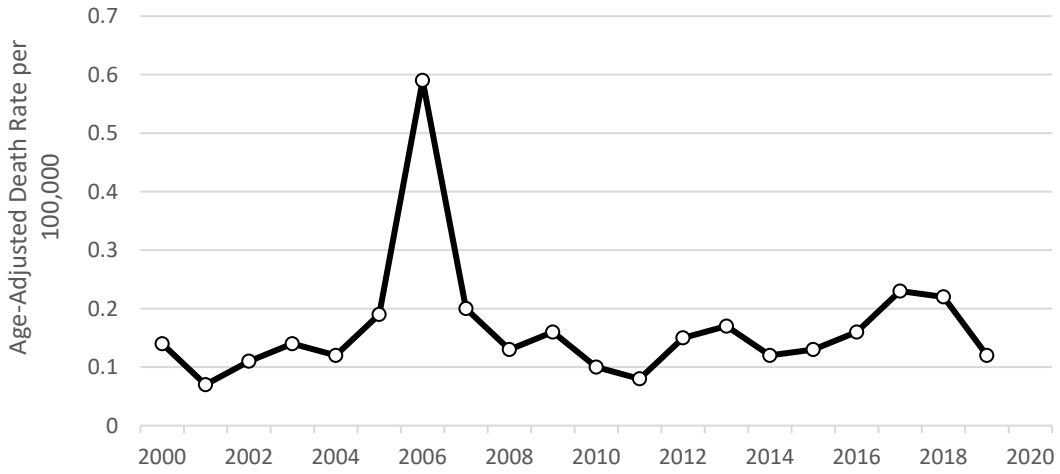
HEAT-RELATED DEATHS AND ILLNESSES

Deaths and illnesses from heat exposure are often unrecognized, misdiagnosed and thus, severely underreported. In 2006, when summertime temperatures were especially high, the reported number of deaths attributed to heat was much higher than any other year. Reported deaths and emergency department visits were also elevated in 2017, another notably warm year.

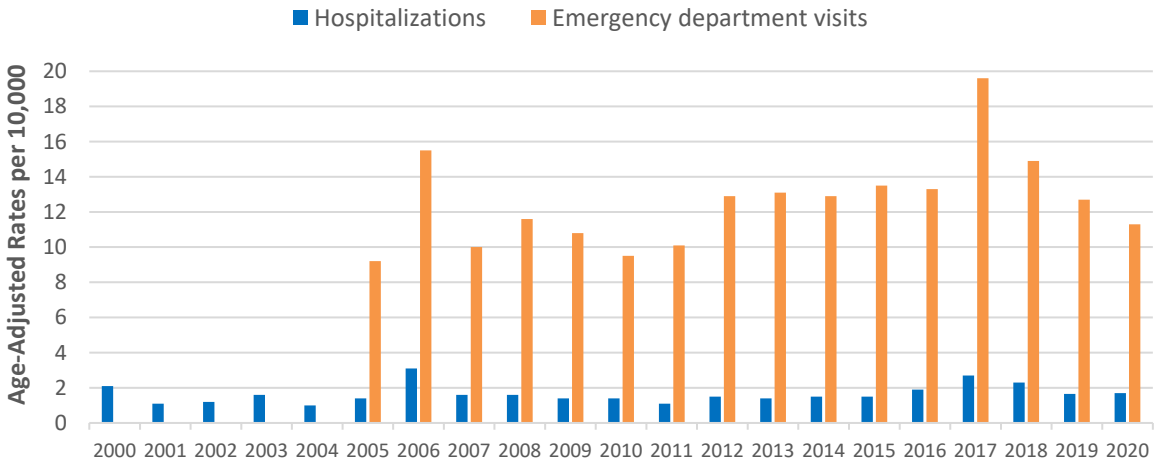
Figure 1. Heat-related deaths in California*



Source: Data set compiled by Tracking California (2021), using data from the Center for Health Statistics

** Reported deaths in May to September due to heat exposure as a main or contributing cause.*

Figure 2. Heat-related illness in California*



Source: Data set compiled by Tracking California (2022), using data from the data from the Office of Statewide Health Planning and Development

** Reported hospitalizations and emergency department visits in May to September. Data for emergency department visits were not available until 2005.*

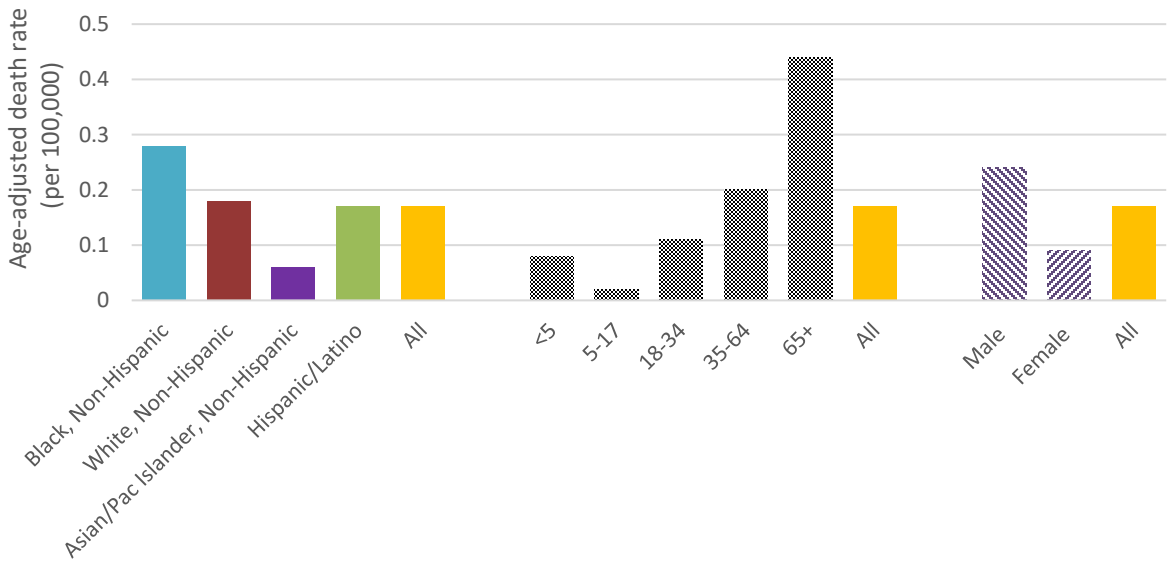
What does the indicator show?

The association between exposure to high temperatures and illness or deaths is well established. The classical case definition of heat illnesses includes ailments such as heat rash, heat cramps, heat exhaustion, and heat stroke. However, because of the stress that elevated ambient temperatures can exert on the body, heat exposure can produce health effects and exacerbate a broad range of health conditions (see below under *Why is this indicator important)*. Health records may not capture heat-related illness if exposure to excess heat is not explicitly documented. Consequently, health cases related to heat are often unrecognized and misdiagnosed. For example, a study of about 300 populous counties across the US estimated that the annual number of deaths attributable to heat was substantially larger than previous estimates reported by the Centers for Disease Control (CDC) and others (Weinberger et al., 2020). A substantial number of deaths occurred at only moderately hot temperatures. While recognizing that lack of consistency in the identification and recording of heat-related death and illness underestimates impacts (Berko et al., 2014), tracking the number of deaths and illnesses attributed either wholly or in part to heat illnesses can provide an indication of the trend in health impacts related to climate change.

Figure 1 presents annual age-adjusted death rates in California for diagnoses specifically attributed to heat, either as a primary or underlying cause, from 1999 to 2019. Figure 2 shows both heat-related hospitalizations (2000 to 2018) and heat-related emergency department (ED) visits (2005 to 2018) in California. No trend is evident for heat-attributed deaths or hospitalizations in California; rates were highest in 2006 (for deaths) and 2017 (for emergency department visits), when summertime temperatures were especially high. The mortality data, and to a lesser extent hospitalization data, do capture the impact of extended heat waves on health over large geographical areas. Emergency department visits show a statistically increasing trend, as expected with the warming temperatures associated with climate change.

Examining these indicators among specific demographics points to greater susceptibility to heat illnesses among adults aged 65 and older, males, and non-Hispanic Blacks. These groups have higher rates of identified heat-related deaths, emergency department visits and hospitalizations than those in other comparable demographic groups (Figures 3 and 4).

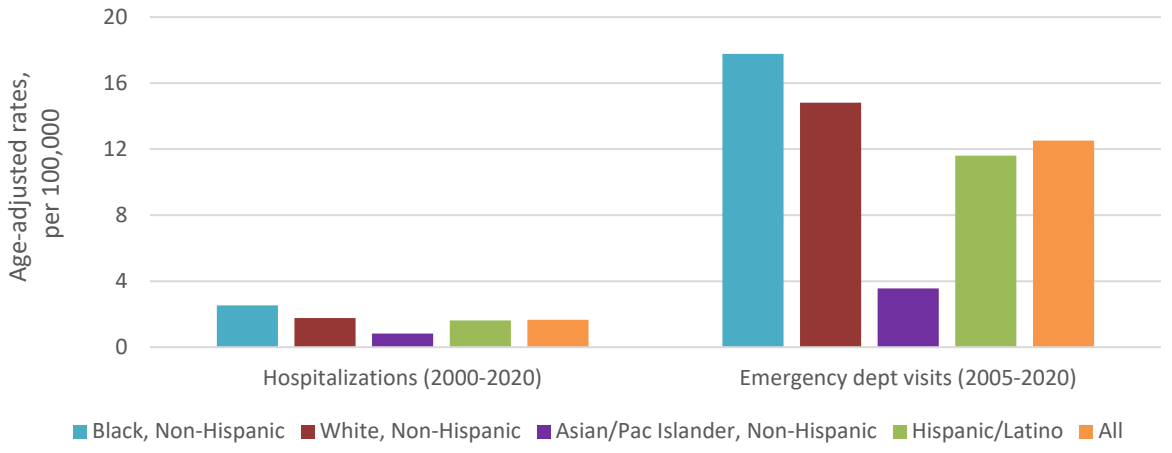
Figure 3. Heat-related death rates in California, by race, age and gender (2000-2019)



Source: Data set compiled by Tracking California (2021), using data from the Center for Health Statistics

** Reported deaths in May to September due to heat exposure as a main or contributing cause.*

Figure 4. Heat-related illness, by race



Source: Data set compiled by Tracking California (2022), using data from the data from the Office of Statewide Health Planning and Development

**Includes death with heat identified as a primary or underlying cause.*

Why is this indicator important?

Heat causes more reported deaths per year on average in the United States than any other weather hazard, yet heat-related illnesses and deaths are generally preventable (Luber et al., 2014; NOAA, 2021). A comprehensive analysis of heat-related deaths in

the US by the CDC found an average of 702 deaths occurred annually during 2004-2018 (Vaidyanathan et al., 2020). CDC noted that understanding patterns of heat-related deaths (for example, by race or ethnicity, age, or income level) is critical to developing more effective surveillance and intervention strategies. Their *Heat and Health Tracker* provides local heat and health information for communities to better prepare for and respond to extreme heat events.

Assessing how heat-related deaths and illnesses change with time provides a specific measure of how climate change-related temperature shifts are impacting human health. As noted above, the cases identified will represent only a small selection of heat-related health effects. Higher temperatures have been linked with increased deaths from all non-accidental causes, and more specifically cardiovascular and respiratory causes (Basu and Malig, 2011; Song et al., 2017). Heat waves and generally higher temperature exposures in California are related to increased health care usage for a wide range of diagnoses including electrolyte imbalance, diabetes, renal, cardiovascular and respiratory diseases (Basu et al., 2012; Guirguis et al., 2014; Green et al., 2010; Knowlton et al., 2009; Malig et al., 2019; Sherbakov et al., 2018). Increases in apparent temperature (measure of ambient temperature adjusted for relative humidity) have also been linked with adverse birth outcomes such as preterm birth, stillbirth, and low birth weight (Bekkar et al., 2020). Additionally, hotter temperatures may increase emergency department visits for mental health-related outcomes, such as for psychiatric conditions and self-harming or aggressive behaviors (Basu et al., 2017b; Liu et al., 2020; Thompson et al., 2018).

Tracking heat-related illnesses and deaths provides critical information for developing adaptation plans and evaluating their successes, especially in relation to heat waves. State and local policies, plans, and programs focusing on heat are already in place in some locations. These may include heat wave early warning and surveillance (observation) systems, accessible cooling centers, public education campaigns on preventing heat-related illnesses, and worker heat-safety regulations. The use of air conditioning has been associated with significant reductions in heat-related hospital visits in California (Ostro et al., 2010). However, during periods of high heat, there is likely to be a greater risk of brownouts or blackouts from overuse of gas and electricity.

Periods of warmer temperatures and heat waves are expected to rise in frequency, duration, and intensity over the next century (IPCC, 2021; Luber et al., 2014). In California, annual average maximum daily temperatures are projected to increase by about 4.4 to 5.8 degrees Fahrenheit (°F) by mid-century, and by about 5.6 to 8.8°F by the end of the century (Bedsworth et al., 2018). These projections suggest an increasing public health burden from heat-related deaths and illnesses.

What factors influence this indicator?

Heat-related illnesses are affected by characteristics of the heat exposure, such as frequency, intensity and duration. Other factors relate to the exposed individuals themselves, such as age, health status, and the degree to which protective measures against heat are taken by individuals and instituted through policy on a broader population-level.

High temperatures and heat waves can impact air quality and pose a threat to public health (Nolte et al., 2018; O'Lenick et al., 2019). Heat can accelerate the formation of ground-level ozone and also trap ozone, particulate matter and other harmful air pollutants. Exposure to these pollutants has been linked to adverse respiratory, cardiovascular, mental health, and reproductive outcomes (Bekkar et al., 2020; Nguyen et al., 2021; US EPA 2019). Air pollution may also work in synergy with extremely high temperatures to increase adverse cardiovascular, respiratory and other health effects (Anenberg et al., 2020).

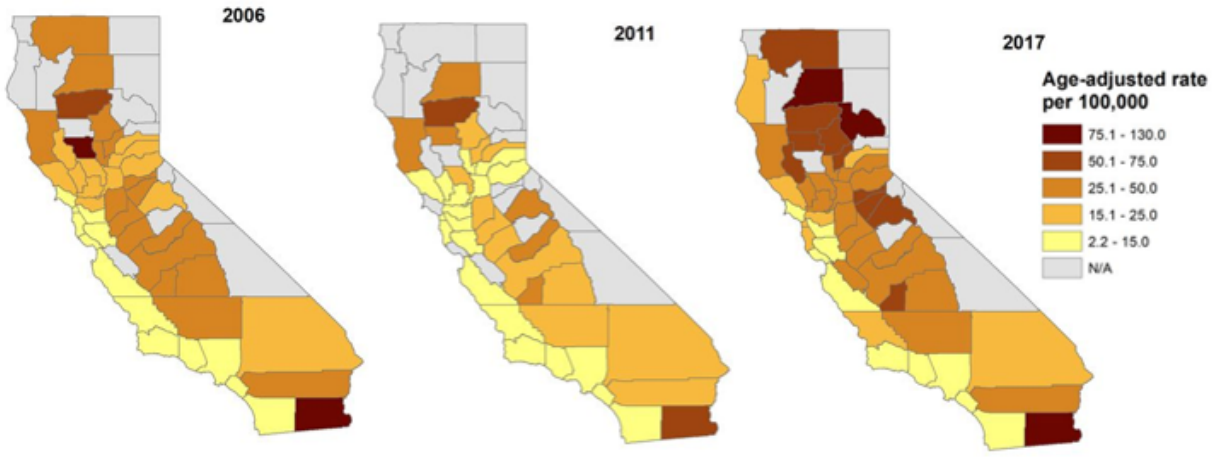
As shown in Figures 1 and 2, heat-related illnesses and deaths in 2006 peaked during the prolonged heat wave that occurred from July 16 to 26 (Knowlton et al., 2009; Margolis et al., 2008). Average apparent temperatures ranged from 81°F to 100°F, which is 4°F greater than the average statewide temperatures in July. The Central Valley region had the highest number of uninterrupted hot days ever recorded, with each day reaching 100°F and greater. Multiple locations in California broke records for the highest number of uninterrupted days over 100°F ever recorded: 11 in Sacramento; 12 in Modesto; and 21 in Woodland Hills near Los Angeles (Kozlowski and Edwards, 2007). In 2017, California experienced record summer heat, with numerous daytime and nighttime heat waves and record high temperatures (DWR, 2018). Death Valley set a new record for highest average monthly temperature in July with a value of 107.4°F. In Redding, the temperature topped 100°F a record 72 times. Statewide, the June/July/August average temperature was also a record high.

Specific characteristics of prolonged heat events may influence the degree to which heat-related health effects are felt. Higher night-time temperatures during heat waves may incur greater effects by preventing respite from high daytime temperatures (Gershunov et al., 2009). Heat waves accompanied by high humidity are especially dangerous, as the humidity prevents sweat from evaporating to cool down the body. Studies report that even short periods of high temperatures are associated with health impacts (Gasparinni and Armstrong 2011; Sherbakov et al., 2018).

Studies of California heat waves found that health impacts were greatest in the Central Valley and along the coast (Guirguis et al., 2014; Knowlton et al., 2009). Coastal populations tend to be less acclimated to higher temperatures and have lower rates of air conditioner ownership. Buildings, dark paved surfaces, lack of vegetation and trees, and heat emitted from vehicles and air conditioners cause cities to generate and retain

heat, a phenomenon known as the "urban heat island effect" (CDPH 2007). Thus, urban residents may experience more heat than people who live in surrounding suburban and rural areas. Figure 5 shows emergency department visit rates across California in 2006 (extended summer heat wave), 2011 (a cool summer season), and 2017 (exceptionally hot summer). Note the distinction between 2006 vs 2017 and which counties are most impacted.

Figure 5. Emergency department visits by county due to heat illness in 2006, 2011 and 2017*



Source: Tracking California 2021

** Maps present age-adjusted rates for emergency department visits by county during two unusually hot summer years (2006 and 2017) and a relatively cool summer (2011).*

As noted above, certain demographic groups may be more vulnerable to heat illness (adults aged 65 and older, males, and non-Hispanic Blacks). Other factors that can increase susceptibility to temperature are young age (5 years and under), pre-existing health conditions (such as heart or lung disease) or certain medications or substances (Ebi et al., 2018; Gronlund et al., 2018; Vaidyanathan et al, 2020). Furthermore, socially isolated people, the poor, and those who have difficulty accessing medical care likely face increased risks during hot weather (Basu and Ostro, 2008; Luber et al., 2014). Pregnant women may be more likely to suffer adverse birth outcomes with heat exposure (Bekkar et al., 2020).

Those engaged in vigorous physical activity, such as workers in construction, firefighting, and agriculture are also at risk. Over the past two decades, reported heat-related illnesses have increased in California (see *Occupational heat-related illness* indicator). In contrast, occupational heat-related deaths has not been well studied. An analysis of worker death rates in the United States from 2000-2010 reported a rate of 0.24 deaths per 1 million workers in California (Gubernot et al. 2016). Compared to the

states with the ten highest rates (Mississippi had the highest, at 1.05 per 1 million workers), California's rate is relatively low, likely due to the promulgation in 2005 of the state's enforceable regulation for prevention of heat illness in outdoor workers.

As adaptation measures are implemented and become more effective, the impacts of higher temperatures on heat illness rates may be mitigated. Measures – both planned and already under way –by state and local government and other entities include early warning and surveillance systems, access to air conditioning through cooling centers or through grants, and public outreach and education, particularly those targeting vulnerable populations. The state's priorities and goals addressing the risks posed by warming temperatures and other climate change impacts are outlined in California's Climate Adaptation Strategy.

Technical considerations

Data characteristics

Heat-related hospitalizations and emergency department visits were identified for the months of May to September by the California Environmental Health Tracking Program (CEHTP, recently renamed "Tracking California"). Tracking California is a program of the Public Health Institute, in partnership with the California Department of Public Health. Cases were included when heat stress was explicitly listed as the primary diagnosis or any other diagnosis. Heat-related diseases were identified using International Classification of Diseases (ICD-9 for 2000-2015, ICD-10 for 2015-2018) codes for: heat stroke and sunstroke; heat syncope; heat cramps; heat exhaustion; heat fatigue; heat edema; other specified heat effects; unspecified effects of heat and light; and exposure to excessive natural heat or sunlight. Causes that were due to a man-made source of heat were excluded. Hospitalization data were available for the years 2000 to 2018, and data on emergency department visits for the years 2005 to 2018.

CEHTP also identified heat-related deaths for the months of May to September, from 2000 to 2019, using ICD-10 codes for the following as the main or contributing causes of death: heat stroke and sun stroke; heat syncope; heat cramps; heat exhaustion; heat fatigue; heat edema; other specified heat effects; unspecified effects of heat and light; and exposure to excessive natural heat; and sunlight. As with the illness dataset, deaths due to a man-made source of heat were excluded. More information about data and methods, including rate calculations, can be found at the Tracking California website.

Strengths and limitations of the data

As noted earlier, the available data on heat-related illnesses and death likely underestimates the full health impact of exposure to heat. Heat-related health effects can manifest in a number of clinical outcomes, and people with chronic health problems are more susceptible to the effects of heat than healthy individuals. Heat-related illnesses and deaths are often misclassified or unrecognized.

The number of heat-related deaths from coroners' reports rely on deaths coded as "heat-related" without universally applied classification of these diseases, and often require knowledge of the circumstances around death to be communicated by other parties. Consequently, few deaths are recorded on death certificates as being heat-related and heat is rarely listed as a main cause of deaths that occur in hospitals or emergency rooms, even when exposure to heat is a contributing factor (English et al., 2009). It is likely that there were three to four times as many deaths in the July 2006 heat wave than were actually reported (Ostro et al., 2009; Joe et al., 2016). Recent studies of annual heat-related deaths in the US explain how the number of deaths is substantially larger than what has been previously reported (Weinberger et al., 2020; Vaidyanathan et al., 2020).

Non-fatal endpoints may similarly be undercounted, as it is often difficult to determine that an illness is heat-related when it involves other organ systems, and there is no standardized training among healthcare providers who make the determination (Madrigano et al., 2015). For example, during the 2006 California heat wave, over 16,000 excess emergency department visits and 1,100 excess hospitalizations were observed. These were much larger than the 2,134 ED visits and 538 hospitalizations officially identified as heat-related, so the majority of cases were not explicitly diagnosed as heat illnesses (Knowlton et al., 2009).

For hospitalizations and emergency department visits, the change in usage of ICD-9-CM to ICD-10-CM in the 4th quarter of 2015 may have resulted in differences in classification of heat-related visits that impact observed patterns in those indicators.

Despite these known limitations, heat-related emergency department visits, hospitalizations and deaths can be used to document changes over place and time, monitor vulnerable areas, and evaluate the results of local climate-adaptation strategies. They are tracked at the national level as part of the National Environmental Public Health Tracking Network, allowing comparisons across states. This tracking provides a better understanding of risks to specific groups, and helps with designing interventions and communication efforts (CDC, 2021).

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References:

Anenberg SC, Haines S, Wang E, Nassikas N and Kinney PL (2020). Synergistic health effects of air pollution, temperature, and pollen exposure: a systematic review of epidemiological evidence. *Environmental Health* **19**(1):130.

Basu R and Ostro BD (2008). A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California. *American Journal of Epidemiology* **168**(6): 632-637.

Basu R and Malig B (2011). High ambient temperature and mortality in California: Exploring the roles of age, disease, and mortality displacement. *Environmental Research* **111**(8):1286-1292.

Basu R, Pearson D, Malig B, Broadwin R and Green S (2012). The effect of high ambient temperature on emergency room visits in California. *Epidemiology* **23**(6):813-20.

Basu R, Gavin L, Pearson D, Ebisu K and Malig, B (2018). Examining the association between apparent temperature and mental health-related emergency room visits in California. *American Journal of Epidemiology* **187**(4), 726-735.

Bedsworth L, Cayan D, Franco G, Fisher L and Ziaja S (2018). *Statewide Summary Report. California's Fourth Climate Change Assessment.* California Governor's Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission.

Bekkar B, Pacheco S, Basu R, and DeNicola N (2020). Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: A systematic review. *JAMA Network Open* **3**(6): e208243.

Berko JID., Saha S, and Parker JD (2014). *Deaths attributed to heat, cold, and other weather events in the United States, 2006– 2010.* National Center for Health Statistics. Hyattsville, MD.

CDC (2021). Heat and Heat-related Illness, National Environmental Public Health Tracking. Retrieved August 20, 2021.

CDPH (2007). *Public Health Impacts of Climate Change in California: Community Vulnerability Assessments and Adaptation Strategies. Report No. 1: Heat-Related Illness and Mortality. Information for the Public Health Network in California.* California Department of Public Health.

DWR (2018). *Hydroclimate Report Water Year 2017*. California Department of Water Resources. Office of the State Climatologist.

Ebi KL, Balbus JM, Luber G, Bole A, Crimmins A, et al. (2018) Human Health. *In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment,* Volume II. Reidmiller DR., Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, and Stewart BC (Eds.). U.S. Global Change Research Program, Washington, DC, USA, pp. 539–571.

English PB, Sinclair AH, Ross Z, Anderson H, Boothe V, et al. (2009). Environmental health indicators of climate change for the United States: Findings from the State Environmental Health Indicator Collaborative. *Environmental Health Perspectives* **117**(11):1673-1681.

Gasparrini A.and Armstrong B (2011). The impact of heat waves on mortality. *Epidemiology* **22**(1): 68-73.

Gershunov A, Cayan DR and Lacobellis SF (2009). The great 2006 heat wave over California and Nevada: Signal of an increasing trend. *Journal of Climate Change* **22**: 6181-6203.

Green R, Basu R, Malig B, Broadwin R, Kim J, et al. (2010). The effect of temperature on hospital admissions in nine California counties. *International Journal of Public Health* **55**(2): 113-121.

Gronlund CJ, Sullivan KP, Kefelegn Y, Cameron L and O'Neill MS (2018). Climate change and temperature extremes: A review of heat- and cold-related morbidity and mortality concerns of municipalities. *Maturitas* **114:**54-59. 2018.

Gubernot DM, Anderson CG and Hunting KL (2016). Characterizing occupational heat-related mortality in the United States, 2000-2010: An analysis using the census of fatal occupational injuries database. *American Journal of Industrial Medicine* **58**(2): 203-211.

Guirguis K, Gershunov A, Tardy A and Basu R (2014). The impact of recent heat waves on human health in California. *Journal of Applied Meteorology and Climatology* **53**(1): 3-19.

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson-Delmotte VP, Zhai A, Pirani SL, Connors C, et al. (Eds.). Cambridge University Press. In Press.

Joe L, Hoshiko S, Dobraca D, Jackson R, Smorodinsky S, et al. (2016). Mortality during a large-scale heat wave by place, demographic group, internal and external causes of death, and building climate zone. *International Journal of Environmental Research and Public Health* **13**(3): 299.

Knowlton K, Rotkin-Ellman M, King G, Margolis HG, Smith D, et al. (2009). The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. *Environmental Health Perspectives* **117**(1): 61-67.

Kozlowski DR and Edwards LM (2007). *An Analysis and Summary of the July 2006 Record-Breaking Heat Wave Across the State of California*. Western Region Technical Attachment 07-05.

Liu J, Varghese BM, Hansen A., Xiang J, Zhang Y., et al. (2021). Is there an association between hot weather and poor mental health outcomes? A systematic review and meta-analysis. *Environment International* **153**, 106533.

Luber G, Knowlton K, Balbus J, Frumkin H, Hayden M, et al. (2014). Chapter 9: Human Health. *In: Climate Change Impacts in the United States: The Third National Climate Assessment*. Melillo JM, Richmond TC, and Yohe GW (Eds.). U.S. Global Change Research Program. pp. 220-256.

Madrigano J, McCormick S and Kinney PL (2015). The two ways of assessing heat-related mortality and vulnerability. *American Journal of Public Health* **105**(11): 2212-2213.

Malig BJ, Wu XM, Guirguis K., Gershunov A. and Basu, R. (2019). Associations between ambient temperature and hepatobiliary and renal hospitalizations in California, 1999 to 2009. *Environmental Research* **177**: 108566.

Margolis HG, Gershunov A, Kim T, English P and Trent R (2008). 2006 California heat wave high death toll: Insights gained from coroner's reports and meteorological characteristics of event. *Epidemiology* **19**(6): S363-S364.

NOAA (2021). Weather Related Fatality and Injury Statistics. National Oceanic and Atmospheric Administration, National Weather Service. Retrieved December 31, 2021.

Nguyen AM, Malig BJ and Basu R (2021). The association between ozone and fine particles and mental health-related emergency department visits in California, 2005-2013. *PLoS One* **16**(4): e0249675.

Nolte CG, Dolwick PD, Fann N, Horowitz LW, Naik V, et al. (2018): Air Quality. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, et al. (Eds.). U.S. Global Change Research Program, Washington, DC, USA, pp. 512–538.

O'Lenick CR, Wilhelmi OV, Michael R, Hayden MH, Baniassadi A, et al. (2019) Urban heat and air pollution: A framework for integrating population vulnerability and indoor exposure in health risk analyses. *Science of the Total Environment* **660:**715-723.

Ostro BD, Roth LA, Green RS and Basu R (2009). Estimating the mortality effect of the July 2006 California heat wave. *Environmental Research* **109**(5): 614-619.

Ostro BD, Rauch S, Green R, Malig B and Basu R (2010). The effects of temperature and use of air conditioning on hospitalizations. *American Journal of Epidemiology* **172**(9): 1053-1061.

Sherbakov T, Malig B, Guirguis K., Gershunov A., and Basu R (2018). Ambient temperature and added heat wave effects on hospitalizations in California from 1999 to 2009. *Environmental Research* **160:** 83-90.

Song X, Wang S, Hu Y, Yue M, Zhang, T, et al. (2017). Impact of ambient temperature on morbidity and mortality: An overview of reviews. *Science of the Total Environment* **586**:241-254.

Thompson R, Hornigold R, Page L., and Waite T (2018). Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. *Public Health* **161:** 171-191.

Tracking California (2021). Heat-Related Deaths Summary Tables, using data from the Center for Health Statistics, 2000-2019. Data provided by Tracking California. Retrieved May 5, 2021.

Tracking California (2022). Heat-Related Illness Query, using data from the Office of Statewide Health Planning and Development, 2000-2020. Retrieved August 16, 2020.

US EPA (2019). *Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019).* U.S. Environmental Protection Agency, Washington, DC.

Vaidyanathan A, Malilay J, Schramm P and Saha S (2020). *Heat-Related Deaths - United States, 2004-2018. MMWR Morbidity and Mortality Weekly Report* **69**(24): 729-734.

Weinberger KR, Harris D, Spangler KR, Zanobetti A and Wellenius GA (2020). Estimating the number of excess deaths attributable to heat in 297 United States counties. *Environmental Epidemiology* **4**(3): e096.