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Re: Technical Estimation of GHG Emissions of Wildfire and Forest Management Activities

On behalf of the Center for Biological Diversity, the John Muir Project of Earth Island Institute, and our members, we are submitting the following comments on the CARB report titled "Draft Greenhouse Gas Emissions of Contemporary Wildfire, Prescribed Fire, and Forest Management Activities, December 2020." We want to thank CARB staff for their work and outreach on this report.

Our comments below request clarification on questions related to CARB's process for developing the technical estimates and incorporating public comment into the three products addressing carbon emissions from wildfire and forest management activities required under SB 901. Our comments also provide specific recommendations for improving CARB's draft estimates, with references to supporting published scientific literature.

In addition, according to CARB's Public Webinar on Staff's Implementation of Section 4 of SB 901 (December 1, 2020), CARB staff will be issuing a second report described as "[a] literature review report summarizing our current scientific understanding of pre-1910 historical fire activity in California."[1] That literature review report is not yet publicly available, so we are

[1] Technical Estimation of GHG Emissions of Wildfire and Forest Management Activities,

submitting comments on the webinar material related to historical fire activity before modern fire suppression, and anticipate that this report will eventually be released for public comment.

A. Questions Regarding the Process for Developing These Reports

(1) We'd appreciate any information CARB can provide regarding the current status of (a) the "standardized system for quantifying the direct carbon emissions and decay from fuel reduction activities," and (b) the literature review report summarizing the "historic baseline of greenhouse gas emissions from California's natural fire regime reflecting conditions before modern fire suppression."

It is our understanding that all of these products are currently in development at CARB, pursuant to SB 901 (2018) and Health and Safety Code Section 38535. We have substantial interest and experience in all of these issues, and would appreciate any information CARB can offer as to how we can best provide input and engage in the development of these products. Specifically, any information on the expected timelines and process would be helpful in coordinating our work.

(2) We would also appreciate any clarity that CARB can offer regarding how these reports are expected to be used in rulemaking and policy decisions. Better understanding the specific applications of the products could help us to focus on the most relevant issues and input.

B. Recommendations for Improving the Carbon Emissions Estimates

1. Contemporary wildfire emissions

(a) FOFEM and LANDFIRE systematically overestimate wildfire emissions; we recommend using field-based empirical data based from actual wildfires.

Research clearly shows that models like FOFEM and LANDFIRE, which are central to the draft report's estimation of wildfire emissions, substantially over-estimate wildfire emissions by using unrealistic biomass combustion factors and under-representing the biomass stored in standing dead trees after fire.[2] Stenzel et al. (2019) highlighted that these models overestimate the wildfire emissions from California's forests by three-to-four times that of actual field-based values, based on reviewing Yosemite forests as a case study:

> Our results illustrate that the use of inaccurate combustion coefficients in models can double forest fire emissions estimates across the western United States. Overestimates increase to three to four times in carbon-dense forests such as the YFDP [Yosemite Forest Dynamics Plot], mostly because models incorrectly combust live trees. Treating carbon released over years to centuries as an

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Public Webinar on Staff's Implementation of Section 4 of SB 901 (December 1, 2020), https://ww2.arb.ca.gov/wildfire-emissions, at Slide 7.

[2] French, Nancy H.F. et al., Model comparisons for estimating carbon emissions from North American wildland fire, 116 Journal of Geophysical Research G00K05 (2011); Stenzel, Jeffrey E. et al., Fixing a snag in carbon emissions estimates from wildfires, 25 Global Change Biology 3985 (2019).

> immediate emission by equating combustion with mortality is simply inaccurate. Omitting snag representation in models compounds this error, because of altered decay and combustion dynamics.[3]

Stenzel et al. (2019) reported that the largest discrepancies between modeled and observed combustion of aboveground biomass exist for live, mature trees, which are the dominant pool of aboveground carbon. While models estimate live tree stem combustion at 30%–80% in high-severity events, post-fire observations in the western United States indicate actual combustion is nearly nonexistent for mature trees in fire-prone ecosystems. Most models also lack standing dead tree carbon pools.

Stenzel et al. (2019) highlighted California as an example where the state government is making land management decisions intended to mitigate climate change based on incorrect overestimates of wildfire emissions:

> Contemporary CO_2 emissions to the atmosphere from fire are often significantly exaggerated because of public and policymaker misconceptions that forests commonly "burn to the ground" during fire and that mortality equals emissions. The reality is instead negligible stem combustion of live, mature trees (i.e., <5%), followed by gradual decomposition over years to centuries. Modeled estimates of fire emissions reinforce public misconceptions, as tree mortality is often mistranslated into 30%–80% of tree carbon emitted immediately and is in conflict with observations. It is important to rectify overestimates because governments are currently using mortality and emissions estimates from fire to inform land management decisions intended to mitigate climate change (California, Executive Department, 2018; …).[4]

Earlier research similarly concluded that FOFEM significantly overestimates combustion and therefore wildfire emissions. For example, French et al. (2011) reported field-data-based wildfire emissions results compared with FOFEM modeling results, finding that FOFEM over-estimated wildfire emissions generally by twofold to threefold (e.g., Biscuit fire, Boundary fire).[5]

In addition to FOFEM, CARB's wildfire estimation methodology uses the NWL Inventory (Inventory of Ecosystem Carbon in California's Natural and Working Lands)[6] and LANDFIRE which similarly make the fundamental errors described in Stenzel et al. (2019) in over-estimating wildfire GHG emissions. Specifically, the LANDFIRE model used by the Inventory classifies post-forest-fire vegetation categories as having less carbon than they actually do. First, the model does not account for the large stores of post-fire carbon persisting in killed trees and other

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[3] Stenzel et al. (2019) at 7.
[4] Stenzel et al. (2019) at 1-2.
[5] French, Nancy H.F. et al., Model comparisons for estimating carbon emissions from North American wildland fire, 116 Journal of Geophysical Research G00K05 (2011).
[6] California Air Resources Board, An Inventory of Ecosystem Carbon in California's Natural and Working Lands, 2018 Edition, https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf (last visited Aug. 5, 2019).

unburned fuels.[7] In practice, the model effectively assumes that when trees are killed, they are vaporized immediately and all the carbon goes into atmosphere, which is demonstrably incorrect. Second, the model makes broad assumptions about changes in vegetation categories based on LANDFIRE satellite imagery (which the Inventory acknowledges leads to substantial vegetation category classification inaccuracy[8]) and the mean carbon density in each vegetation category. Significant wildfire emissions overestimates can occur when a mature forest that has high-intensity fire is reclassified as shrubland but still has large amounts of carbon stores in the snags and downed logs that are not counted.

CARB can correct for these flawed wildfire emissions estimates by using field data of carbon consumption from actual wildfires. For example, field studies of large, intense fires find only about 11% of carbon in forest vegetation, duff, litter, and soil is consumed in a fire, and only 3% on average of the carbon in trees is consumed.[9] In a study of moderate-intensity fire areas in the Rim Fire in California, on average, only one-tenth of one percent of the carbon in trees was consumed.[10] There was a higher level of consumption of smaller-diameter material—shrubs, needles, and twigs on the forest floor—but this accounted for only a small portion of the aboveground carbon consumed.

(b) Rapid carbon sequestration by vegetation re-growth after wildfire counteract the emissions from wildfires.

An ecologically relevant temporal scale for estimating wildfire emissions is critical to accurately accounting for the carbon sequestered by vigorous post-fire growth, which can counter-balance carbon emissions from wildfire within a decade post-fire. At present, CARB's wildfire estimates inherently assume that vegetation does not grow back after fire. In reality, the release of nutrients as a result of fire stimulates rapid and massive forest regrowth that quickly sequesters carbon.[11] Field studies show that vigorous post-fire regrowth quickly returns forests to carbon sinks within a decade or less after fire.[12] As such, researchers generally consider wildfires to be carbon neutral events once full biomass recovery has occurred.

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[7] California Air Resources Board, Technical Support Document for the Natural & Working Lands Inventory, December 2018 Draft, https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory_technical.pdf (last visited Aug. 5, 2019), at 19 ("The fire-attributed stock changes account only for carbon contained in live and dead pools associated with the post-fire (e.g. 2012) vegetation type, and have no memory of the previous vegetation type, i.e. they do not account for potential post-fire carbon persisting in unburned fuels or in killed trees.")

[8] California Air Resources Board, An Inventory of Ecosystem Carbon in California's Natural and Working Lands, 2018 Edition, https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf, at 47-48.

[9] Campbell, J., et al., Pyrogenic carbon emission from a large wildfire in Oregon, United States, 112 Journal of Geophysical Research Biogeosciences G04014 (2007).

[10] Stenzel et al. (2019) at Table 1.

[11] Meigs, G., et al., Forest fire impacts on carbon uptake, storage, and emission: The role of burn severity in the Eastern Cascades, Oregon, 12 Ecosystems 8 (2009); Hanson, C.T., Landscape heterogeneity following high-severity fire in California's forests, 42 Wildlife Society Bulletin 264 (2018); Hanson, C.T., and T.Y. Chi. 2021. Impacts of postfire management are unjustified in spotted owl habitat. Frontiers in Ecology and Evolution 9: Article 596282.

[12] Meigs, G., et al., Forest fire impacts on carbon uptake, storage, and emission: The role of burn severity in the Eastern Cascades, Oregon, 12 Ecosystems 8 (2009); Campbell, J.C. et al., Carbon emissions from

Recent research has also highlighted the importance of pyrogenic carbon—the charcoal left behind by wildfire—in trapping forest carbon for centuries to millennia after wildfire and helping mitigate climate change, and has recommended this long-term carbon storage be considered in carbon accounting for wildfires.[13]

2. Forest management activities

(a) Research shows that the largest losses of carbon from US and California forests are due to logging practices, not wildfire or other natural disturbance processes.

The report should incorporate the research showing the largest source of carbon loss from US and California forests is historic and current logging practices. As a result of decades of intensive logging, today's forests have much less carbon than they once did,[14] currently reduced to an estimated half their carbon sequestration potential.[15] For example, Harris et al. (2016) estimated that 85% of carbon emissions from US forests between 2006 and 2010 were caused by timber harvest, compared to 12% from wildfire, insect outbreaks, wind damage and drought combined.[16] In California, logging was responsible for 60% of the carbon emissions from forests, compared to 32% from wildfire.[17] This is because wildfire consumes a small percentage of forest carbon while improving availability of key nutrients and stimulating rapid forest regeneration. When trees die from drought and native bark beetles, no carbon is consumed or emitted initially, and carbon emissions from decay are small and slow; meanwhile, decaying wood keeps forest soils productive and enhances carbon sequestration capacity over time.

In contrast, logging and thinning not only reduce current standing carbon stocks, releasing much of this above-ground and below-ground carbon to the atmosphere and worsening climate change, but also reduce the forest's future rate of carbon sequestration, and its future carbon storage capacity, by removing trees that otherwise would have continued to grow and remove CO_2 from the atmosphere.[18] Protecting intact forests and allowing cut forests to naturally grow back are

decomposition of fire-killed trees following a large wildfire in Oregon, United States, 121 Journal of Geophysical Research: Biogeosciences 718 (2016).

[13] Jones, Matthew W. et al., Global fire emissions buffered by the production of pyrogenic carbon, 12 Nature Geoscience 742 (2019).

[14] In the Sierra Nevada, logging is estimated to have removed most (82%) of the historical acreage of old-growth mixed conifer forests, largely due to clear-cutting, high-grading of big trees, and other logging practices. See Beesley, D. 1996. Reconstructing the landscape: an environmental history, 1820-1960. *In* Sierra Nevada Ecosystem Project: final report to Congress. Vol. II. Assessments and scientific basis for management options. Centers of Water and Wildland Resources, Davis, Calif. Pp. 1-24.

[15] Erb, Karl-Heinz et al., Unexpectedly large impact of forest management and grazing on global vegetation biomass, 553 Nature 73 (2018).

[16] Harris, N.L. et al., Attribution of net carbon change by disturbance type across forest lands of the conterminous United States, 11 Carbon Balance and Management 24 (2016). The study concluded that "increasing the US net forest C sink would require shifts in current forest management practices."

[17] Harris et al. (2016) at Table 5.

[18] Mitchell, S.R. et al., Forest fuel reduction alters fire severity and long-term carbon storage in three Pacific Northwest ecosystems, 19 Ecological Applications 643 (2009); Law, B.E. and M.E. Harmon, Forest sector carbon management, measurement and verification, and discussion of policy related to climate change, 2 Carbon Management 73 (2011); Campbell, J.L. and A.A. Ager, Forest wildfire, fuel

recognized as a vital part of the climate solution. According to an analysis by Moomaw et al. (2019), growing existing forests intact to their ecological potential--termed *proforestation*—maximizes forest biological carbon sequestration and is critical for limiting global warming to 1.5°C and avoiding the worst harms from the climate crisis.[19]

(b) An accurate carbon estimate must account for cradle-to-grave emissions from forest management.

An emissions estimate must account for cradle-to-grave emissions from forest management activities to accurately represent the carbon impacts from these activities and their effect on meeting the state's climate goals. One example of an available methodology for accounting for cradle-to-grave forest management emissions from the California forest sector is Hudiburg et al. 2019 ("Meeting GHG reduction targets requires accounting for all forest sector emissions").[20]

Cumulatively, the methodological issues named here result in a significant underestimation of emissions from forest management activities, and a significant overestimation of emissions from wildfire, which can mislead policy recommendations and undermine the state's ability to meet its climate targets. For example, Harris et al. (2016) estimated that in California forests, twice as much carbon is emitted due to timber harvest than wildfire (i.e., carbon emissions due to harvest were ~5.6 MMT C and emissions due to wildfire were ~2.9 MMT C).[21] In contrast, the draft report estimates that emissions from forest management are about the same as from wildfire (i.e., 3.9 MMT C for forest management not including prescribed fire and 3.8 MMT C for wildfire).

(c) Estimates of emissions from forest management activities must account for the substantial soil carbon losses, and prolonged loss of forest cover, due to impacts and damage from logging practices.

The draft report's estimates of emissions from forest management activities are significantly under-estimated, in part because they do not account for soil carbon loss from logging practices. Logging is well-documented to compact and damage forest soils with heavy machinery and remove vital nutrients stored in trees, leading to significant loss of soil carbon.[22] These harms to soils also significantly reduce forest productivity (the rate at which trees and plants will grow),

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reduction treatment, and landscape carbon stocks: a sensitivity analysis, 121 Journal of Environmental Management 124 (2013).

[19] Moomaw, William R. et al., Intact forests in the United States: Proforestation mitigates climate change and serves the greatest good, 2 Frontiers in Forests and Global Change (2019).

[20] Hudiburg, Tara W. et al., Meeting GHG reduction targets requires accounting for all forest sector emissions, 14 Environmental Research Letters 095005 (2019).

[21] Harris et al. (2016) at Table 5.

[22] Elliot, William J. et al., The Effects of Forest Management on Erosion and Soil Productivity, Symposium on Soil Quality and Erosion Interaction, Keystone, CO, July 7, 1996; Walmsley, J.D. et al., Whole tree harvesting can reduce second rotation forest productivity, 257 Forest Ecology and Management 1104 (2009); Buccholz, Thomas et al., Mineral soil carbon fluxes in forests and implications for carbon balance assessments, 6 GCB Bioenergy 305 (2014); Achat, David et al., Forest soil carbon is threatened by intensive biomass harvesting, 5 Scientific Reports (2015); Achat, David et al., Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis, 348 Forest Ecology Management (2015).

which substantially reduces the capacity of forest ecosystems to absorb, sequester, and store carbon.[23] Available estimates from the scientific literature can be used to estimate the soil carbon losses, and prolonged loss of forest cover from soil damage, resulting from forest management activities.

(d) The quantitation of emissions needs to integrate the cumulative impacts of mechanical equipment and logging on the integrity of relationships between trees and the forest's essential arbuscular mycorrhizal fungi and ectomycorrhizal fungi.

A vast majority of vascular plants including trees live in symbiosis with arbuscular mycorrhizal fungi, which serve functions including carbon sequestration and mitigation of nutrient losses in soil.[24] Forests take decades to recover from massive clear-cuts, which is related to the possibly irreversible impacts of deforestation on fungi that are an essential, largely subterranean component of the forest.[25] The disruption of mycorrhizal interactions and therefore on long-term carbon sequestration processes would need to be accounted for. Deforestation not only removes the trees that are being cut down, but also impacts trees that are still alive by disrupting the mycorrhizal network.[26]

(e) The estimate should include carbon loss calculations for non-fire management in non-forest vegetation types.

Non-fire vegetation management that has been implemented in non-forest habitats should be included in the report's carbon emissions calculations. Wildfire and prescribed fire emissions are provided for various habitat types, including forests, woodlands, shrublands, and grasslands, but only emissions from forests and trees due to non-fire forest management are provided. The carbon emissions of vegetation clearance of non-forest ecosystems provide critical context for these estimates.

Non-forest habitats play an important role in the carbon cycle. For example, shrublands, including chaparral and sage scrub communities, have been found to store a significant amount of carbon in their aboveground biomass under normal weather conditions.[27] In a review

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[23] *Id.*; see also Hanson, C.T., and T.Y. Chi, Impacts of postfire management are unjustified in spotted owl habitat, 9 Frontiers in Ecology and Evolution Article 596282 (2021) (34% of previously forested areas rendered deforested for decades due to impacts of logging, including logging roads, skid trails, and landings).

[24] Bothe, Hermann et al., The potential role of arbuscular mycorrhizal fungi in protecting endangered plants and habitats, 20 Mycorrhiza 445 (2010); Martínez-García, Laura B. et al., Symbiotic soil fungi enhance ecosystem resilience to climate change, 23 Global Change Biology 5228 (2017).

[25] Runyan, Christiane W. et al., Physical and biological feedbacks of deforestation, 50 Reviews of Geophysics RG4006 (2012).

[26] Lagomarsino, Valentina, Exploring the Underground Network of Trees—The Nervous System of the Forest (2019), https://sitn.hms.harvard.edu/flash/2019/exploring-the-underground-network-of-trees-the-nervous-system-of-the-forest/

[27] Bohlman, Gabrielle N. et al., Estimating biomass in California's chaparral and coastal sage scrub shrublands, 65 Madroño 28 (2018); Fusco, Emily J., et al, Accounting for aboveground carbon storage in shrubland and woodland ecosystems in the Great Basin, 10 Ecosphere 8 (2019); Gratani, Loretta et al., Mediterranean shrublands carbon sequestration: environmental and economic benefits, 18 Mitigation and

conducted by Bohlman et al. (2018), above-ground biomass of shrub communities were found to be as high as 3461 g/m^2, with the amount of carbon stored increasing with the age of the stand. Removal of these carbon stocks should be accounted for.[28] In addition, although below-ground biomass is rarely measured or calculated in shrubland communities, some shrubland species have been found to have 41 to 47% of their biomass below the surface,[29] and chaparral roots have been found four meters (>13 feet) deep in weathered bedrock.[30] This suggests that a substantial amount of carbon may be stored belowground in these habitats, not just in their roots, but also in the microbial communities and mycorrhizal fungi that work in concert with root systems to trap carbon in biomass and soil pores and suppress decomposition of humic substances.[31] Intact shrublands with more diverse plant communities have been found to stimulate the formation of soil pores that support optimal microbial functioning and carbon accrual.[32] And increased root surface area supports more mycorrhizae that aid in nutrient uptake and facilitate carbon flow and soil carbon accumulation.[33] Soil carbon in fire-adapted ecosystems likely responds differently to wildfire disturbance compared to vegetation clearance practices. An analysis and discussion of the impacts of vegetation management to above- and below-ground carbon of non-forest ecosystems is important to understanding the context of these particular estimates.

3. Historical wildfire baseline

(a) There is significantly less fire in California's forests today than historically.

Numerous scientific studies indicate that there is substantially less fire of all severities in the great majority of western U.S. mixed-conifer, mixed-evergreen, and yellow pine forests—including California forests—than occurred historically.[34] It is well established that California's forests are experiencing a significant fire deficit compared with pre-settlement conditions. The report cites Stephens et al. (2007) and should also incorporate other studies demonstrating the

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Adaptation Strategies for Global Change 1167 (2013); Luo, Hongyan et al., Mature semiarid chaparral ecosystems can be a significant sink for atmospheric carbon dioxide, 13 Global Change Biology 386 (2007).

[28] Bohlman, Gabrielle N. et al., Estimating biomass in California's chaparral and coastal sage scrub shrublands, 65 Madroño 28 (2018).

[29] *Id.*

[30] Sternberg, P. D. et al., Root distribution and seasonal water status in weathered granitic bedrock under chaparral, 72 Geoderma 89 (1996).

[31] Kravchenko, A. N. et al., Microbial spatial footprint as a driver of soil carbon stabilization, 10 Nature Communications 1 (2019); Soudzilovskaia, Nadejda A. et al., Global mycorrhizal plant distribution linked to terrestrial carbon stocks, 10 Nature Communications 1 (2019).

[32] Kravchenko, A. N. et al., Microbial spatial footprint as a driver of soil carbon stabilization, 10 Nature Communications 1 (2019).

[33] *Id.*; Finlay, Roger D., Ecological aspects of mycorrhizal symbiosis: with special emphasis on the functional diversity of interactions involving the extraradical mycelium, 59 Journal of Experimental Botany 1115 (2008); Orwin, Kate H. et al., Organic nutrient uptake by mycorrhizal fungi enhances ecosystem carbon storage: a model-based assessment, 14 Ecology Letters 493 (2011).

[34] Hanson, C.T. et al., Chapter 1: Setting the stage for mixed- and high-severity fire. In: DellaSala, D.A., and C.T. Hanson (Editors). The ecological importance of mixed-severity fires: nature's phoenix. Elsevier Inc., Waltham, MA, USA (2015).

current fire deficit, including Mouillet and Field (2005), Marlon et al. (2012), Odion et al. (2014), Parks et al. (2015), and Murphy et al. (2018).[35]

According to Stephens et al. (2007), prior to 1800, an estimated 18 to 47 times more area burned each year in California, including 20 to 53 times more forest area, than has burned annually during recent decades: "skies were likely smoky much of the summer and fall." This study estimated that 1.8 million to 4.8 million hectares burned each year in California prior to 1800, of which 0.5 million to 1.2 million hectares were forest, compared to just 102,000 hectares burned each year between 1950-1999, of which 23,000 hectares were forest. Based on this extreme fire deficit, Stephens et al. (2007) recommend "increasing the spatial extent of fire in California [as] an important management objective."

Parks et al (2015) reported that California forests, including Sierra Nevada and southern Cascades forests, experienced a significant fire deficit during the 1984-2012 study period, attributed to fire suppression activities. Odion et al. (2014) similarly reported multiple lines of corroborating evidence that there is currently much fire, including less high-severity fire, in western mixed-conifer and ponderosa pine forests than compared with historical levels. Mallek et al. (2013) also confirmed the fire deficit in California's forests, concluding that "modern rates of burning are far below presettlement levels for all forest types."

(b) There is no basis for the estimation that wildfire emissions in today's fires release significantly more carbon per acre than historically.

The report estimates that wildfire emissions today release 3.6 times more CO_2 per acre than historically, but this specific estimate is not supported by references or rationale. Specifically, the report estimated historical emissions released ~ 7.5 MT CO_2 per acre compared with current average emissions of 27 MT CO_2 per acre.[36] However, research indicates that there is much less biomass in California forests today than historically due to a long history of logging. According to McIntyre et al. (2015), Sierra Nevada forests are 30% less dense, and Tranverse and Peninsular Range forests are 40% less dense, in terms of basal area in the 2000s compared to the 1930s.[37] Therefore, based on the lower amount of biomass in California's forests today than historically, it is counter-intuitive that CO_2 emissions per acre would be so much higher today. This claim appears to be based on the assumption that current forest fires are more intense than

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[35] Mouillot, F. and C. Field, Fire history and the global carbon budget: a 1º x 1º fire history reconstruction for the 20th century, 11 Global Change Biology 398 (2005); Stephens, S.L. et al., Prehistoric fire area and emissions from California's forests, woodlands, shrublands and grasslands, 251 Forest Ecology and Management 205 (2007); Marlon, J.R. et al., Long-term perspective on wildfires in the western USA, 109 PNAS E535 (2012); Odion, D.C. et al., Examining historical and current mixed-severity fire regimes in Ponderosa pine and mixed-conifer forests of western North America, 9 PLoS ONE e87852 (2014); Parks, S.A. et al., Wildland fire deficit and surplus in the western United States, 1984-2012, 6 Ecosphere Article 275 (2015); Murphy, Brendan P. et al., Beyond the 1984 perspective: Narrow focus on modern wildfire trends underestimates future risks to water security, 6 Earth's Future 1492 (2018).

[36] Technical Estimation of GHG Emissions of Wildfire and Forest Management Activities, Public Webinar on Staff's Implementation of Section 4 of SB 901 (December 1, 2020), https://ww2.arb.ca.gov/wildfire-emissions, at Slide 46.

[37] McIntyre, P.J. et al., Twentieth century shifts in forest structure in California: denser forests, smaller trees, and increased dominance of oaks, 112 PNAS 1458 (2015) at Figure 1a.

historical fires, but this assumption is not supported by current and comprehensive scientific literature, which indicates that historical fires in ponderosa pine and mixed-conifer forests of California typically included 22-39% high-severity fire,[38] which is consistent with current high-severity fire levels.[39] The main difference between historical times and now is that we have far less fire in our forests, as discussed above.

Conclusion

The Center for Biological Diversity and John Muir Project would be pleased to work with CARB to address the issues identified here, and to provide any additional citations and information pursuant to these comments. Along with these comments, we are providing the pdfs of the cited scientific references. We are happy to talk with CARB staff about our comments and recommendations, and welcome continued discussion.

Sincerely,

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Encl.
Cited references uploaded to the following link at Microsoft OneDrive:
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[39] Miller J.D., et al., Trends and causes of severity, size, and number of fires in northwestern California, USA, 22 Ecological Applications 184 (2012); Hanson, C.T., and D.C. Odion, Is fire severity increasing in the Sierra Nevada mountains, California, USA? 23 International Journal of Wildland Fire 1 (2014).

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