Health Impacts of Future Prescribed Fire Smoke: Considerations from an Exposure Scenario in California

Andrew Rosenberg, MPH
California Department of Public Health

Ana Rappold, PhD
US EPA

Center for Healthy Communities
Environmental Health Investigations Branch

Disclosures & Funding

No conflicts of interest

The contents of this report are solely the responsibility of the authors and do not necessarily represent the official views of the California Department of Public Health or any other agency or entity.

This project was supported in part by a grant from the California Department of Forestry and Fire Prevention's (CAL FIRE) Forest Health Research Program (Agreements #8GG19803 & 8GG20801), as part of California Climate Investments. California Climate Investments is a statewide program that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas (GHG) emissions, strengthening the economy, and improving public health and the environment—particularly in disadvantaged communities.

Public Health Impact of Prescribed Fire (PHIRE) Study

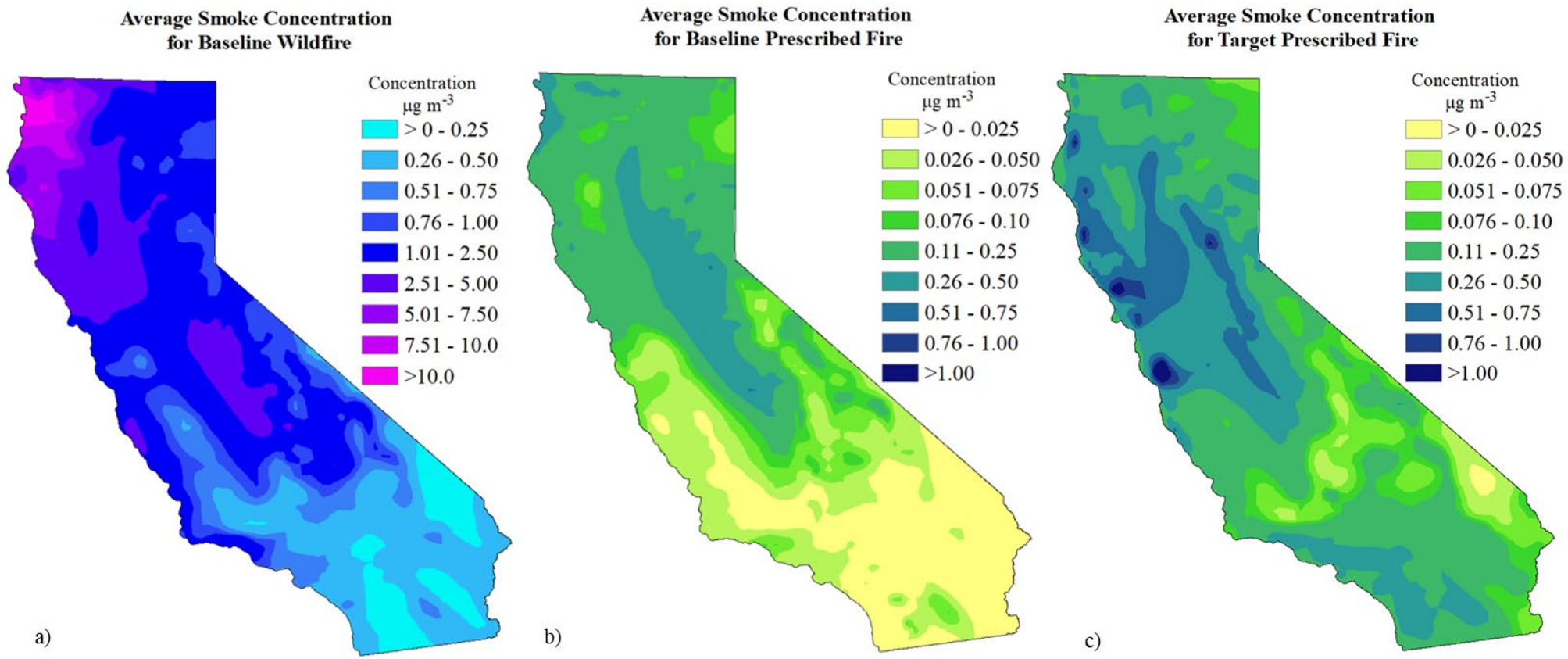
- Exposure Modeling – Sonoma Technology
  - Kramer et al., 2023 (https://doi.org/10.1016/j.atmosenv.2023.119993)
- Health Analysis – CDPH and US EPA
  - Thilakaratne et al., 2023 (https://pubmed.ncbi.nlm.nih.gov/36520960/)
  - Rosenberg et al. 2024 (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023EF003778)
- Community Studies – CDPH
  - Hoshiko et al., 2021 (CDPH Prescribed Fire Listening Session Report)
  - Hoshiko et al., 2023 (https://www.mdpi.com/1660-4601/20/2/1210)

How does the increased use of prescribed fire impact air quality and public health?

- Wildfire (WF) frequency and intensity are increasing in the western U.S.
- Prescribed (Rx) fires must increase to combat this threat.
  - California is scaling up to a target of 1,000,000 acres/year for fuels treatment by 2025.[a]
  - This will include 400,000-500,000 acres/year of beneficial fire treatments.[b]
- Limited knowledge on prescribed fire smoke impacts on air quality and health

[a] *Agreement for Shared Stewardship of California's Forest and Rangelands (2020)*
[b] *California's Strategic Plan for Expanding The Use of Beneficial Fire (March 2022)*

All Scenarios: Average Smoke Concentrations



Historical WF

Historical Rx

Future Projected Rx

STi | Sonoma Technology

Kramer et al., 2023

CDPH | Center for Healthy Communities
Environmental Health Investigations Branch

Objectives

1) Assess the air quality impacts of $PM_{2.5}$ from wildfire (WF) and prescribed fire (Rx) on the California population in the past (Historical Period, 2008-2016) and a Future Rx Scenario that meets the statewide target.

2) Quantify the cardiorespiratory health burden associated with total ambient $PM_{2.5}$ exposure on days impacted by WF or Rx smoke in the Historical Period and Future Rx Scenario.

3) Evaluate the projected change in the $PM_{2.5}$-attributed burden in the Future Rx Scenario compared to the Historical Period.

Data

- **$PM_{2.5}$ -attributable ED visits**
  - Daily emergency department (ED) visit counts in California (2008 – 2016)
  - Estimated associations between $PM_{2.5}$ exposure and cardiorespiratory ED visits[d]
  - Calculated the $PM_{2.5}$ -attributable number of ED visits across days and ZIP codes

- **Modeled daily ambient $PM_{2.5}$ concentrations ($aPM_{2.5}$)[e]**

- **HYSPLIT wildfire ($WF\text{-}PM_{2.5}$) & prescribed fire ($Rx\text{-}PM_{2.5}$)**
  - Modeled daily ZIP code average WF- and Rx-derived $PM_{2.5}$ concentrations

[d]Thilakaratne et al. (2022)
[e]Di et al. (2019)

Future Prescribed Fire Scenario

- Hypothetical fire management scenario that projected increased prescribed burning up to 500,000-acres per year across California.[c]
- Prescribed fire simulations were applied on lands designated by CAL FIRE as high priority, based on wildfire risk and housing density (***Orange*** and ***Red*** regions)
- Represents an aggressive fire management scenario that achieves the target and leads to more direct population exposures

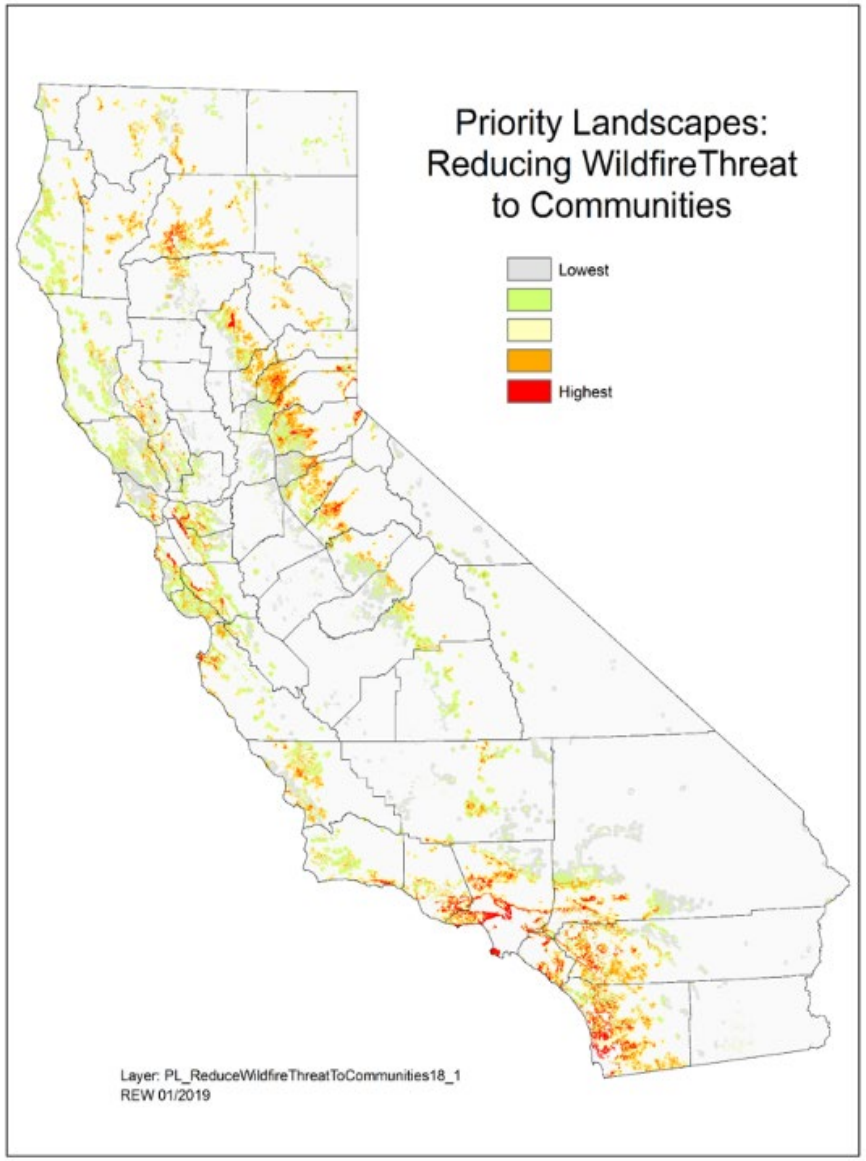


Figure 2. Reducing Wildfire Threat to Communities (2018)

Source: CAL FIRE, 2022

EPA

CDPH Center for Healthy Communities Environmental Health Investigations Branch

Methods and Results

I. Population Exposure by fire type

II. Average Daily Burden rates on smoke-impacted days

III. Fraction of $aPM_{2.5}$-burden by fire type

IV. Change in average Annual Burden rates between Historical Period and Future Prescribed Fire scenario

Identification of "smoke days" and categorization of "smoke strata"

- WF- and Rx-$PM_{2.5}$ concentrations used to characterize smoke events as a "smoke day" and by "smoke strata"

- **"Smoke strata"** include stratum of no smoke (0) and ranges of concentrations between 0.01 and >150 µg/m^3

- Calculated **population exposure**
  - # persons exposed each day (person-days)
  - Captures the cumulative exposure across all smoke days, by smoke strata, and fire type

I. Population exposure impacts from wildfire and prescribed fire smoke $PM_{2.5}$

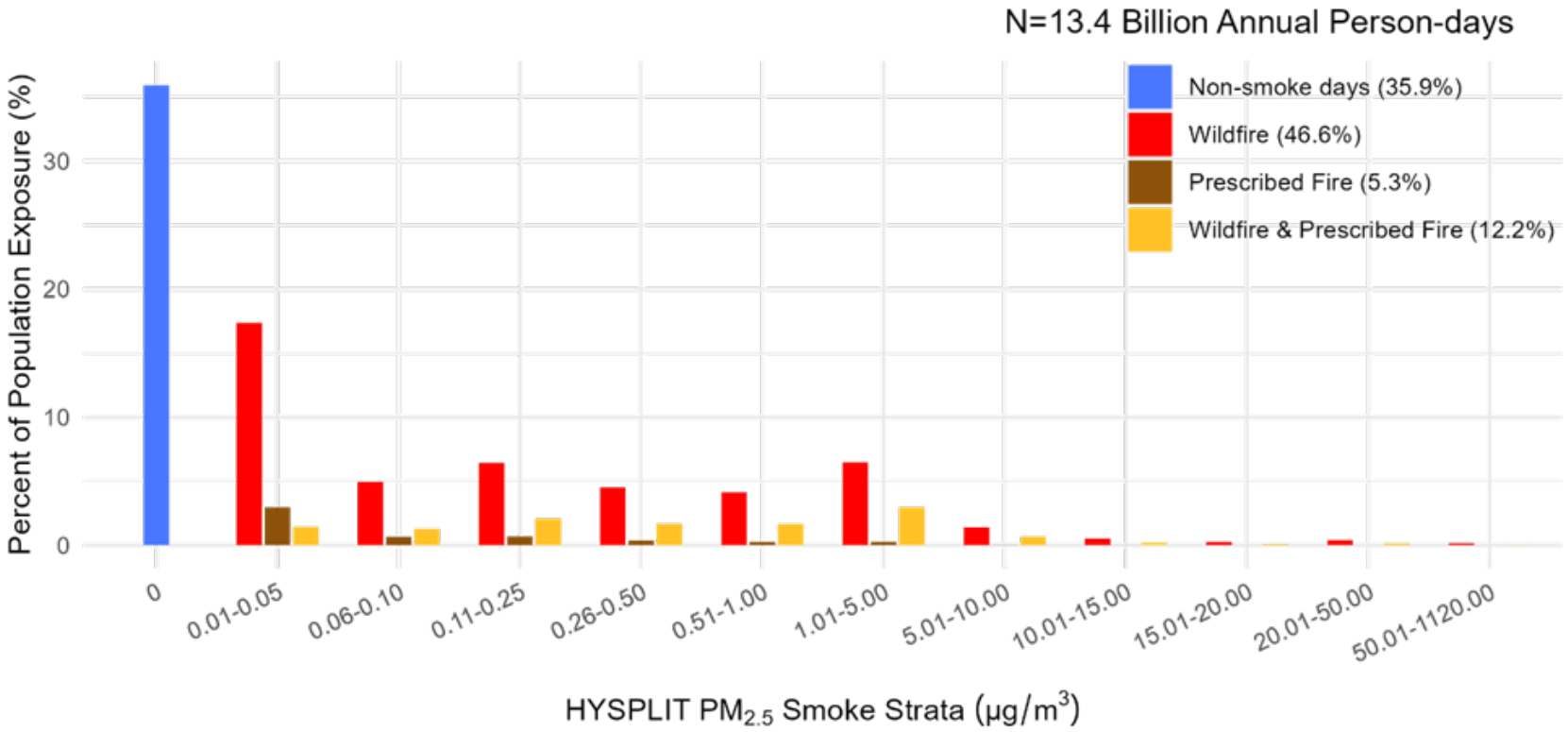


Figure 2. Distribution of Population Exposure (in Person-days) in the Historical Period (2008-2016).

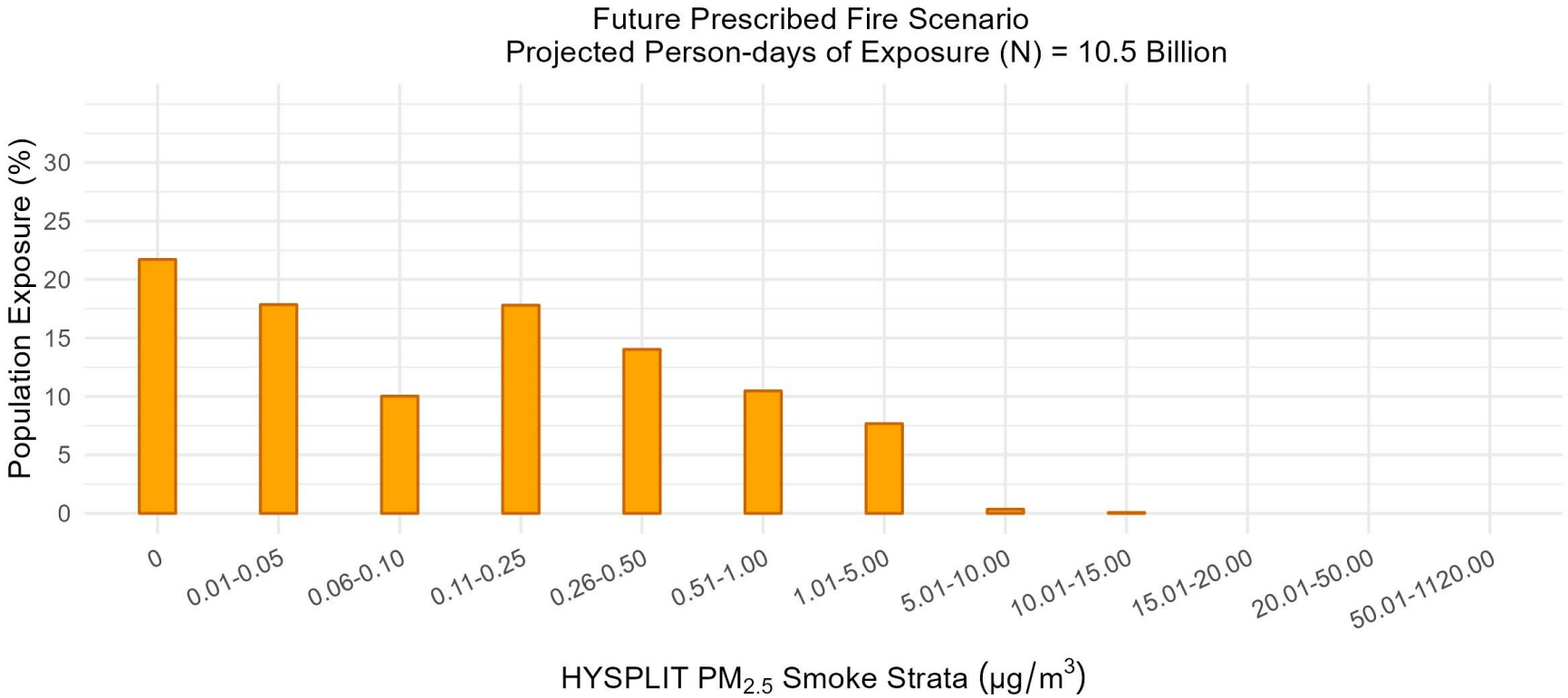


Figure 3. Distribution of Population Exposure (in Person-days) in the Future Prescribed Fire Scenario.

Estimation of $PM_{2.5}$-associated health burden for ambient $PM_{2.5}$, wildfire, and prescribed fire smoke

- The $aPM_{2.5}$-attributed number of cardiorespiratory ED visits were expressed as average daily burden rates per 100,000 persons by smoke strata and fire type

- Characterized the fraction of the $aPM_{2.5}$ burden on days impacted by wildfire, prescribed fire, or both, and on smoke-free ZIP-days

Daily $aPM_{2.5}$ burden rates on days affected by smoke – Historical Period (2008-2016)

- **Strata-specific $aPM_{2.5}$ Burden Rates**
  - Represents the statewide average rate of total ambient $PM_{2.5}$-related ED visits among the population by smoke strata and fire type

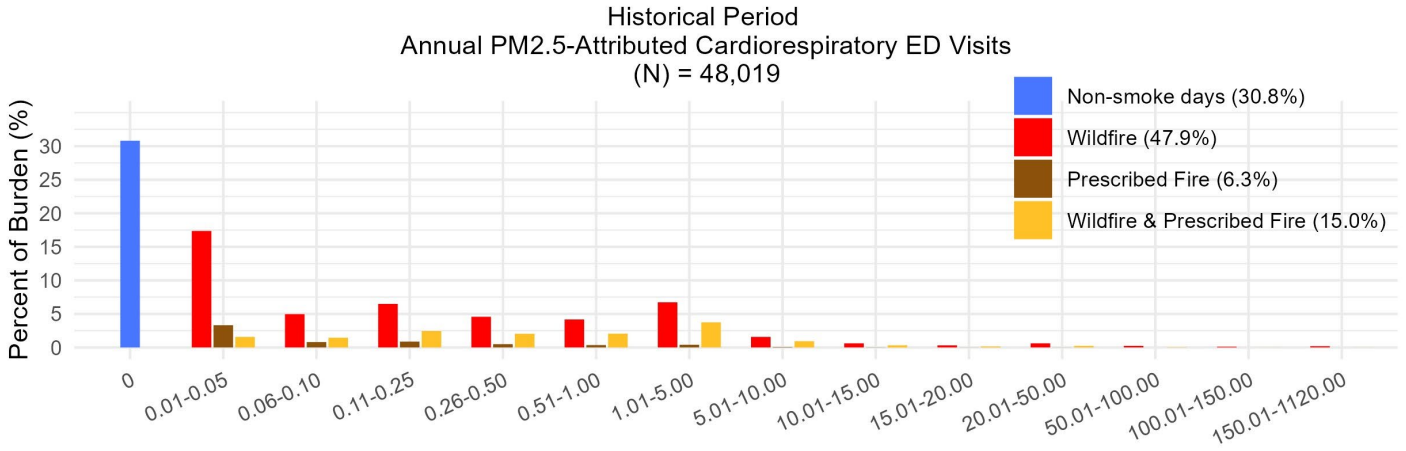
- Burden rates reflect the exposure, based on:
  - Total ambient $PM_{2.5}$ concentration on a given smoke day
  - Population size of a given ZIP code
  - Average ED visit burden within each smoke stratum

Daily $aPM_{2.5}$ burden rates - Future Prescribed Fire Scenario

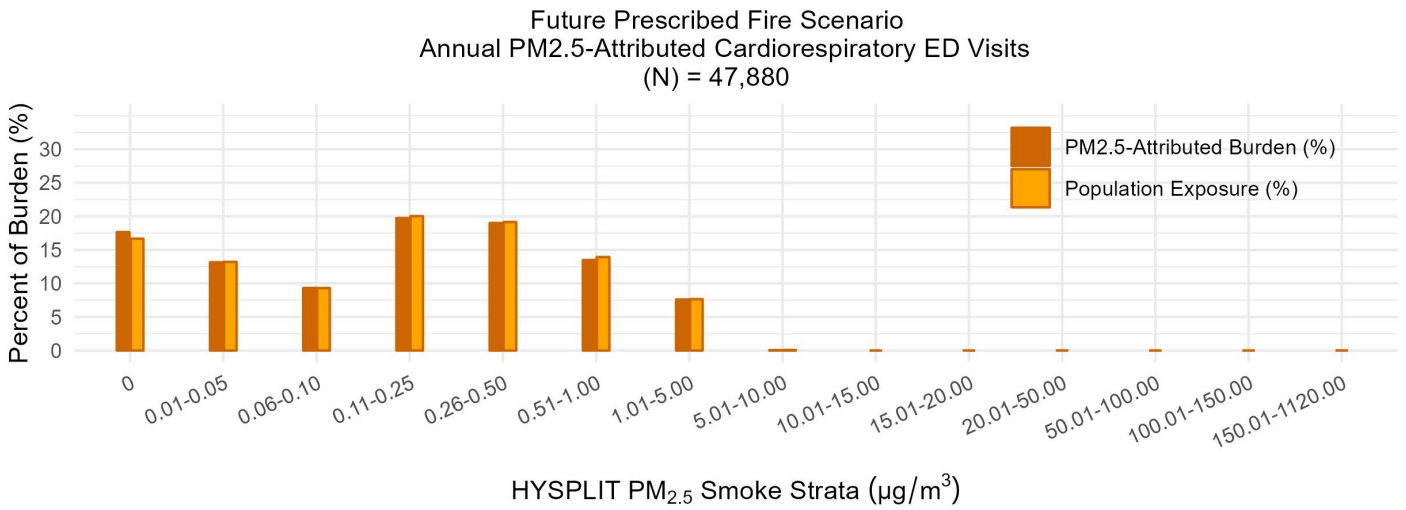
- Applied the $aPM_{2.5}$-attributed number of ED visit in the Historical Period
  - Matched by ZIP code and day-of-year to each day impacted by smoke in the Future Scenario
  - Summed across days in each ZIP code by smoke stratum
- Daily rates were averaged within each smoke stratum per 100,000 persons

III. Cardiorespiratory burden attributable to total ambient $PM_{2.5}$ on wildfire, prescribed fire, and non-smoke impacted days

a.



b.



EPA

CDPH Center for Healthy Communities Environmental Health Investigations Branch

II. Daily burden rates attributed to wildfire- and prescribed fire-related $PM_{2.5}$

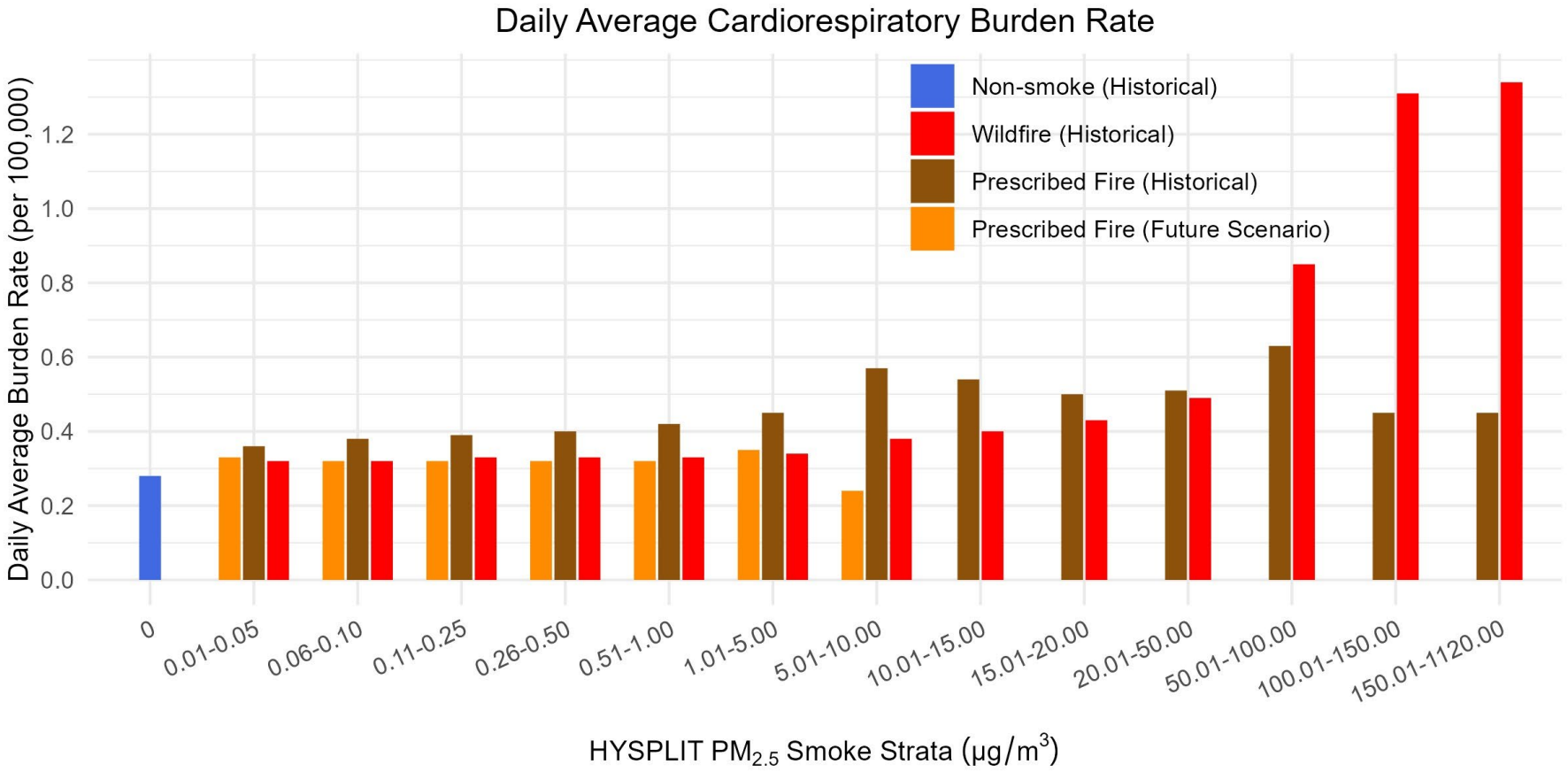
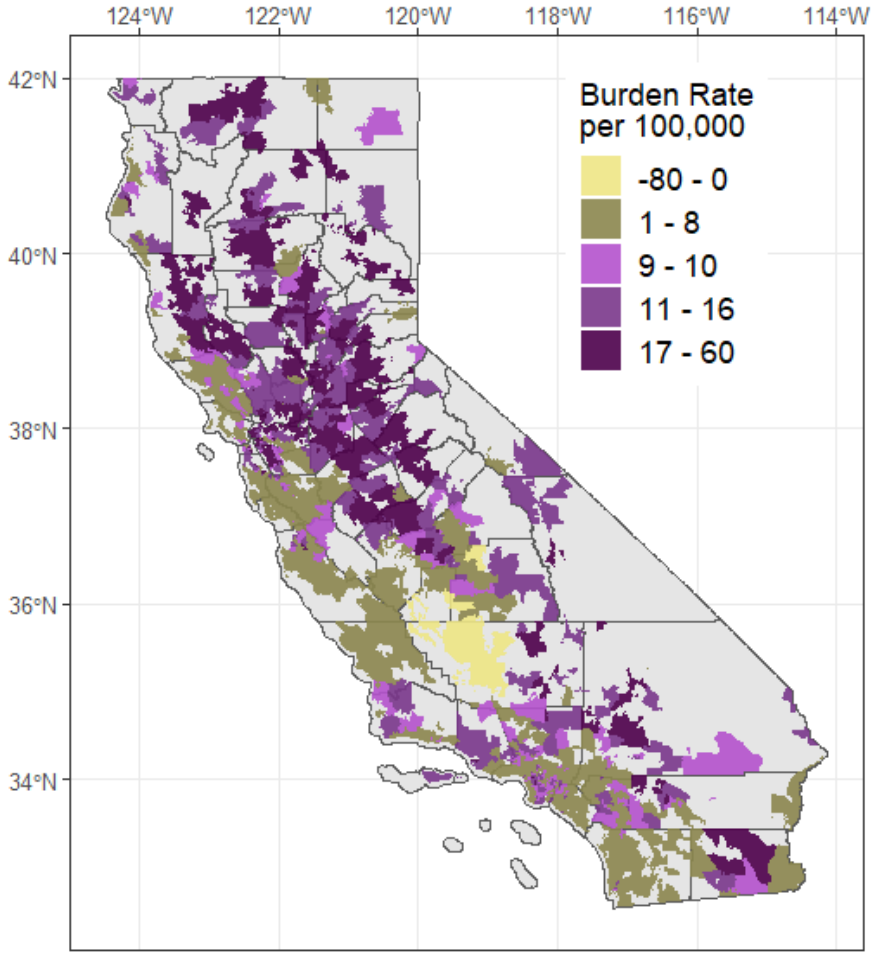


Figure 4. Average Daily $PM_{2.5}$-attributed Burden Rates for Cardiorespiratory Emergency Department (ED) Visits by HYSPLIT-modeled $PM_{2.5}$ Smoke Strata ($\mu g/m^3$).

Annual Prescribed Fire-attributed $PM_{2.5}$ burden rates – Historical and Future Scenario

- Annual rates reflect cumulative health impacts attributed to prescribed fire smoke
  - Applied non-smoke impacted daily burden rates (zero-smoke stratum)
  - Estimated the difference between the $aPM_{2.5}$-attributed ED visit burden and the zero-smoke $aPM_{2.5}$-attributed burden rate
- Compared the Rx smoke-attributed burden in the Future Scenario compared to the Historical Period

IV. Change in Annual Burden Rates per 100,000 persons between the Historical Period and Future Prescribed Fire Scenario.



n = 3,671 ED Visits

EPA

CDPH

Center for Healthy Communities
Environmental Health Investigations Branch

Conclusions

- Population exposure to prescribed fire smoke (number of persons exposed per year) was projected to be 15 times greater in the future scenario. However, these exposures were associated with lower concentrations of Rx-$PM_{2.5}$.
- The increased number of exposure days led to an overall increase in the future health burden.
- Areas in the northern, central, and southern regions experienced the largest burden increase in the Future Prescribed Fire scenario.

Key Points

- A California model of future prescribed burning in high-priority wildfire risk areas suggested more people will experience smoke.
- An increased number of exposure days in the future scenario led to an overall increase in the future health burden.
- The excess future health burden was due to the cumulative impact of lower exposure days and high population density in high-priority areas.

Implications

- With increased prescribed fire, regions already impacted by poor air quality may experience more frequent smoke days.
- Knowledge of these impacts can inform strategies for health risk communications, including preparedness and education.
- Opportunity for a more integrated approach that intersects public health, forest management, and hazard mitigation planning.

Practical Actions

- Advanced planning in affected communities is needed to mitigate potential health impacts.
- Enhanced messaging and advisories for prescribed fire and wildfire smoke events to reach communities most in need.
- Reduced barriers to accessing tools and resources to manage smoke exposure.

Strategies: Health protection measures to mitigate smoke impacts

- **Coordination** across agencies
- **Planning** guidance for local health jurisdictions
- **Notification** advanced advisories of planned smoke events
- **Communications** public health risk messaging
- **Health Education** exposure risks and health protection
- **Resources** smoke monitoring, information, and physical (PPE, air filters, clean air centers)

Citation for this work

Rosenberg, A., Hoshiko, S., Buckman, J. R., Yeomans, KR., Hayashi, T., Kramer, SJ., Huang, SM., French, NHR., & Rappold, AG. (2024, Feb 7). Health Impacts of Future Prescribed Fire Smoke: Considerations from an Exposure Scenario in California. Earth's Future. http://doi.org/10.1029/2023EF003778

Other References

[a]State of California and USDA Forest Service Pacific Southwest Region. (2020). Agreement for shared stewardship of California's forest and rangelands. Retrieved from https://www.gov.ca.gov/wp-content/uploads/2020/08/8.12.20-CA-Shared-Stewardship-MOU.pdf

[b]California Wildfire and Forest Resilience Task Force. (2022). California's strategic plan for expanding the use of beneficial fire. Retrieved from https://wildfiretaskforce.org/wp-content/uploads/2022/05/californias-strategic-plan-for-expanding-the-use-of-beneficial-fire.pdf

[c]Kramer, S. J., Huang, S., McClure, C. D., Chaveste, M. R., & Lurmann, F. (2023, 2023/08/02/). Projected smoke impacts from increased prescribed fire activity in California's high wildfire risk landscape. Atmospheric Environment, 119993. https://doi.org/https://doi.org/10.1016/j.atmosenv.2023.119993

[d]Thilakaratne, R., Hoshiko, S., Rosenberg, A., Hayashi, T., Buckman, J. R., & Rappold, A. G. (2022, Dec 15). Wildfires and the Changing Landscape of Air Pollution-related Health Burden in California. Am J Respir Crit Care Med. https://doi.org/10.1164/rccm.202207-1324OC

[e]Di, Q., Amini, H., Shi, L., Kloog, I., Silvern, R., Kelly, J., Sabath, M. B., Choirat, C., Koutrakis, P., Lyapustin, A., Wang, Y., Mickley, L. J., & Schwartz, J. (2019, 2019/09/01/). An ensemble-based model of PM2.5 concentration across the contiguous United States with high spatiotemporal resolution. Environment International, 130, 104909. https://doi.org/https://doi.org/10.1016/j.envint.2019.104909

Contact Information:

Andrew Rosenberg, MPH (Andrew.rosenberg@cdph.ca.gov)

Environmental Health Investigations Branch
California Department of Public Health
Richmond, CA, USA

Ana G. Rappold, PhD (Rappold.ana@epa.gov)

Center for Public Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC, USA