Climate Impacts on Health and Vulnerable Communities

Public Health and Climate

Climate change is expected to be the greatest public health threat of the 21st century. This growing challenge amplifies the need for an open, collaborative, dedicated climate and health infrastructure, with robust research and predictive capacity (Watts et al., 2017; World Health Organization, 2017). The impact of climate change on health in San Diego is mainly through the exacerbation or modification of existing environmental health impacts (e.g. heat waves, extreme precipitation, wildfires) but also the introduction of new ecological challenges (e.g. invasive or changes in relative abundance of species).

Current data to inform predictions of disease burden, evaluate health-related climate interventions, and support the development of a regional adaptation plan has notable gaps and is siloed within different sectors. The County of San Diego, local universities, community-based organizations, non-profit organizations, local governments, and other stakeholders are willing to work together to identify and address gaps in the region's adaptation effort going forward toward making San Diego the most resilient community in the U.S.

MOST VULNERABLE POPULATION AND COMMUNITIES

Vulnerabilities to climate extremes are spatially variable. Inland communities are most vulnerable to the impacts from wildfire, though the region as a whole (including the coast) is at risk from smoke exposure and poor air quality resulting from fires. Heat will likely affect the entire region with coastal populations experiencing a higher level of vulnerability due to lack of air conditioning while inland populations will be vulnerable through exposure to dangerously hot temperatures. Coastal areas and areas prone to flooding, including Tijuana River watershed, San Diego River, Imperial Beach, and Mission Valley, will be at risk of both the direct effects (evacuations and damages) and indirect effects of flooding. Indirect events include enhanced exposure to vector borne diseases and to pollutants flushed into the watershed.

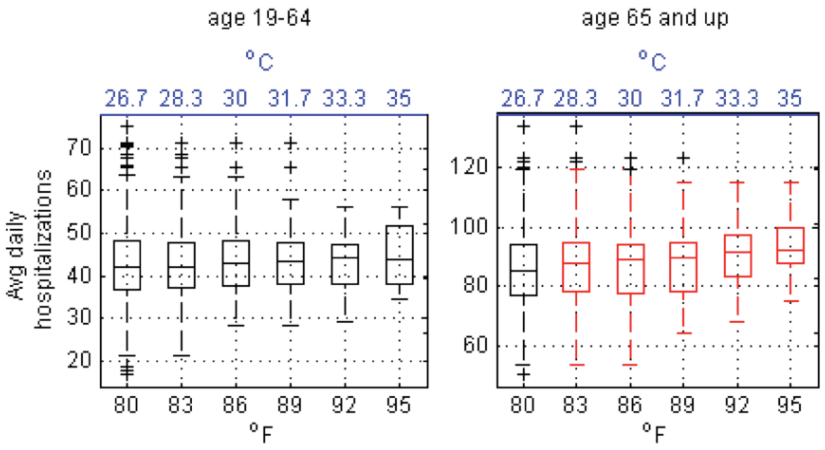
Generally, the most vulnerable populations from extreme events are those who lack resources, are socially isolated, or whose health is already compromised. People with preexisting or underlying health conditions, with chronic illnesses (e.g. asthma), and the uninsured are especially vulnerable to the impacts of climate change (Benmarhnia et al., 2015; Reid et al., 2009). For example, cardiovascular and respiratory illnesses are exacerbated by heat and air pollution (Analitis et al., 2014). Lessons learned from past natural disasters demonstrate that people with preexisting conditions are not always able to obtain needed medications and access medical equipment and/or devices during and following a natural disaster for a variety of reasons, including power outages, transportation, a and insurance issues. Depending on their health status, senior citizens may be especially vulnerable (Figure 33) resulting from the combination of chronic health problems, limited mobility, and social isolation. This is true for elderly living alone or in skilled nursing facilities.

Further, socioeconomic disadvantages also restrict the capacity of individuals to avoid the negative health impacts of climate change, to mitigate those impacts, or cope with them as they become threat multipliers. This is particularly true for the unsheltered or homeless. Flash floods, vector borne disease, mudslides, and extreme heat are just a few of the elements that would be experienced more profoundly by someone who is unsheltered living in areas directly affected by these extremes. For example, the risk factors for morbidity and mortality from heat correlate closely

with the characteristics of homeless individuals. One such characteristic is pre-existing psychiatric illness which has been shown to triple the risk of death from extreme heat (Bouchama et al., 2007). Reaching the unsheltered with key messages about risk and adaptation also presents a challenge, as seen in the 2017 hepatitis A virus outbreak. A lack of a permanent address creates additional challenges for both the individual and the agencies seeking to provide help or response.

San Diego's proximity to the busiest land border crossing in the world makes it a likely region for asylum seekers, migrants, and immigrants from all over the world. San Diego has been the foremost receiver in California for the resettlement of refugees (43% of state total). These groups may be isolated geographically, socially, linguistically, and politically, making them more vulnerable to the impacts of climate change and natural disasters. Migrant workers may also be more reluctant to evacuate from a wildfire or remain inside in air-conditioned spaces due to limited means or concerns over lost wages or deportation. For example, three states (Arizona, California, and Texas) accounted for 94.5% of non-citizen heat deaths, and the risk was greatest among Hispanic immigrants between the ages 18 and 24 (Taylor et al., 2017). As a result, researchers are urging tailored heat prevention messages for people at greatest risk.

FIGURE 33



Daily average hospitalizations for zip codes in San Diego County within the coastal region for days exceeding a give Tmax temperature threshold for different age categories. Red indicates results are significantly different from a reference taken as days cooler than 75°F. Data Is from 1999-2013. Source: Figure 7 from Guirguis et al. (2018a), provided by K. Guirguis.

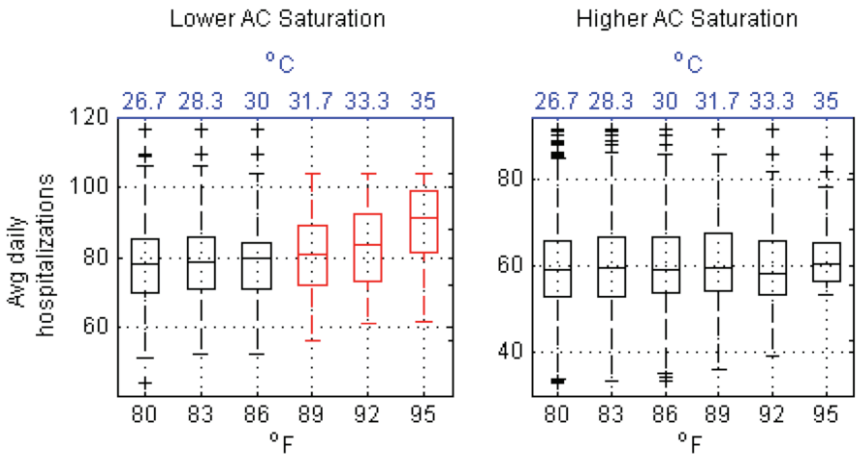
CLIMATE CHANGE IMPACTS ON PUBLIC HEALTH IN SAN DIEGO COUNTY

Human health effects associated with extreme heat are expected to increase significantly, including heat-related illness and cardiovascular failure (Mora et al., 2017). The National Weather Service (NWS) reports that between 1987 and 2016, heat was the number one weather-related killer in the United States and claimed more lives on average than floods, lightning, tornadoes, and hurricanes or other weather-related events (National Weather Service, 2017). For example, the July 2006 heat wave in California, which exhibited unprecedented magnitude and unusually high humidity levels (Gershunov et al., 2009), resulted in over 600 excess deaths (Ostro et al., 2009), over 1200 excess hospitalizations for cardiovascular and other diseases (Kristen Guirguis et al., 2014), and over 16,000 excess emergency-department visits (Knowlton et al., 2009), with disproportionate effects along the coast relative to inland locations. The effect of high apparent temperature, a combination of hot temperatures and high humidity, can have a greater impact in mortality (heat-related deaths) in coastal areas than inland areas (Rupa Basu, 2009). Observed trends and our analyses of climate-model projections suggest that heat waves are becoming more common, stronger, longer lasting and, importantly, more humid in California (Gershunov et al., 2009; Gershunov & Guirguis, 2012).

A recent scientific review found people living in hotter areas within cities had an overall 6% higher risk of mortality/morbidity compared to those in cooler areas, and those living in less vegetated areas had 5% higher risk compared to those living in more vegetated areas (Schinasi et al., 2018). In parallel, differences may exist between coastal and inland zones. Recent work in San Diego showed that heat-related health impacts are observed at lower temperatures in the coast than in the inland and desert regions (K. Guirguis et al., 2018). This is in part due to coastal residents being less acclimated to heat and less likely to have air conditioning (Figure 34). However, a challenge for implementing policy to protect human health is that there is no standard definition for a heat wave. Definitions can vary according to the specified high-end temperature thresholdsti (e.g., 95th or 99th percentile), the number of consecutive days (e.g. 2, 3 or more) or the temperature metric that is used (e.g. maximum, minimum, or diurnal temperatures) (Kent et al., 2014; Xu et al., 2016). An ongoing study at UC San Diego by Benmarhnia (unpublished) compared different heat wave definitions (~30) within the County of San Diego and found the definition to be important for identifying local thresholds at which the highest number of attributable emergency room visits occurred. While the definition of a heat wave does not, of course, cause the illness, different characteristics of the heat wave, such as nighttime temperature, duration, or maximum temperature, affect how heat waves impact health. Thresholds varied within the city, due to differences in microclimate conditions and sociodemographic composition. These findings highlight the importance of considering different heat wave definitions for intervention purposes even within a single city. The Western Region of the National Weather Service recently developed a health-focused heat warning system that accounts for local variation in climatology and has begun to issue tiered heat alerts using different temperature thresholds for different locations and for different levels of vulnerability (National Weather Service, https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=sgx).

The projected increase in wildfire risk directly relates to an increase health risk from the fires and the smoke produced by the fires. Smoke contains particulate matter, ozone, carbon monoxide, and nitrogen dioxide, all of which are associated with reparatory and cardiovascular negative heath impacts. A recent study of health impacts from wildfires smoke in exposure in 2015 showed that wildfires smoke increased cardiovascular and respiratory health risk as a result of medium and high smoke density exposure (Wettstein et al., 2018). The study showed that most significant health impacts were to people over 64 years old and the largest increases in relative risk were for dysrhythmia,

FIGURE 34



Same as figure 33 but for different saturations of air conditioning. Source: Figure 4 from Guirguis et al. (2018a), provided by K. Guirguis.

heart failure, and chronic obstructive pulmonary disease (COPD). As smoke can travel large distances from the fires, the health impacts of smoke is a vulnerability to all of San Diego County, not only regions in fire prone areas.

In general, climate change is expected to increase vector borne diseases (Campbell-Lendrum et al., 2015), though the factors involved are complex and the incidence of disease will depend on both environmental and demographic factors. A potential precursor to changes in vector-borne disease is the recent massive expansion of invasive mosquito species, *Aedes aegypti* and *Aedes albopictus* (Figure 35), which have the potential to transmit infectious diseases such as chikungunya, dengue, and the Zika virus. Temperatures and pooling water are two critical factors in a mosquito's life cycle and, subsequently, their potential to spread disease. At warmer temperatures, mosquitos lay eggs more frequently, feed more frequently, and the incubation period of viruses they carry decreases, allowing mosquitos to transmit viruses more quickly after becoming infected. Also, at higher temperatures, some highly virulent genotypes of West Nile virus replicate more efficiently than low pathogenic genotypes. Research suggests this has contributed to the emergence of pathogenic strains (Reisen, 2013). Increased flooding due to higher increased extreme precipitation events can flush out immature mosquito stages but leave behind pools of water in natural and man-made structures throughout the region which provide abundant habitat for mosquitos to breed. Rising seawater levels and high tides can also create brackish water habitat in coastal areas in which certain adapted mosquitos can breed. Aided by increasing temperatures, the time it takes for a mosquito to complete its life cycle is shortened in these new water pools, which can yield many thousands of new, adult mosquitos. On the other hand, the mosquito life cycle is shortened by high temperature and low humidity, which could decrease their ability to spread disease. Thus, there is a balancing act. In general, though, it is largely thought that vector borne diseases will increase with climate change (Campbell-Lendrum et al., 2015).

FIGURE 35

Aedes aegypti and *Aedes albopictus*.

COLLABORATION AND ADAPTATIONS

The County is working towards communicating health risks associated with excessive heat. Below is an example of the region's adaptation to excessive heat taken from the County's updated Excessive Heat Response Plan (Table 5; EHRP, 2017). In San Diego County, the Plan is in effect from May 1 to September 30 each year, and at other times during the year if unusually high heat events occur. The activation of the EHRP by the County's Public Health Services (PHS) occurs when the NWS issues a heat alert product indicating a heat event in one or more areas of San Diego County. PHS informs all stakeholders of the appropriate preventive action. The County Health Officer determines that a Heat Emergency exists based on the threat to public health and safety. The designated staff in the Public Health Preparedness and Response (PHPR) branch of the PHS serves as the EHRP Coordinator when the plan is activated. The County Communications Office issues standardized health and safety messages to the public via the press and social media as well as working with external partners to disseminate key information.

Public Health Services (PHS) also has partnered with the County Office of Emergency Services (OES) in a Partner Relay effort to disseminate messages to vulnerable communities in the event of a natural disaster or public health emergency, such as the during heatwaves as mentioned above. Other disasters include the recent Lilac fire and Hepatitis A outbreak. The County has established networks and action plans to address any emergency; however, this valuable information is less likely to reach the over 400,000 non-English speaking individuals that live in the region. The Partner Relay improves the communication with communities that speak languages other than English, by establishing relationships with community leaders to understand the best method to communicate emergency information. Through ongoing discussions and meetings with leaders representing eight language groups (Spanish, Tagalog, Chinese, Korean, Arabic, Vietnamese, Somali, and Karen), they determined that the best method of communication was to use existing networks and phone trees/partner relays to disseminate emergency information. Over 300 individuals representing non-profit organizations, houses of worship, and refugee resettlement agencies have agreed to partner with the County in disseminating information to their communities during emergencies. The OES maintains the Ready San Diego app providing access to an online communication platform where information is shared with trusted partners and they in turn share the information with their community in various languages. In preparation for adaptation planning, it also co-developed a Climate and Profile Report and Vulnerability Assessment in collaboration with the CalBRACE Project in the California Department of Health Office of Health Equity. Both of these adaptations also help promote climate justice (see next section), by ensuring climate hazard communication reaches the most vulnerable communities.

TABLE 5

MONTH	COASTAL	VALLEYS	MOUNTAIN REGIONS	DESERT REGIONS
Oct - May	100	105	95	113
June	100	105	100	115
July	100	105	100	117
August	100	105	100	117
September	100	105	100	115

Excessive Heat Warning Criteria (°F) in San Diego

CLIMATE & CHILDREN'S HEALTH

During a heat wave in October 2017, 85 schools in San Diego had to close early due to extreme heat. Children, especially those under age 5, are particularly vulnerable to heat, poor air quality, and UV radiation, including having reduced ability to regulate body temperature compared to adults. Research shows that children also perceive thermal environments differently than adults (Mors et al., 2011) and may not recognize the early signs of heat stress. San Diego Unified School District is the first district in the County to adopt a climate action plan, with plans to install air conditioning in all schools. Design interventions, such as shade for reduced radiation and evaporative cooling through misters and vegetation/natural surfaces, are also well-known to reduce overheating (Brown et al., 2015), with the added benefit that certain trees/plants are able to absorb air pollutants.

The County Vector Control Program (VCP) mitigates the impacts of vector-borne diseases to the health, well-being, and economy of the County by: 1) limiting mosquito numbers in critical areas; 2) educating residents on how to prevent mosquitos from breeding on their property in open containers or other water sources, and protect themselves from getting bitten, and; 3) mobilizing residents to report mosquito breeding sites and sentinel dead bird species to the VCP. The Department of Environmental Health utilizes an in-house molecular diagnostic laboratory to provide highly sensitive and rapid disease test results so that informed, data-driven control measures can be quickly instituted. It also works closely with local and state agencies, universities, research centers, and private foundations to find new ways to control mosquitos and prevent the spread of disease.

A multi-beneficial adaptation approach to improve health as climate changes at the city level is the City of San Diego's Urban Forestry Program. As mentioned above living in vegetated areas reduce health risks (Schinasi et al., 2018). The Urban Forestry Program supports climate adaptation in many ways, and by providing cooler green space and improved air quality the Program supports improved community health now and in the future.

Climate Justice

VULNERABLE COMMUNITIES

San Diego County is one of five counties in California with a high percentage of socially vulnerable populations to climate change impacts, according to a study funded by the California Energy Commission in 2012. Social vulnerability is defined as the susceptibility of a given population to harm from exposure to a hazard, directly affecting its ability to prepare for, respond to, and recover. Social vulnerability is a function of diverse demographic and socio-economic factors that influence a community's sensitivity to climate change. Understanding vulnerability factors and the populations that exhibit these vulnerabilities is critical for crafting effective climate change adaptation policies and disaster response strategies. This is also important to achieving climate justice, which is the concept that no group of people should disproportionately bear the burden of climate impacts or the costs of mitigation and adaptation (Cooley et al., 2012). To better understand climate justice issues statewide, the Fourth Assessment includes a report on climate and environmental justice issues facing California due to projected impacts from climate change. More information on climate justice issues for both the San Diego region and statewide may be found in this report (Climate Justice Summary Report, 2018).

In the San Diego region, city and County health and emergency management agencies, the non-profit community, faith-based organizations, and others support programs address climate justice directly or indirectly through delivery of public health services, infrastructure development, and advocacy and empowerment projects with a focus on vulnerable and disadvantaged communities. Primary climate impacts in the region disproportionately affecting these populations include increasing temperatures, particularly relative to air quality and heat waves. Increased frequency and intensity of heat waves will exacerbate already existing challenges such as air pollution and associated public health risks including asthma, cardiovascular and respiratory disease, and related conditions. Warmer temperatures year-round could lead to growing mosquito populations, increasing the regional occurrence of West Nile virus and potentially introducing tropical diseases such as chikungunya, dengue, and the Zika virus (see previous section).

In San Diego, disadvantaged communities such as Barrio Logan, Logan Heights, and National City already have the highest rates of child asthma hospitalization, breathe polluted air from trucks, freeways and industrial sources, live in homes lacking energy affordable energy bills, and lack access to safe, affordable, and convenient transit to jobs,

health care, parks, and cooling centers. In January 2017, California released the updated version of its pollution-screening tool, CalEnviroScreen. The data indicate that these same communities in San Diego remain among the top 5-10% of communities in the state most impacted by pollution. CalEnviroScreen combines environmental, health, and socioeconomic information to identify communities most affected by pollution. Since the last version, released in 2014, the state has added new factors to measure cardiovascular disease and housing cost burden, as well as incorporated air-monitoring data from the border region to more thoroughly evaluate air quality in border communities.

SAN DIEGO EFFORTS IN SUPPORT OF CLIMATE JUSTICE

San Diego County's draft Climate Action Plan largely focuses on GHG emissions reduction plans and strategies, some of which will have co-benefits for disadvantaged communities (County of San Diego, 2017). The Plan includes a section on adaptation and resilience that references the adaptive capacity of the County to address climate impacts and outlines strategies such as cooling centers for underserved communities in the face of increasing and more intense heat waves. The City of San Diego Climate Action Plan includes reference to City Council Policy 800-14, which prioritizes capital improvements in under-served communities and points to the use of the CalEnviroScreen to identify these communities and prioritize projects in census tracts ranking in the top 30% of CalEnviroScreen scores. This policy also prioritizes projects located in areas eligible for the Community Development Block Grant funds, and projects located within a half mile of affordable housing. The assumption is that co-benefits in adaptive capacity to climate impacts will be realized through these projects.

The Single-family Affordable Solar Homes Program (SASH) program is structured to provide qualifying single-family homeowners with access to solar technology while also providing green jobs training, employment, and community engagement opportunities. GRID Alternatives is the non-profit organization responsible for administering the program and has installed systems on 885 homes in San Diego County. These SASH funds enabled communities that have been historically left out of the renewable energy market to become integral partners in building a sustainable solar industry.

Current solar photovoltaic systems on affordable housing properties have historically been used to offset electricity costs in common areas, benefiting property owners instead of tenants. California's newest solar program for low-income renters, the Solar on Multifamily Affordable Housing (SOMAH) program (Assembly Bill 693 2017), will bring $1 billion in rooftop solar to low-income renters over 10 years. The new program, anticipated for launch in August of 2018, is intended to fund 300 megawatts of new solar projects with the potential to serve over 150,000 low-income renters at over 2,000 affordable housing properties across the state. Low-income tenants will receive credits on utility bills through tariffs, namely virtual net metering (VNEM) tariffs. VNEM tariffs provide a mechanism for allocating bill credits from system generation among the property occupants, including both common area electric accounts and the accounts of tenants. Under SOMAH, tenants receive at least 51% of the VNEM credits from any solar project.