

Physical, Mental, and Financial Impacts From Drought in Two California Counties, 2015

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Objectives. To evaluate health impacts of drought during the most severe drought in California's recorded history with a rapid assessment method.

Methods. We conducted Community Assessments for Public Health Emergency Response during October through November 2015 in Tulare County and Mariposa County to evaluate household water access, acute stressors, exacerbations of chronic diseases and behavioral health issues, and financial impacts. We evaluated pairwise associations by logistic regression with pooled data.

Results. By assessment area, households reported not having running water (3%–12%); impacts on finances (25%–39%), property (39%–54%), health (10%–20%), and peace of mind (33%–61%); worsening of a chronic disease (16%–46%); acute stress (8%–26%); and considering moving (14%–34%). Impacts on finances or property were each associated with impacts on health and peace of mind, and acute stress.

Conclusions. Drought-impacted households might perceive physical and mental health effects and might experience financial or property impacts related to the drought.

Public Health Implications. Local jurisdictions should consider implementing drought assistance programs, including behavioral health, and consider rapid assessments to inform public health action. (*Am J Public Health.* 2017;107:783–790. doi:10.2105/AJPH.2017.303695)

Drought has been defined in hydrological, meteorological, agricultural, and socioeconomic contexts¹; however, the population health impacts of drought have not been well-described. Drought can reduce available surface water and deplete water-bearing aquifers, potentially disproportionately affecting persons served by private wells or small water systems. Unlike acute disasters, years may pass before water supplies become limited, and years of recovery might be necessary before water supplies normalize. Severe droughts are slow-onset and long-duration disasters with far-reaching impacts on the economy, environment, and affected communities.

Previous studies have identified economic losses, infrastructure changes, diminished access to services, environmental degradation, and social network disruptions as potential impacts of drought.^{2–4} The extent of direct and indirect health consequences might

depend on drought severity and duration as well as the underlying population vulnerability and available resources.^{5,6} Among the hypothesized adverse effects are exacerbations of respiratory diseases (e.g., asthma, allergies, dust pneumonia, bronchitis) resulting from increased airborne dust and particulate matter; increases in vector-borne disease incidence because of environmental degradation; increases in waterborne diseases attributable

to worsening surface water quality or increased groundwater catchment areas when wells are over-pumped; and infectious diseases resulting from compromised hygienic practices.⁷ Among persons living in drought-impacted environments, including those who depend on agriculture for their livelihood, financial stressors (e.g., lost work, food affordability, and infrastructure costs such as well drilling) and population loss resulting from migration⁸ might lead to adverse outcomes such as depression and anxiety^{2,3,9} and possibly suicide.^{10,11} Poverty, a social determinant of health, can increase during a drought because of closures of business, job losses, and incurred debts.^{5,7} Migration has an impact on community-level cohesion and family structures, further eroding community resources.⁴

In 2015, California was in its fourth year of the most severe drought since becoming a state in 1850.¹² Approximately 2 million Californians are served by private wells or small water systems,¹³ and from summer 2014 to November 2015, 2455 private wells had been reported as dry statewide, affecting an estimated 12 275 residents.¹⁴ California's governor, Edmund G. Brown Jr, proclaimed a State of Emergency in January 2014,¹⁵ and as of November 2015, California recorded 63 emergency proclamations from cities, counties, tribal governments, and special

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districts.¹⁴ The drought has also devastated California's forests, potentially increasing wildfire risks; in October 2015 Governor Brown issued a State of Emergency proclamation addressing drought-associated tree mortality.¹⁶

In 2015, the California Department of Public Health collaborated with Mariposa County Health Department (Mariposa County) and Tulare County Health and Human Services Agency (Tulare County) to gather data about the health status of drought-stricken communities. We conducted Community Assessments for Public Health Emergency Response (CASPERs),¹⁷ an epidemiological method that allows household-level data, gathered from 210 interviews, to be generalized to the sampling frame of interest.¹⁸ CASPER methodology is designed to rapidly provide evidence-based actionable information to inform public health and emergency management decisions and action. This project was done in response to a governor-declared state of emergency and, to our knowledge, this is the first time CASPER methodology has been applied to a slow-onset natural disaster. This report describes our use of CASPER to quantify the public health impacts of drought.

METHODS

The average annual temperatures in Tulare County range between 52 °F and 79 °F, with monthly average high 99 °F in July, and the average annual precipitation is 29 centimeters.¹⁹ Tulare County has approximately 460 000 residents, of whom 32% are younger than 18 years and 10% are aged 65 years or older, 63% are Hispanic or Latino (Hispanic or Latino can be of any race), 50% speak a language other than English at home, 28% are in poverty, and 57% live in an owner-occupied housing unit.²⁰ Tulare County is the second-leading producer of agricultural commodities in the United States. As of September 2015, Tulare County had 1308 dry private wells affecting more than 6000 residents.²¹ Most were located in the southern part of the county in East Porterville and its environs, where dry wells had been reported since 2014; additional dry wells were reported in the northern part of the county beginning 2015. Tulare

County partnered with the California Department of Housing and Community Development and other agencies to implement relocation assistance for eligible residents that offsets costs of moving out of a home with no running water (i.e., piped water, tap water). Tulare County also provided bottled water and nonpotable water tanks, low-interest loans and utility and rental assistance, and emergency food assistance to residents affected by the drought. Tulare County and organizations responding to the drought have had to contend with false rumors that government agencies would condemn homes or take custody of children in homes without water (D. R., Tulare County Health and Human Services Agency, e-mail communication, April 14, 2016).

The average annual temperatures in Mariposa County range between 41 °F and 67 °F, with monthly average high of 89 °F in July and an average annual precipitation of 93 centimeters.²² Mariposa County has approximately 18 000 residents, of whom 17% are younger than 18 years and 25% are aged 65 years or older, 81% are non-Hispanic White, 10% speak a language other than English at home, 16% are in poverty, and 73% live in an owner-occupied housing unit.²⁰ Tourism associated with Yosemite National Park is the main industry. Mariposa County reported 140 dry wells affecting more than 700 residents.²¹ The drought has also had a severe impact on the forests in the county, with an estimated 30% to 50% mortality of pine, fir, and oak (D. T., Mariposa County Health Department, e-mail correspondence, January 15, 2016).²³ Tree mortality in Mariposa County has increased the risk of devastating wildfires and associated respiratory diseases. Economic impacts of tree mortality include homeowners' insurance rates increasing by 350% in heavily impacted areas and 170% throughout the county, an estimated 1.4 billion board feet of timber inventory lost, and losses to local woodcutting and harvesting business secondary to decreased demand and increased supply of local firewood for winter heating (Eric Sergienko, Mariposa County Health Department, e-mail correspondence, September 9, 2016). Mariposa County has also made dry well assistance and behavioral health assistance available to residents affected by

the drought (D. T., Mariposa County Health Department, e-mail correspondence, January 15, 2016).

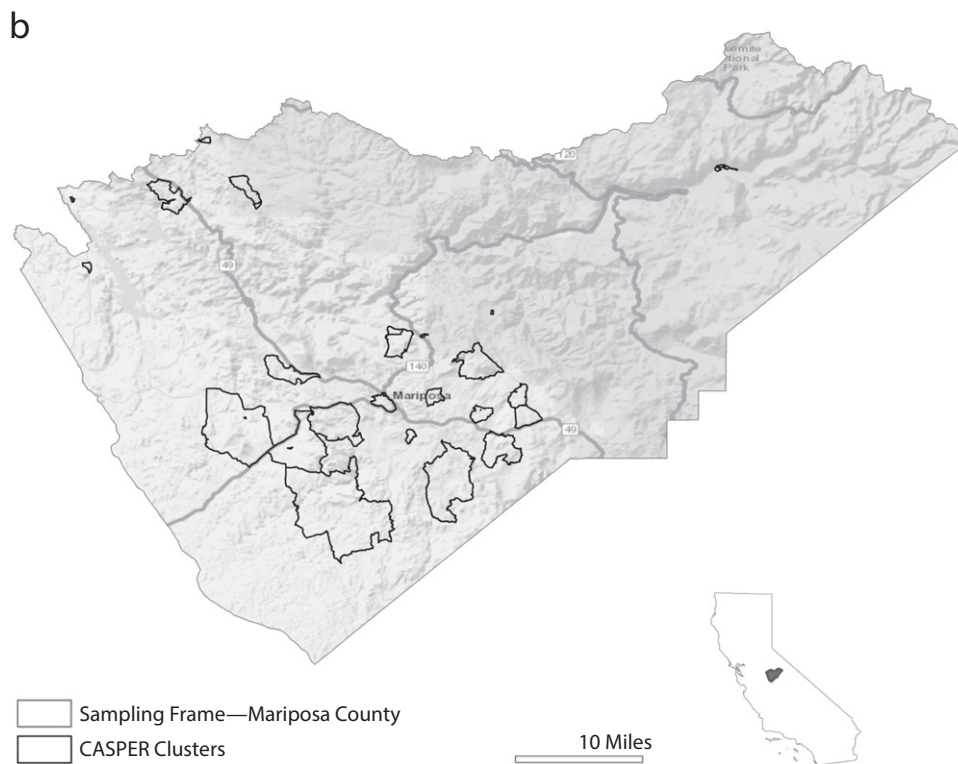
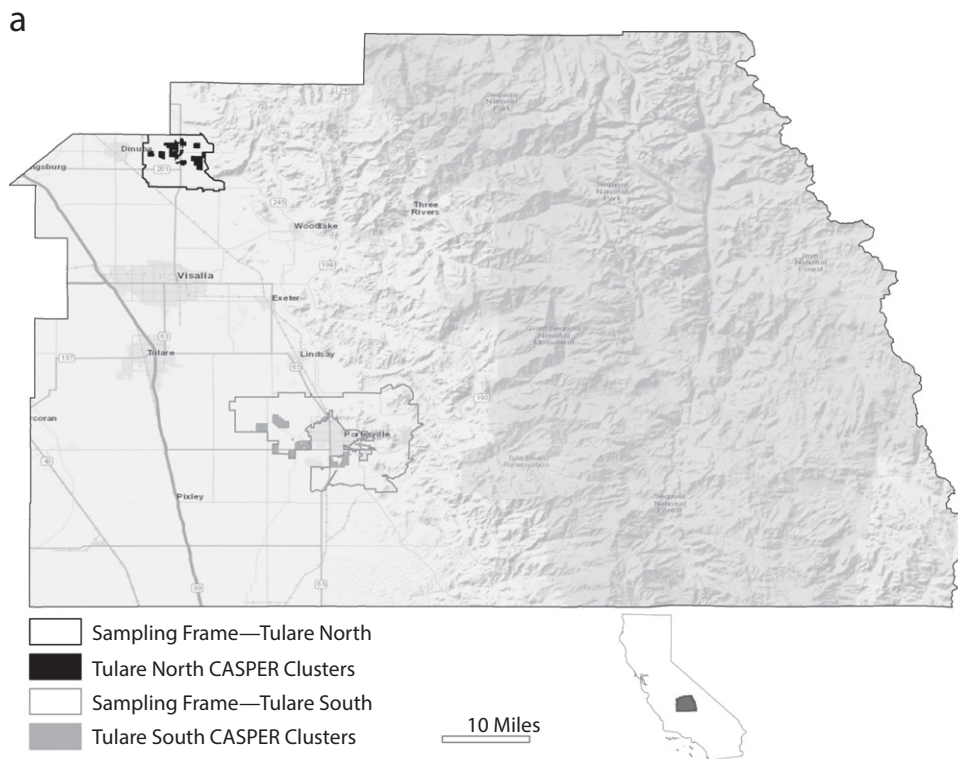
Sampling Frame and Cluster Selection

Tulare County chose to conduct 2 simultaneous CASPERs, with both sampling frames designed to enrich for private well ownership. The North Tulare sampling frame included the towns of Cutler and Orosi and the vicinity (town residents receive municipal water systems and nearby residents rely upon well water; Figure 1). The South Tulare sampling frame included East Porterville and its environs (specifically excluding the City of Porterville, which is served by a municipal water system). Mariposa County chose a single county-wide sampling frame. We used the 2010 TIGER/Line With Selected Demographic and Economic Data Shapefile and the 2010 Census Redistricting Data Summary File for delineating sampling frame geography and estimating population and housing units.^{24,25}

The 2-stage sampling randomly selects 30 clusters (typically Census blocks) from the sampling frame with probability of selection proportional to the number of housing units in the cluster; field teams select 7 households to interview in each cluster by systematic random sampling. Most Census blocks in each sampling frame had fewer than 7 housing units; we therefore modified cluster selection by aggregating adjacent Census blocks to achieve a minimum of 7 occupied housing units with the SAS version of the New York State Health Department's Geographic Aggregation Tool, version 1.31 (New York State Health Department, Troy, NY). We randomly selected 3 clusters in the North Tulare sampling frame twice. In Mariposa County, we randomly selected one cluster twice and one 3 times; we also selected 5 additional clusters as contingency for remote areas.

Conducting CASPERs and Questionnaire Design

Fifteen 2-person interview teams each in the North and South Tulare sampling frames conducted CASPER surveys October 20 to 22, 2015. In Mariposa County, 7 to 10 teams conducted CASPER surveys



Note. CASPERs = Community Assessments for Public Health Emergency Response. Maps were created with ArcGIS software by Esri, with World Street Map base layer.

FIGURE 1—CASPER Sampling Frames in (a) Tulare County and (b) Mariposa County: California, October–November 2015

November 12 to 14, 2015, and 3 to 5 teams November 16 to 20, 2015. Teams selected 7 households in each cluster by systematic random sampling and made 3 attempts to contact an adult resident at a given household before replacing the household with another. Interview teams received just-in-time training on household sampling and questionnaire administration to reduce interviewer and sampling bias.¹⁷

We developed a questionnaire addressing household demographics; knowledge, attitudes, and practices regarding the drought; access to and use of water; water conservation practices; perceived impacts of the drought including behavioral and mental health, exacerbations of chronic diseases, and employment; and preferred communication methods (see questionnaire available as a supplement to the online version of this article at <http://www.ajph.org>). We selected topics on the basis of priority interests of Mariposa and Tulare Counties. We adapted questions from previous CASPERs,^{17,26} the California Health Interview Survey, the National Health and Nutrition Examination Survey, and the Behavioral Risk Factor Surveillance Survey. Mariposa County also included questions addressing water-conserving behaviors, perceptions of the forecasted El Niño precipitation events, insurance coverage, and needs for special medical equipment and supplies. Tulare County also included questions regarding perceptions and concerns about outdoor dust levels and needs for special medical equipment and supplies. This report focuses on questions addressing the drought's impact on households.

When we took questions from existing surveys, we reframed high-literacy questions to be lower literacy and adjusted individual-based questions to reflect a household-based perspective. Questionnaires were translated into Spanish. An interviewer read the questions aloud and recorded the respondent's answers.

Data Analysis

We calculated weighted percentages and 95% confidence intervals by using the population of the sampling frame, the total number of clusters, and the number of completed surveys in each cluster (we

adjusted weights for substitute Mariposa clusters to account for different selection probability). Only weighted results are presented in the article text, tables, and figures; both weighted and unweighted results are presented in Tables A through D (available as supplements to the online version of this article at <http://www.ajph.org>). We did not calculate weighted percentages for survey answers given by fewer than 10 households and these are noted as not calculated.

We identified potential pairwise associations by literature review.^{3,7,8} We pooled data from the 3 sampling frames and used the methods of Murti et al.²⁷ to evaluate pairwise associations by logistic regression weighted for survey design. We calculated crude odds ratios and odds ratios adjusted for owning versus renting a home, or for having a child younger than 18 years or adult aged 65 years or older in the household. We chose a statistical significance threshold of *P* equal to .01 to account for multiple posthoc comparisons.

We conducted all statistical analyses with SAS version 9.4 (SAS Enterprises, Cary, NC).

RESULTS

In the North Tulare sampling frame, teams approached 372 homes; 242 households answered the door; 185 of 210 possible interviews were completed (contact rate 50%, cooperation rate 76%, completion rate 88%); and 99 (54%) interviews were conducted in Spanish. In the South Tulare sampling frame, teams approached 328 homes; 257 households answered the door; 207 of 210 possible interviews were completed (contact rate 63%, cooperation rate 81%, completion rate 99%); and 68 (33%) were conducted in Spanish.

In Mariposa County, 2 sampled clusters were too remote to be accessible during daylight hours by judgment of county staff, and we randomly selected 2 replacement clusters from the pool of 5 additional clusters; this sampling frame, therefore, consisted of 32 clusters with a target of 224 interviews. Teams approached 383 homes; 240 households answered the door; 179 of 224 possible interviews were completed (contact rate 47%, cooperation rate 75%, completion rate 80%); and 2 (1%) were conducted in Spanish.

Survey Responses

Household demographics. Household sizes were largest in North Tulare and smallest in Mariposa County (Table 1 and Table A). Households in the North Tulare sampling frames were most likely to have a member younger than 18 years, and households in Mariposa County were most likely to have a member aged 65 years or older. Most households in each sampling frame reported owning their homes. Most households in Mariposa County and South Tulare spoke English as their primary language at home, whereas most households in North Tulare spoke Spanish as their primary language at home. Demographic findings for each sampling frame were similar to those of the US Census Bureau.²⁰

Access to water and services. Most households in South Tulare and Mariposa County and some in North Tulare used a private well as the household's water source before the drought (Table 1 and Table B). As a result of the drought, some households (North Tulare 8%, South Tulare 12%, Mariposa County not calculated) did not have running water in their homes with cost being the main barrier to getting running water (Table B). Bottled water was the most common household water source for these households, and households most often obtained the bottled water by purchasing it themselves.

Health effects and chronic disease exacerbation. Some households in each sampling frame reported that the drought had negatively affected the health of a household member, most commonly in South Tulare (Figure 2 and Table C). Whereas households in Mariposa County were most likely to report that a member had a chronic disease (Table 1 and Table C), households in South Tulare were most likely to report worsening of the disease since the drought began (Figure 2 and Table C). Among households reporting a worsening of a chronic disease, some reported that they had sought additional medical care (20% South Tulare; North Tulare and Mariposa not calculated; Table C). Most households in North and South Tulare reported that outdoor dust levels had increased since the drought began (59% and 66%, respectively; Table C). Of those reporting increased dust, most (68% and 61%, respectively) reported that the increased dust

TABLE 1—Household Demographics, Prevalence of Chronic Disease and Mental Health Conditions, and Access to Water Before the Drought: Tulare County and Mariposa County CASPERs, California, October–November 2015

Characteristic	North Tulare (4803 Housing Units, 185 Households Interviewed)		South Tulare (5575 Housing Units, 207 Households Interviewed)		Mariposa (10 188 Housing Units, 179 Households Interviewed)	
	Range or No.	Mean (Median) or % (95% CI)	Range or No.	Mean (Median) or % (95% CI)	Range or No.	Mean (Median) or % (95% CI)
Household size ^a	1–10	4.2 (4.0)	1–14	3.7 (3.0)	1–8	2.6 (2.0)
Households with ≥ 1 member in the following age categories ^a						
< 18 y	2659	63 (56, 70)	2474	50 (42, 58)	2035	26 (19, 32)
≥ 65 y	1092	26 (20, 32)	1354	28 (21, 34)	3650	46 (39, 53)
Own or rent home						
Own	2293	51 (42, 59)	2675	52 (40, 63)	6334	80 (71, 89)
Rent	2205	49 (40, 57)	2511	48 (37, 60)	1485	19 (10, 28)
Primary language spoken at home						
English	1304	29 (22, 35)	3021	58 (48, 68)	7674	97 (93, 100)
Spanish	3055	67 (61, 73)	1840	35 (26, 45)	NC	
English and Spanish	NC		251	5 (2, 8)	NC	
Member of household has preexisting chronic disease	1035	23 (16, 29)	1486	29 (22, 35)	2876	36 (26, 46)
Member of household has preexisting mental health condition	307	7 (3, 11)	938	18 (13, 24)	1497	19 (9, 29)
Water source before drought						
Private well	1300	29 (13, 44)	3260	63 (48, 78)	5897	74 (60, 89)
Municipal water system	3168	70 (54, 85)	1560	30 (16, 45)	1145	14 (4, 25)
Small water system	NC		399	8 (0, 15)	681	9 (0, 18)
Bottled water	860	19 (7, 31)	276	5 (0, 11)	777	10 (2, 17)

Note. CI = confidence interval; NC = not calculated. Weighted counts and percentages were not calculated for answers given by fewer than 10 households; therefore, weighted percentages might not total 100%. Total number of housing units in each sampling frame is estimated by decennial census.²⁴ Weighted percentages account for the population of the sampling frame, completed surveys in each cluster, and number of clusters.

^aHousehold size and age categories of residents could not be determined because of errors by interviewers for households as follows: North Tulare, 13 households; South Tulare, 11 households; Mariposa County, 1 household.

had caused health concerns, most commonly allergies (31% and 30%), asthma (27% and 23%), and other unspecified respiratory issues (24% and 22%; Table C).

Mental health effects. Some households in each sampling frame reported that the drought had a negative impact on their household's peace of mind, most commonly in Mariposa (Figure 2 and Table C). Some households reported a drought-related experience in the past 30 days indicating acute mental stress (Figure 2 and Table C); among these households, 50% in North Tulare and 24% in South Tulare reported seeking help (Mariposa County not calculated; Table C). Households in South Tulare and Mariposa County were most likely to report that a member of the household had a mental health condition (Table 1 and

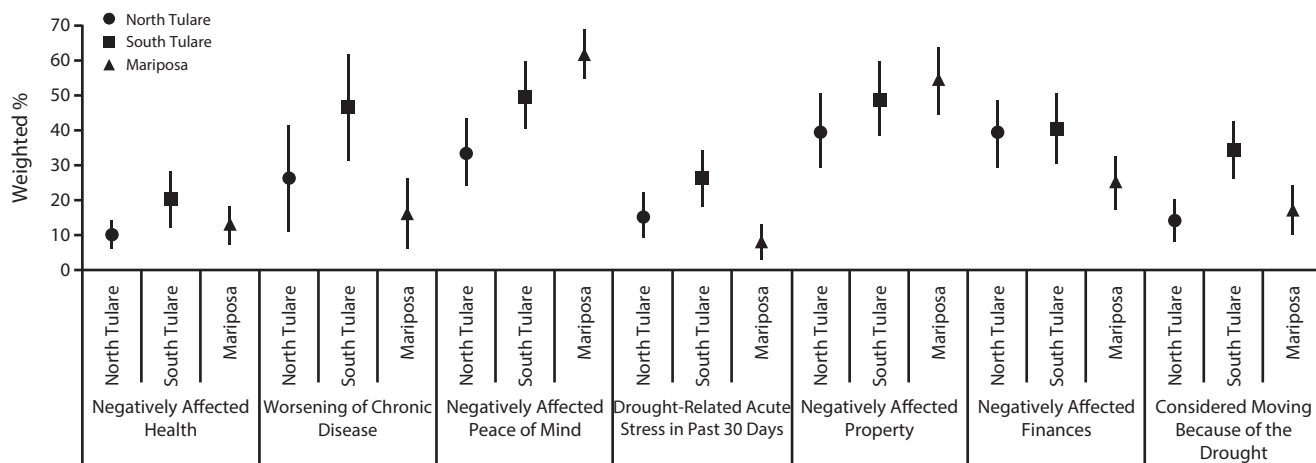
Table C), and households in South Tulare were most likely to report worsening of the disease since the drought began (38%; North Tulare and Mariposa County not calculated; Table C).

Property and financial impacts, and considering moving. Some households in each sampling frame reported that the drought had a negative impact on their property, most commonly in Mariposa (Figure 2 and Table C). Although none of the survey questions specifically addressed tree deaths, 16% of respondents in Mariposa County volunteered that dead or dying trees were having an impact on their household. Households in North Tulare and South Tulare were most likely to report that the drought had a negative impact on their finances (Figure 2 and Table C). Many also reported that they have considered moving (e.g., to another part of

California or out of state) because of the drought (Figure 2 and Table D).

Associations Between Perceived Impacts and Health Outcomes

According to analysis of pooled data, households reporting impacts on either finances or property had greater odds of reporting impacts on health of a household member; however, none of the tested exposures were associated with worsening chronic disease (Table 2). Households reporting impacts on their finances or on their property also had greater odds of reporting impacts on peace of mind or that a member of the household had experienced drought-related acute stress in the past 30 days; none of the tested exposures were associated with



Note. CASPERs = Community Assessments for Public Health Emergency Response. Household-based weighted prevalence rates are shown. Vertical lines indicate 95% confidence intervals. Percentages of households reporting a worsening of a chronic disease were calculated as proportion of households that reported a member having a chronic disease.

FIGURE 2—Impacts of the Drought on Health, Mental Health, Property, Finances, and Considering Moving: Tulare County and Mariposa County CASPERs, California, October–November 2015

reporting a worsening mental health condition. Each tested exposure was associated with greater odds of reporting thinking about moving.

Adjusting for owning versus renting the home, or for having a child younger than 18 years or adult aged 65 years or older in the household did not change the odds ratio point estimate by 10% or more for any tested

pairwise association; therefore, only crude odds ratios are presented.

DISCUSSION

CASPERs have most commonly been used in the context of acute disasters or preparedness, and this application of

CASPER to quantify population-level health impacts of an ongoing, long-duration disaster provides a new dimension to descriptive disaster epidemiology by identifying suitable and fallow routes of future study. Of particular note, differences in drought impacts are likely attributable to differences in geography, climate, groundwater availability, and demographics of these counties. The majority of

TABLE 2—Weighted Logistic Regression of Pairwise Comparisons of Pooled Tulare County and Mariposa County CASPERs: California, October–November 2015

Variable	Negatively Affected Health, Weighted OR (95% CI)	Negatively Affected Peace of Mind, Weighted OR (95% CI)	Considering Moving, Weighted OR (95% CI)	Worsening Chronic Disease, Weighted OR (95% CI)	Worsening Mental Health Condition, Weighted OR (95% CI)	Drought-Related Acute Stress in Past 30 Days, Weighted OR (95% CI)
Household does not have running water	1.38 (0.43, 4.39)	1.32 (0.54, 3.22)	2.27 (1.12, 4.58)	0.94 (0.25, 3.47)	0.83 (0.13, 5.54)	1.85 (0.82, 4.06)
Household had private well before drought	1.55 (0.73, 3.29)	2.50 (1.51, 4.14)	1.95 (1.23, 3.10)	1.04 (0.43, 2.50)	1.19 (0.31, 4.60)	0.83 (0.50, 1.38)
Negatively affected household finances	8.62 (3.83, 19.38)	2.92 (1.78, 4.79)	1.86 (1.12, 2.84)	0.49 (0.20, 1.23)	0.58 (0.16, 1.62)	3.12 (1.92, 5.08)
Negatively affected household property	3.93 (1.88, 8.22)	4.17 (2.56, 6.80)	1.69 (1.14, 2.49)	0.87 (0.38, 1.97)	1.02 (0.31, 3.89)	2.00 (1.20, 3.34)

Note. CI = confidence interval; OR = odds ratio.

households in Mariposa County reported impacts on their property and many households volunteered concern about dead or dying trees on their property, which suggests that many drought impacts in Mariposa are specifically related to the costs of disposing of dead or dying trees or geographic isolation.^{28,29} Environmental degradation and financial stressors are associated with adverse drought-associated behavioral health outcomes in causal models,⁸ and studies of the association of drought-related tree deaths and behavioral health outcomes might be warranted. By contrast, South Tulare households were the most likely to report that the drought had affected their health, that they had experienced acute stress related to the drought, and that they had considered moving because of the drought; these differences might be attributable to households in South Tulare experiencing dry wells for longer than North Tulare and Mariposa.

Our pooled analysis indicated a potential association between drought impacts on household property or finances with both physical and mental health impacts. These findings are consonant with reports demonstrating associations between drought and mental stressors and community stressors during the 2003 to 2012 Australian drought, as well as with the causal processes of drought-associated behavioral health outcomes previously described.^{2,3,8} The analyses presented here support the hypothesis that health effects of drought other than mental health are possible.⁷ However, it is not possible to fully characterize health effects by using household-based interviews or to compare household-based findings to existing individual-based health prevalence data (e.g., the 2014 California Health Information Survey estimates that 7.7% [95% confidence interval = 7.0, 8.4] of Californians likely have had serious psychological distress in the past year³⁰), and it might be difficult to specifically associate a worsening of a chronic disease or behavioral health condition with the drought.

These findings are subject to some limitations. CASPER collects data over an interval of days, which should be considered when one is attributing health effects to a multiyear disaster. Two clusters from Mariposa County were not visited because of their inaccessibility; therefore, the data

presented here might not be representative of households in the remote areas of Mariposa County. We conducted surveys during daytime hours, potentially biasing responses toward nonemployed respondents. It is possible that respondents' willingness to participate may have been related to their perceptions of drought impact severity on their household. The CASPER technique was designed to gather situational awareness about the affected community for decision-makers in the context of an emergency or for predisaster planning; therefore, we recommend interpreting the results of pooled posthoc analyses with caution. We also recommend using caution in direct comparisons of the impacts of drought by county or in generalizing these findings to other counties or states impacted by drought, as county differences in population demographics, environmental factors, community resources, and community resilience might differently mitigate these public health impacts.

Despite these limitations, our findings suggest that households perceive a connection between their physical and mental health and the drought, and support observations that persons in a drought were more likely to have a mental health problem or report their health as poor.^{3,9} Furthermore, they provide a foundation and direction for future detailed studies of the public health impacts of drought. These findings were also used to inform and augment ongoing drought response operations. Tulare County is conducting language-appropriate outreach to inform residents of available drought assistance, has expanded behavioral health services and outreach to those under acute drought-related stress, and is piloting partnering behavioral health, public health, and food assistance services (D. R., Tulare County Health and Human Services Agency, e-mail communication, April 14, 2016). Mariposa County used the health conditions data to promote emergency preparedness initiatives to better identify populations with special needs and used CASPER data to inform drought adaptation plans specific to Mariposa County through a cooperative agreement with the Centers for Disease Control and Prevention (California Building Resilience Against Climate Effects).

CASPER is part of a spectrum of disaster epidemiology methods, and the utility of each

might vary by disaster type and duration. CASPERs are relatively quick, inexpensive to conduct, are generally considered by institutional review boards to be public health practice, and can provide rapid situational awareness data for key decision-makers. Jurisdictions that need a hypothesis-generating approach or that do not have the resources or time to conduct observational or interventional studies in response to a disaster might consider a rapid assessment approach such as the one described here. **AJPH**

CONTRIBUTORS

All authors participated in the development, conduct, and reporting of these assessments, including planning, data collection and analysis, and writing and reviewing article drafts.

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R. Roisman died before the publication of this article, and her coauthors would like to pay tribute to her exceptional public health leadership.

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HUMAN PARTICIPANT PROTECTION

The California Health and Human Services Agency's Committee for the Protection of Human Subjects determined that this investigation was public health practice (i.e., nonresearch), and therefore exempt from institutional board review approval.

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