roofing and building materials, and following additional Firewise recommendations (35). To limit some of the other environmental problems associated with living in the WUI, homeowners can keep cats inside and dogs on a leash, limit fertilizer and pesticide use, and landscape with native plants (9). To reduce wildfire impacts, communities can coordinate fuel reduction efforts, educate homeowners, train firefighters, and establish wildfire management plans. Insurance companies can offer reduced premiums for communities taking mitigation action to incentivize community-level efforts to reduce wildfire losses. Communities and local jurisdictions could anticipate wildfires and environmental impacts more explicitly when planning future land use to avoid housing expansion in high-risk wildfire areas and other environmentally sensitive areas (36). State and federal agencies typically do not regulate development directly, but can allocate resources to areas experiencing rapid WUI growth, support local and regional planning efforts, and provide important research data and information to help communities adapt to fire-prone environments. Agencies managing public lands could consider targeted purchases of private inholdings to limit future housing growth within the administrative boundaries of public lands, which has been particularly rapid (37). In summary, there are many concrete management actions and policy responses that can limit the negative effects of WUI growth on wildfire risk and other environmental problems, but changes will require efforts at all levels by homeowners and community leaders, local and county governments, and state and federal agencies.

Housing development in the WUI greatly exacerbates wildfire problems and other environmental issues in the United States (1, 5, 8), and globally (16, 18–20). Our results highlight the magnitude and rapid rates of WUI growth in the US, underscoring the urgency of identifying what can be done to address WUI growth and its associated wildfire challenges (3). Past federal fire policy has focused largely on fighting and preventing wildfires and on fuel reduction, public outreach campaigns, and other actions (38). Although laudable, such efforts are unlikely to be successful by themselves, because housing growth is clearly the dominant cause of WUI growth, as well as a major factor contributing to wildfire occurrence and cost. As long as WUI growth is unchecked, wildfire problems will likely worsen. On a more hopeful note, to the extent that WUI growth reflects an affinity for nature, the evident consequences and costs of growth could prompt discussions on how to sustain those highly valued ecosystems in which so many people have chosen to live.

Materials and Methods

Our WUI definition is based on the definition published by the US government in the Federal Register (39) and that has been widely used for WUI assessments in the past (1, 14, 40). It specifies two types of WUI, intermix and interface. Intermix WUI is where houses and wildland vegetation intermingle, with both a housing density of >1 house per 40 acres (6.17 houses/km^2) and >50% of the area in wildland vegetation. Interface WUI represents settled areas that have <50% vegetation, but lie within

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1.5 miles (2.4 km) of a densely vegetated area (at least 75% wildland vegetation) that is at least 5 km^2 in size (so that settlements near small urban parks are not included in the WUI).

Our WUI assessment was based on two main datasets: US Census data, which provided housing data (TIGER shape files for block boundaries, plus Census summary files for attribute data), and the US Geologic Survey's NLCD, which provided information on wildland vegetation. We derived housing data from the US Decennial Censuses for 1990, 2000, and 2010 at its finest resolution, the census block level. However, a major obstacle to conducting change analyses is that census block boundaries frequently change from one decade to the next, preventing direct change analyses (27). Indeed, 62% of all blocks changed their boundaries from 1990 to 2000, and 56% changed from 2000 to 2010, invalidating any housing density change analysis that does not account for these boundary changes. We used additional information available from the US Census Bureau as relationship files that details for each decade which blocks of the starting date were at least partly contained by which block in the second decade, and vice versa, to calculate the number of 1990 and 2000 housing units for the boundaries for each 2010 census block.

Based on the Census Bureau relationship files, we first allocated 1990 housing units to 2000 block boundaries by identifying the type of relationship for each 1990 block to 2000 block(s), classifying the relationship as one-to-one, one-to-many, many-to-one, or many-to-many. For one-to-one and many-to-one relationships, 1990 housing units were allocated directly to corresponding 2000 blocks. For one-to-many relationships, 1990 housing units were allocated proportionally based on the number of housing units in the 2000 blocks. For many-to-many relationships, we identified the least common denominator of polygons that fully contained groups of both 1990 and 2000 blocks. For each least common denominator polygon, we then summed the 1990 housing units and allocated them based on the proportion of the 2000 housing units. To minimize instances of many-to-many relationships and maximize direct relationships, we removed blocks that were classified as water in 1990 and as vacant in 2000, as well as all 1990 and 2000 blocks that intersected by <1% of their area. Once 1990 housing units were allocated to 2000 census block geometry, we repeated the process using the 2000–2010 relationship files to allocate 2000 housing units to 2010 block boundaries. We then joined the 1990 housing units allocated to 2000 block boundaries with the 2000–2010 relationship files, and repeated the process to allocate 1990 housing units to 2010 block boundaries. The end result of our algorithms are 1990 and 2000 housing units allocated to the 2010 block geometry across the conterminous United States, i.e., a dataset that permits valid analyses of housing growth across the United States at fine spatial resolution and that minimizes erroneous changes due to changing census block boundaries.

We further refined census block boundaries by integrating them with information on the boundaries of protected areas. The boundaries of protected areas were provided by the Protected Area Database, version 2. Where protected areas intersected census block boundaries, we assumed that the houses in that block were located in nonprotected areas only. However, where census blocks with houses were entirely within a protected area, we made no changes, and assumed a uniform housing density throughout the block.

The 30-m resolution NLCD provided us with data on wildland vegetation. We analyzed both the 1992/93–2001 and the 2001–2011 land cover change products and calculated the percentage of each NLCD land cover class within each census block after refinement by the protected area boundaries. We included forest and grass/shrub land cover classes as wildland vegetation and excluded open water, urban, barren, wetlands, and ice/snow.

For each decade, we mapped the WUI separately, by combining 1990 Census data with 1992/93 data from the 1992/93–2001 land cover change product, and 2000 and 2010 Census data with 2001 and 2011 data from the 2001–2011 land cover change product. We first identified all intermix WUI areas based on the housing and vegetation thresholds. We then identified contiguous vegetation areas that were at least 5 km^2 in size and had >75% wildland vegetation, selecting areas within 2.4 km that were above the housing threshold (but below the 50% vegetation threshold), and labeling these as interface WUI. When census blocks were only partly within this distance, we split them.

The NLCD change products are not fully consistent, in that the 2001 land cover in the 1992/93–2001 change product differs from the 2001 land cover in the 2001–2011 change product. Thus, we conducted a sensitivity analysis and mapped the 2001 WUI twice, based on the two representations, and then compared the resulting WUI maps. The differences between the two WUI maps were very minor.

To calculate the number of homes within fire perimeters over time, we analyzed all fire perimeters of fires that burned between 1990 and 2015 according to the Monitoring Trends in Burn Severity (MTBS) dataset, which includes all fires >404 ha (1,000 ac) in the West and 202 ha (500 ac) in the East. We then assessed which census blocks were at least partially within these fire perimeters and calculated an area-weighted estimate of the number of housing units within the fire perimeters in 1990 (177,000), 2000 (210,000), and 2010 (286,000). We note that this is a conservative estimate of the number of houses affected by wildfires because the MTBS dataset does not include small fires.

ACKNOWLEDGMENTS. We thank J. Diffendorfer and J. Slate for providing valuable feedback on an earlier version of this manuscript. Support for this research was provided by the US Forest Service Northern Research Station, the interagency Joint Fire Sciences program, the Land Change Science Program in the US Geological Survey Climate and Land Use Mission Area, and PhD fellowships from the Fulbright Exchange program and the Foundation for Science and Technology of Portugal (to P.M.A.).

1. Radeloff VC, et al. (2005) The wildland-urban interface in the United States. Ecol Appl 15:799–805.
2. Alexandre PM, Mockrin MH, Stewart SI, Hammer RB, Radeloff VC (2015) Rebuilding and new housing development after wildfire. Int J Wildland Fire 24:138–149.
3. Calkin DE, Cohen JD, Finney MA, Thompson MP (2014) How risk management can prevent future wildfire disasters in the wildland-urban interface. Proc Natl Acad Sci USA 111:746–751.
4. Syphard AD, et al. (2007) Human influence on California fire regimes. Ecol Appl 17: 1388–1402.
5. Balch JK, et al. (2017) Human-started wildfires expand the fire niche across the United States. Proc Natl Acad Sci USA 114:2946–2951.
6. Bowman DM, et al. (2009) Fire in the earth system. Science 324:481–484.
7. Bowman DM, et al. (2011) The human dimension of fire regimes on Earth. J Biogeogr 38:2223–2236.
8. Schoennagel T, et al. (2017) Adapt to more wildfire in western North American forests as climate changes. Proc Natl Acad Sci USA 114:4582–4590.
9. Bar Massada A, Radeloff VC, Stewart SI (2014) Biotic and abiotic effects of human settlement in the wildland-urban interface. Bioscience 64:429–437.
10. Gonzalez-Abraham CE, et al. (2007) Patterns of houses and habitat loss from 1937 to 1999 in northern Wisconsin, USA. Ecol Appl 17:2011–2023.
11. Gavier-Pizarro GI, Radeloff VC, Stewart SI, Huebner CD, Keuler NS (2010) Housing is positively associated with invasive exotic plant species richness in New England, USA. Ecol Appl 20:1913–1925.
12. Loss SR, Will T, Marra PP (2013) The impact of free-ranging domestic cats on wildlife of the United States. Nat Commun 4:1396.
13. Larsen AE, MacDonald AJ, Plantinga AJ (2014) Lyme disease risk influences human settlement in the wildland-urban interface: Evidence from a longitudinal analysis of counties in the northeastern United States. Am J Trop Med Hyg 91:747–755.
14. Martinuzzi S, et al. (2015) The 2010 Wildland-Urban Interface of the Conterminous United States (US Forest Service, Newtown Square, PA), p 123.
15. Syphard AD, Radeloff VC, Hawbaker TJ, Stewart SI (2009) Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. Conserv Biol 23:758–769.
16. Modugno S, Balzter H, Cole B, Borrelli P (2016) Mapping regional patterns of large forest fires in wildland-urban interface areas in Europe. J Environ Manage 172: 112–126.
17. Argañaraz JP, et al. (2017) Assessing wildfire exposure in the wildland-urban interface area of the mountains of central Argentina. J Environ Manage 196:499–510.
18. Buxton M, Haynes R, Mercer D, Butt A (2011) Vulnerability to bushfire risk at Melbourne's urban fringe: The failure of regulatory land use planning. Geogr Res 49: 1–12.
19. Lampin-Maillet C, et al. (2010) Mapping wildland-urban interfaces at large scales integrating housing density and vegetation aggregation for fire prevention in the south of France. J Environ Manage 91:732–741.
20. van Wilgen BW, Forsyth GG, Prins P (2012) The management of fire-adapted ecosystems in an urban setting: The case of Table Mountain National Park, South Africa. Ecol Soc 17:8.
21. Abatzoglou JT, Williams AP (2016) Impact of anthropogenic climate change on wildfire across western US forests. Proc Natl Acad Sci USA 113:11770–11775.
22. Hawbaker TJ, et al. (2017) Mapping burned areas using dense time-series of Landsat data. Remote Sens Environ 198:504–522.
23. National Interagency Fire Center (2017) Historical wildland fire information: suppression costs, 1985-2016. Available at https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf. Accessed February 16, 2018.
24. Hammer RB, Radeloff VC, Fried JS, Stewart SI (2007) Wildland-urban interface housing growth during the 1990s in California, Oregon, and Washington. Int J Wildland Fire 16:255–265.
25. Theobald DM, Romme WH (2007) Expansion of the US wildland-urban interface. Landsc Urban Plan 83:340–354.
26. Drummond MA, Loveland TR (2010) Land-use pressure and a transition to forest-cover loss in the eastern United States. Bioscience 60:286–298.

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27. Syphard AD, et al. (2009) Assessing housing growth when census boundaries change. Int J Geogr Inf Sci 23:859–876.
28. Homer C, et al. (2015) Completion of the 2011 National Land Cover Database for the conterminous United States: Representing a decade of land cover change information. Photogramm Eng Remote Sens 81:345–354.
29. Gude P, Rasker R, van den Noort J (2008) Potential for future development on fire-prone lands. J For 106:198–205.
30. Stewart SI, et al. (2009) Wildland-urban interface maps vary with purpose and context. J For 107:78–83.
31. Abrams JB, Gosnell H, Gill NJ, Klepeis PJ (2012) Re-creating the rural, reconstructing nature: An international literature review of the environmental implications of amenity migration. Conserv Soc 10:270–284.
32. Bradbury M, Peterson MN, Liu JG (2014) Long-term dynamics of household size and their environmental implications. Popul Environ 36:73–84.
33. Flannigan MD, Krawchuk MA, de Groot WJ, Wotton BM, Gowman LM (2009) Implications of changing climate for global wildland fire. Int J Wildland Fire 18:483–507.
34. Cohen JD (2000) Preventing disaster: Home ignitability in the wildland-urban interface. J For 98:15–21.
35. Syphard AD, Brennan TJ, Keeley JE (2014) The role of defensible space for residential structure protection during wildfires. Int J Wildland Fire 23:1165–1175.
36. Syphard AD, Bar Massada A, Butsic V, Keeley JE (2013) Land use planning and wildfire: Development policies influence future probability of housing loss. PLoS One 8: e71708.
37. Radeloff VC, et al. (2010) Housing growth in and near United States protected areas limits their conservation value. Proc Natl Acad Sci USA 107:940–945.
38. Schoennagel T, Nelson CR, Theobald DM, Carnwath GC, Chapman TB (2009) Implementation of National Fire Plan treatments near the wildland-urban interface in the western United States. Proc Natl Acad Sci USA 106:10706–10711.
39. USDA; USDI (2001) Urban wildland interface communities within vicinity of federal lands that are at high risk from wildfire. Fed Regist 66:751–777.
40. Bar-Massada A, Stewart SI, Hammer RB, Mockrin MH, Radeloff VC (2013) Using structure locations as a basis for mapping the wildland urban interface. J Environ Manage 128:540–547.

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APPEAL EXHIBIT N

Source: Eagle Aerials/Hunsaker & Associates, 2001

HDR

FIGURE 4.8.4
Proposed Regional Wildlife Movement Corridors
Saddleback Meadows
Draft Revised Subsequent EIR 566

APPEAL EXHIBIT O

US Fish and Wildlife Service
Carlsbad Fish and Wildlife
2730 Loker Avenue West
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(760) 431-9440
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CA Dept. of Fish & Game
South Coast Regional Office
4949 Viewridge Avenue
San Diego, CA 92123
(858) 467-4201
FAX (858) 467-4299

In Reply Refer To: [ds Jun 26 2002]
FWS-OR-1023.10

Mr. Tim Neely, Division Manager
Orange County Planning and Development Services
Environmental Planning Services Division
300 North Flower Street
Santa Ana, California 92702-4048

Re: Draft Revised Subsequent Environmental Impact Report (State Clearing House No. 19996121072) for the Saddleback Meadows Project, County of Orange, California

Dear Mr. Neely:

The U.S. Fish and Wildlife Service (Service) and the California Department of Fish and Game (Department), hereafter referred to as the Wildlife Agencies, have reviewed the Draft Revised Subsequent Environmental Impact Report (DEIR) for the construction of the Saddleback Meadows Project, in the County of Orange, California. The project proposes development of 299 single-family houses on a 229.2-acre site in the lower foothills of the Santa Ana Mountains in southern Orange County. The proposed project also includes two new paved access roads off of El Toro Road and an adjacent offsite 1.4 million-gallon water reservoir. The Wildlife Agencies have commented on various development proposals and environmental documents for this project since 1994. As we have stated in our previous comments, the proposed project poses significant unmitigated impacts to future Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP) reserve design for the Southern Subregion of Orange County.

Responsibilities of the Wildlife Agencies

The Department is identified as a Trustee Agency pursuant to the California Environmental Quality Act (CEQA) section 15386 and is responsible for the conservation, protection, and management of the State's biological resources. The Department is also responsible, pursuant to the California Endangered Species Act, California Fish and Game Code 2050 *et seq*., for the protection of species listed by the State as endangered or threatened or identified as species of concern, and the habitats they require. The Department also manages the NCCP Program (California Fish and Game Code 2800 *et seq*.), a regional conservation planning effort, that includes southern Orange County.

The Service's primary mission is to work "with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people." The

Service has legal responsibility for the welfare of migratory birds, anadromous fish, and endangered animals and plants occurring in the United States. Specifically, we administer the Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 *et seq.*), and work in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401 as amended,16 U.S.C. 661 *et seq.*). Section 7 of the Act requires Federal agencies to consult with the Service should it be determined that their actions may affect federally listed threatened or endangered species. Take incidental to otherwise lawful activities can be permitted under the provisions of sections 7 (Federal consultations) or 10 (permits) of the Act.

As noted in the DEIR, the Service has completed formal consultation with the U.S. Army Corps of Engineers (Corps) and issued a biological opinion (FWS-OR-1023.8) on the Saddleback Meadows Project's effects on the federally endangered Riverside fairy shrimp (*Streptocephalus woottoni*, "fairy shrimp") and its designated critical habitat and designated critical habitat for the threatened coastal California gnatcatcher (*Polioptila californica californica*, "gnatcatcher"), in accordance with section 7 of the Act. To clarify, however, our biological opinion evaluated the 283-unit alternative, not the proposed 299-unit alternative discussed in the DEIR. If the 299-unit Alternative is pursued, reinitiation of consultation with the Corps would be required. Although impacts to federally listed species and their designated critical habitat have been addressed in the cited biological opinion for the Saddleback Meadows project, evaluation of impacts to wildlife movement for non-listed species in relation to development of an NCCP/HCP is outside the purview of section 7 of the Act.

Relationship of the Project to Regional Conservation Planning Efforts

The NCCP Act was approved in 1991 and established a program to provide for regional protection and perpetuation of natural wildlife diversity while allowing compatible land use and appropriate development growth. The program provides an alternative to "single-species" conservation via the formulation of regional, natural community-based habitat protection programs. The first NCCP/HCP projects in California focused on providing adequate conservation and mitigation for impacts to coastal sage scrub vegetation, the preferred plant community of the gnatcatcher.

Following the Federal listing of the gnatcatcher in 1993, the Service adopted a Special Rule for the gnatcatcher pursuant to section 4(d) of the Act incorporating the conservation and process guidelines established by the State under the NCCP Act. The guidelines set forth procedures for the creation of regional and subregional conservation plans. In accordance with the guidelines, jurisdictions enrolled in the NCCP planning program can authorize a limited amount of interim loss of coastal sage scrub during the planning period subject to six interim habitat loss provisions[1]. However, the interim habitat loss provisions are only applicable until adoption of a

[1] The following mandatory findings must be met for a project to be approved pursuant to the interim habitat loss provisions of the Special 4(d) Rule: 1) The habitat loss does not cumulatively exceed the 5% guideline; 2) The habitat loss will not preclude connectivity between areas of high habitat values; 3) The habitat loss will not preclude or prevent the preparation of the subregional Natural Community Conservation Plan; 4) The habitat loss has been minimized and mitigated to the maximum extent practicable in accordance with the Conservation Guidelines; 5) The habitat loss will not appreciably reduce the likelihood of the survival and recovery of listed species in the wild; and 6) The habitat loss is incidental to otherwise lawful activities.

regional or subregional conservation plan. In summary, per the NCCP program, conservation planning within enrolled jurisdictions may be governed by an adopted regional or subregional conservation plan, or is subject to the interim habitat loss provisions of the Special 4(d) Rule.

As an enrolled jurisdiction in the NCCP program, the County of Orange (County) has both an adopted subregional conservation plan that applies to its Central and Coastal subregions (the Orange County Central-Coastal NCCP/HCP) and is participating in development of the Southern Subregion NCCP/HCP. The County has committed to work with the Wildlife Agencies to ensure that projects within its jurisdiction do not prevent connectivity between areas of high habitat values or preclude reserve design options for the Southern Subregion NCCP/HCP.

Reserve Design Inconsistency

Our primary concern with the proposed project is the significant impact it poses to the major lower elevation wildlife movement corridor/linkage along the Santa Ana Mountain foothills of southern Orange County. Saddleback Meadows, together with the adjacent Saddle Creek and Live Oak properties, represents the only remaining unobstructed low elevation wildlife corridor/linkage between the Central and Southern Subregions of the Orange County NCCP/HCP planning areas. To highlight its importance, Orange County's Central-Coastal NCCP/HCP identifies this area as a key corridor/linkage between the subregions. The proposed development on Saddleback Meadows along the eastern and northern portions of the site as shown in Alternative 2 (the No Project, "Existing Entitlement" Alternative), Alternative 3 (the F/TSP EIR 531 Staff Alternative A), Alternative 5 (the Cluster/Single-Family/Multi-Family Residential Alternative), or Alternative 8 (the Reduced Residential Alternative) of the DEIR could substantially eliminate this corridor/linkage and, thereby, severely constrain movement of mule deer, coyote, mountain lion and other large mammals from O'Neill Regional Park in the Southern Subregion to the Central Subregion NCCP/HCP reserve. We raised similar concerns regarding the proposed development on the Saddle Creek property in our comments on the recently circulated DEIR- State Clearing House No. 199111120 (FWS-OR-1309.1).

Pursuant to the CEQA Guidelines (Section 15130), a revised DEIR should discuss cumulative impacts of a project when the project's incremental effect is cumulatively considerable and should review the impacts in light of past, present and future probable projects that could result in related impacts, including those outside of the control of the lead agency. However, this current, revised DEIR does not adequately address cumulative impacts to the low-elevation wildlife corridor/linkage through the Saddleback Meadows, Saddle Creek and Live Oak properties. Also, it appears that a comprehensive plan for maintaining a viable corridor/linkage through these properties has not been completed. For example, the Saddleback Meadows DEIR shows a northern wildlife corridor extending from Saddleback Meadows through the adjacent Saddle Creek property. However, the Saddle Creek DEIR does not show this corridor, which would be blocked by the residential development proposed in the DEIR. In addition, development on the Live Oak property could further limit wildlife movement between the subregions. Therefore, the Saddleback Meadows DEIR should evaluate cumulative impacts to wildlife movement in consideration of past development, the proposed development on the Saddle Creek and Live Oak properties and other probable developments, and demonstrate that the Saddleback Meadows

project will not preclude the retention of a viable low-elevation wildlife corridor/linkage connecting the Central and Southern Subregions through all three properties. We wish to work with the County and property owners to develop a comprehensive plan to accomplish this vital component of the Southern Subregion NCCP/HCP.

To address our concerns for Saddleback Meadows, the Wildlife Agencies recommend further consideration of Alternative 4 (F/TSP EIR 531 Staff Alternative B) of the DEIR as it would allow continued movement of wildlife through the area while still meeting the project's objective of "develop(ing) a single-family, rural community that balances residential development with protection of on-site sensitive resources and values of the surrounding community." Alternative 6 (the 44/178 Alternative) may be able to mitigate significant impacts to wildlife movement if remedial grading requirements can be limited within the corridor/linkage area.

Geotechnical

According to the DEIR, the site is characterized by several unfavorable geotechnical conditions including unstable landslides and presence of ground water that could compromise the site's ability to support the project. Mitigation would include the construction of canyon subdrains and back drains to minimize or eliminate the effects of ground water. The Final EIR (FEIR) should discuss how these changes would affect groundwater availability and timing for use by riparian vegetation in upper Aliso Creek.

Hydrology/Beneficial Uses

The Santa Ana Regional Water Quality Control Board has designated the existing biological beneficial uses of "warm freshwater habitat," "wildlife habitat," and "rare, threatened, or endangered species" for portions of Aliso Creek, including the reach downstream from the proposed Saddleback Meadows project. The Wildlife Agencies are concerned about the onsite and downstream effects the project-related changes in the surface flows may have on these beneficial uses and on the habitats and biological resources supported by Aliso Creek. In addition to modifications in peak flows resulting from an increase in impervious surface, we are concerned about changes in the velocity, volume, duration, and frequency of dry-weather and non-peak wet-weather flows. Even small changes in the flow regime often effect changes in the stream community that, over time, can seriously damage stream habitats. Increases in flows from impervious surfaces associated with urbanization can result in: 1) stream bed scouring and habitat degradation; 2) shoreline erosion and stream bank widening; 3) loss of aquatic species; and 4) decreased baseflow (USEPA 1999). Downstream sections of Aliso Creek are known to be sediment-deficient and have already been adversely affected by scour, erosion and subsequent habitat degradation. The Wildlife Agencies recommend that every effort be made to integrate measures to ensure full protection of the beneficial uses and biological resources of Aliso Creek. The development design and construction operations should minimize the modifications of dry and wet-weather flows and integrate onsite best management practices (BMPs) that would attenuate the flows to reduce impacts on the stream morphology and habitats onsite and downstream. Examples of BMPs to consider include appropriately sized grassy swales and vegetated detention basins. Proper design of structural BMPs will require analyses of the

sediment transport and hydrological regime of the headwaters of Aliso Creek. The project is located within Reach 1 of the *Aliso Creek Watershed Management Feasibility Study, Orange County, California* prepared for the Corps. We recommend this study be consulted to determine possible effects of the project on the Aliso Creek watershed.

Significance Criteria for Biological Resources

The thresholds of significance for biological resources provided in section 4.8.2 of the DEIR do not appear to be consistent with the CEQA definition of rare, threatened, and endangered species (see CEQA Guidelines, § 15380). In addition, The Department recommends that the significance criteria in the body of the DEIR be revised to be consistent with CEQA Sections 15064.7 and 15065, and Appendix G of the CEQA guidelines.

Annual Grasslands

The project proposes that mitigation requirements for cumulative impacts to raptor foraging habitat (consisting primarily of coastal sage scrub and grasslands) will be met in conjunction with the proposed coastal sage scrub habitat mitigation. The Department recommends mitigation measures be incorporated specifically for impacts to annual grassland. These areas provide foraging areas for raptors and small mammals and proposed impacts to a total of 103.7 acres on- and offsite should be considered significant. Appendix I.1 of the DEIR indicates that raptor species including Cooper's hawk (*Accipiter cooperii*), a state species of special concern (CSC), sharp-shinned hawk (*A. striatus,* CSC), red tailed hawk (*Buteo jamaicensis*) red shouldered hawk (*B. striatus*), and American kestrel (*Falco sparverius*) were observed during surveys of the project site, and other species including northern harrier (*Circus cyaneus,* CSC) and loggerhead shrike (*Lanius ludovicianus,* CSC) have at least a moderate potential of using the grasslands onsite for foraging. We therefore recommend that annual grassland mitigation at a 0.5:1 preservation-to-impact ratio in an offsite area with long-term conservation potential be included in the FEIR.

Intermediate Mariposa Lily

The DEIR states that impacts to intermediate mariposa lily (*Calochortus weeddii* var. *intermedius*) would not be significant. This species is listed by the California Native Plant Society as a "1B" plant (Plants rare, threatened, or endangered in California and elsewhere). Species included on List 1B must be fully considered under CEQA. The Department recommends that the FEIR include mitigation for impacts to this species (for example, see Rancho Potrero Leadership Academy EIR, County of Orange, 2001).

Cactus Wren

According to the DEIR, impacts to the cactus wren (*Campylorhynchus brunneicapillus cousei*) are not considered significant. As proposed in Appendix I.3 to the DEIR, the coastal sage scrub mitigation plan does not specifically include salvage or container stock planting of prickly-pear

(*Opuntia* spp.) required for cactus wren nesting and foraging. By providing suitable replacement habitat, a potentially significant impact to cactus wren may be mitigated. To provide replacement habitat for cactus wren impacted by implementation of the project, we recommend that the coastal sage scrub plant palette is revised to include a substantial amount of prickly-pear. This may be achieved by salvage of existing plant material followed by direct replanting within the mitigation area or by collecting pads prior to impact and rooting them in containers. In addition, we recommend that reference sites currently supporting cactus wren be chosen to provide an appropriate baseline for comparison.

Oak Woodland Mitigation Plan

Mitigation for oak woodland impacts is described on page 4.8-26 of the DEIR and we concur with the restoration approach in concept. However, unlike the coastal sage scrub mitigation plan, details of the oak woodland mitigation strategy are not adequately described in Appendix I.3 such that the impacts can be shown to be mitigated below a level of significance. For example, the proposed locations for oak woodland restoration should be depicted and described. In addition, container sizes, understory species, and maintenance activities specific to the oak woodland restoration should be detailed.

The Wildlife Agencies appreciate the opportunity to review and comment on the DEIR. If you have any questions please contact Mr. David Zoutendyk of the Service at (760) 431-9440 or Mr. Brad Henderson of the Department at (310) 214-9950.

Sincerely,

/s/
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Literature Cited

U.S. Environmental Protection Agency. 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012. Pp. 4-24