Title
Can San Diego beat the heat? A targeted approach to improving the Cool Zone system in San Diego County for heat vulnerable populations

Author
Espinoza, Isabella

Publication Date
2023

Can San Diego beat the heat?

A targeted approach to improving the Cool Zone system in San Diego County for heat vulnerable populations

Isabella Espinoza

Master of Advanced Study, Climate Science and Policy

June 2023

Capstone Advisory Committee

tarik benmarhnia
tarik benmarhnia (Jun 28, 2023 12:12 PDT)

Tarki Benmarnhia, Ph.D. | *Committee Chair*

Assistant Professor, Climate, Atmospheric Science and Physical Oceanography & Family Medicine and Public Health

Scripps Institution of Oceanography, University of California, San Diego

Signature has been removed for privacy purposes

Anna Dimitrova, Ph.D. | *Committee Member*

Postdoctoral Scholar, Climate, Atmospheric Sciences, and Physical Oceanography

Scripps Institution of Oceanography, University of California, San Diego

Signature has been removed for privacy purposes

Cheryl Peach Ph.D. | *Committee Member*

Director of Scripps Educational Alliances

Scripps Institution of Oceanography, University of California, San Diego

Abstract

Extreme heat events (EHE) result in the highest number of weather-related deaths, taking more lives than every other weather-related disaster combined (National Weather Service). Access to AC is one of the most important determinants of heat-related health outcomes (Barreca *et al.*, 2016; Guirguis *et al.*, 2018). However, the initial cost of installing or purchasing an AC plus the increased cost of electricity from running the AC is a huge barrier for a significant portion of the population. Cool Zones provide an opportunity to cool a large portion of the population at a lower cost and energy demand than increasing household AC penetration. This project aims to improve the understanding of the spatial distribution of vulnerable populations in San Diego County in relation to the existing cooling centers intended to serve those populations and to make recommendations on how to improve awareness, accessibility, and utilization.

Table of Contents

Introduction and Background

Extreme heat events (EHE) result in the highest number of weather-related deaths, with over 600 direct deaths and about 12,000 indirect deaths reported annually in the US (Shindell *et al.*, 2020) more than every other weather-related disaster combined (National Weather Service). For the purposes of this paper, EHEs are defined here as days that are much hotter than average to the point of emergency designation by local officials. However, since there is no universal definition of EHEs or heat waves it is difficult to compare EHEs in different geographical areas (Sherbakov *et al.*, 2018) and even within a specific region (McElroy *et al.*, 2020). Given that heat is experienced differently depending on climatic conditions and local temperature acclimation, the most important factor when defining an EHE in a given area is to be sure that an emergency will be declared at a threshold that protects the health of the greatest number of individuals (Guirguis *et al.*, 2018).

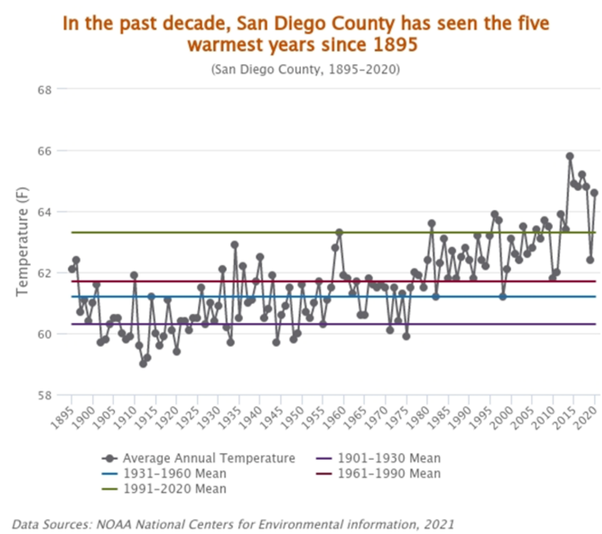


Figure 1. Temperature trends in San Diego County from 1895-2020

The past 5 years in San Diego County have been the hottest on record and increasing temperature trends are expected to continue (Figure 1). By the end of the century, the number of heat wave days in San Diego is expected to increase by 20-50% (Kalansky *et al.*, 2018). An increase in expected heat wave days likely means an increase in the number of heat-related deaths; however, heat-related deaths and illnesses are preventable if the right interventions are deployed in time (National Weather Service).

Early Warning Systems (EWS) are an essential component of reducing heat-related mortality and illness. Early warning systems involve forecasting expected EHEs, and include response plans for what steps should be taken to avoid negative health outcomes (Lowe, *et al.* 2011). Currently, San Diego County utilizes National Weather Service alerts to declare EHEs, however due to extreme regional temperature differences in San Diego County, an alert system based on within city temperature data would be more effective at improving heat-related health outcomes during EHEs (Guirguis *et al*., 2018).

Cooling centers are designated air conditioned public spaces, and are one such intervention which can be highly effective for protecting vulnerable individuals from heat related illness and death during EHEs. Cooling centers are operated by local governments, private organizations, or a combination of both; typically becoming operational after the declaration of an EHE or heat emergency by local government officials. Despite its preventability, reducing heat-related illness and death can be challenging due to the combination of social and behavioral factors that contribute to heat exposure and susceptibility. At-risk individuals might not deem themselves as being high risk or fully understand the dangers of prolonged heat exposure. Designing effective action plans requires a good understanding of which populations and locations are under high heat vulnerability and effectively communicating necessary information on health impacts and available resources in a timely manner. The purpose of this study is to understand the spatial distribution of vulnerable populations in San Diego County in relation to the distribution of existing cooling centers which are intended to serve those populations.

San Diego County sees a 14.6% increase in hospitalizations during extreme heat days over cooler days, specifically in the coastal region (Guirguis *et al.*, 2018). Increased risk for hospitalization is determined by several factors, including age, access to air conditioning (AC), income, and homeownership (Guirguis *et al.*). Of these factors, access to AC is the most important determinant of heat-related health outcomes (Barreca *et al.,* 2016; Guirguis *et al.,* 2018). The 2019 California Residential Appliance Survey found that just under 60% of San Diego households utilize some form of AC (DNV GL Energy Insights USA, Inc. 2020). This leaves over 40% of San Diego households without access to AC, which increases their risk of heat related illness. The same report showed that residents without AC access are more likely to be from low-income households, highlighting the importance of distinguishing vulnerable populations. In their survey of all California residents, only about 30% of low income residents had access to AC while 55% of medium and high-income residents had AC access (DNV GL Energy Insights USA, Inc. 2020).

People exposed to extreme heat for long periods of time are at risk of over 27 different adverse health outcomes , impacting seven different organs (Mora *et al.* 2017). Heat related illnesses are caused by varying temperature conditions, depending on the individuals and their level of susceptibility. Social vulnerabilities like income, education, vehicle access, and chronic illness all increase the likelihood of experiencing heat related illness or mortality (Conlon *et al.* 2020; Bradford *et al.* 2015; Kisner *et al.* 2012). For this reason, equity must be at the center of planning for heat emergencies. If no action is taken to prepare for extreme heat events, the Southern Coast of California will likely experience as many as 20 additional deaths per 100,000 residents, adding up to about 3,500 extra heat-related deaths per year, and even more heat related hospitalizations (The Risky Business Project, 2014).

The initial cost of installing or purchasing an AC plus the increased cost of electricity from AC utilization are huge barriers to accessing AC for a significant portion of the population. Moreover, the high energy demand of AC further contributes to greenhouse gas (GHG) emissions and releases heat directly into the environment surrounding them, exacerbating the impacts of EHEs. As the energy grid functions currently, it cannot withstand any additional demand during heat emergencies. This was exemplified by the heatwave in September 2022 when rolling blackouts were narrowly avoided by an alert asking residents to reduce all non-essential energy use. Additionally, Stone Jr. *et al* (2021) found that electrical grid failure or "blackout" events have increased by more than 60% over the past 5 years with 46% of those events occurring during the hottest months of the year. Despite the need to decrease stress on the electrical grid it remains important that older residents and residents with limited mobility benefit from existing energy rebates and programs designed to increase access to personal AC. Hopefully, future policies and programs will increase grid capacity without increasing GHG emissions and improved technologies will increase AC efficiency. Until then, solutions other than personal AC need to be considered when planning for heat emergencies.

In San Diego County, cooling centers are called Cool Zone; they are activated based on NWS Heat Alerts which occur at a heat index of 105 (County of San Diego, 2022). The county designates all public libraries and some other government buildings as Cool Zones automatically, however there is an option for private organizations to apply to be designated as Cool Zones. Currently, the standard for becoming a Cool Zone in San Diego County is low; applying only requires filling out a one-page document with 9 requirements that provide insufficient guidance on how to best serve the general public or vulnerable community members during an EHE (Appendix A). However, none of the guidelines mention anything about offering water, helpful or interesting activities, or access to social service or medical resources.

In the summer of 2022 there were 96 operating Cool Zones in San Diego County, the majority of which were public libraries pre-designated by the county. The distribution of Cool Zones is determined solely by which organizations choose to apply to become Cool Zones and where government buildings designated as Cool Zones are already located. Improving access to Cool Zones not only needs to involve equitable distribution, but also requires improving the way existing Cool Zones operate and increasing public awareness around the positive impact of utilizing Cool Zones. The San Diego County web page on Excessive Heat offers very little information on the Cool Zone program, with minimal insight into what someone should expect if they visit a Cool Zones, and primarily advertises Cool Zones as a cooling strategy for senior citizens. In order to determine how Cool Zones can better serve the communities around them, a better understanding of the vulnerable populations living around existing Cool Zone facilities needs to be developed.

A social vulnerability analysis was conducted in order to determine the location of heat vulnerable populations in relation to existing Cool Zones in San Diego County. The results from the vulnerability index were used to create a vulnerability score for each Cool Zone. Once the vulnerability scores were calculated a vulnerability scorecard was created for each Cool Zone breaking down the percent of the population experiencing each of the predetermined vulnerability factors. This information can be used by decision makers, when determining the most effective interventions to improve heat-related health outcomes for vulnerable community members.

Literature Review

Health and Social Impacts of Extreme Heat

Extreme heat is known to impact seven vital organs and five vital pathways in the human body, with at least 27 ways in which heat can result in death (Mora *et al.*, 2017). Prolonged exposure to high temperatures interferes with the body's ability to perform numerous regulatory processes which can lead to heat stroke, among other medical emergencies (Mora *et al.* 2017). Tracking instances of heat related illness and mortality during EHEs is difficult because cases of heat related illness and mortality are often under or un-reported (Sherbakov *et al.*, 2018). Despite being under-reported, heat-related hospitalizations and mortality are costly. In an analysis of the cost of six different climate change-related events, the 2006 California heat wave was estimated to be $5.4 billion, the second highest of the six events (Knowlton *et al.*, 2011). When normalized, the 2006 California heat wave was the most expensive event, costing $148,792 per 1,000 people (Knowlton *et al.*, 2011). The same study found that the 2006 California heat wave was a once-in-a-century occurrence, but with current climate conditions, heat waves of that magnitude are expected to start occurring on a yearly basis.

Schmeltz *et al.* (2016) examined the economic burden of heat-related hospitalizations and found that income, ethnicity, and gender all impacted expected hospitalization costs. Heat-related health costs were higher among ethnic minorities, even though Whites accounted for 65% of total hospitalizations. Women, adults ≥65, and people experiencing poverty also encountered high costs due to hospitalization. It is also important to note that since lower-income and older people are more likely to have public health insurance, much of the costs of hospitalizations are paid for with tax-payer dollars. Therefore, spending tax-payer dollars to avoid heat related hospitalizations could end up saving money in the long run, though a cost-benefit analysis would need to be conducted to determine the economic tradeoffs. The economic cost of labor productivity lost to extreme heat events is staggering. The Atlantic Council (2021) projects that with baseline climate conditions, the United States alone could lose $100 billion annually due to labor lost to extreme heat. Ultimately, it is clear that the economic costs related to extreme heat will be devastating. While no study has stated the benefits outright, mitigating extreme heat and having a well-developed heat response plan can save billions of dollars in hospitalization and labor costs alone, while also saving lives and reducing heat related hospitalizations.

Cooling Centers as a Mitigation Strategy

The effective implementation of cooling centers is one possible low-energy maximum-impact response to EHEs. The Centers for Disease Control (CDC) defines cooling centers as, facilities or buildings with air conditioning (AC) that are open to the public during heat emergencies designated as a site to provide respite and safety during extreme heat. Libraries, community centers, senior centers, and gymnasiums can all be used as cooling centers as long as they are open to the public free of charge and meet a small list of criteria. Regardless of where they are located, cooling centers have the ability to save lives (Widerynski *et al.*, 2017).

However, Guirguis *et al.* (2018) examined the current threshold required to declare a heat emergency and noted the national threshold of a 105 heat index to declare a heat emergency is not suitable for California due to dryer climate conditions and lower acclimation of residents to extreme heat. Heat Response Plans need to be specific for the climate of the area they are serving so emergency heat alerts can be disseminated appropriately. With the strong effects of urban heat island effects, earlier thresholds for declaring heat emergencies would give people who experience the hottest temperatures more time to prepare. A more thorough understanding of micro heat islands in cities will allow for a more robust understanding of when heat emergency notifications should be triggered. This is to say that improving the access and suitability of Cool Zones is important, but will only be effective if other appropriate heat mitigation and adaptation strategies are adopted concurrently.

Barriers to access and utilization of Cool Zones

Currently, there is a gap in research on cooling center utilization, with most studies focusing on inequitable distribution. Experiencing one or more social vulnerability factors increases a person's risk for heat related illness, however members of socially vulnerable groups often struggle to access cooling centers. In a comparative study across 25 cities, Kim *et al.* (DATE) found that residents ≥65 were less covered by cooling centers in reference to the general population coverage in all cities. Voelkel *et al.* (2018) showed that access to cooling centers was also determined by income and race, with lower-income and non-white populations having disproportionately low access to cooling centers. The exact cause of the disparities is not fully understood, but Voelkel *et al* (2018) speculates that people with low incomes are more likely to live in areas where housing is more affordable, typically near highways and more industrial areas, and that certain minority groups are more likely to live in close proximity, causing people of similar demographics to be isolated from cooling centers. Additionally, adults ≥65 and people with limited mobility can struggle with accessing cooling centers that are not located within a reasonable distance because of slower walking speeds (Voelkel *et al.,* 2018). Overall there is relatively strong evidence that vulnerable populations are underserved by cooling centers, but more research needs to be done on why certain communities are being excluded from these life saving cooling centers.

Information on how often, and by whom, Cool Zones are utilized is widely unknown. What is known is that utilization is low. While there are lots of studies examining the distribution of cooling centers to determine if they are equitably placed or easily accessible to community members (Kisner *et al.*, 2012; Chamberlain, 2022), there are few studies trying to understand why people are not using cooling centers or what could make them better for people already using them. This includes examining how much of the population is within a 15 minute walk of a Cool Zone and how accessible Cool Zones are through public transit. Bradford *et al.* (2015) emphasize the importance of understanding the geo-spatial distribution of factors contributing to heat vulnerability, and in their study, aim to use that information to answer the question of optimal placement. Lack of awareness around Cool Zones is one major barrier that needs to be overcome in developing a successful Cool Zone system. Despite being well-documented that spending even a few hours in a cooling center decreases the chance of heat-related illness (Widerynski *et al.*, 2017), very few people know about cooling centers or feel like they need to use them even if they fall into a vulnerable classification. To be effective, cooling centers not only need to be equitably distributed, but also need to be well advertised and set up in a manner that makes utilization desirable.

<u>Access to AC and Energy Demand</u>

Access to AC is one of the most important, if not the most important, determinants of heat-related health outcomes (Barreca *et al.*, 2016; Guirguis *et al.*, 2018). However, the initial cost of installing or purchasing an AC plus the increased cost of electricity from running the AC is a huge barrier for a significant portion of the population. AC ownership disparities can be predicted by someone's income, race/ethnicity, and home ownership (Guiruis *et al.*, 2018). With three distinct climate regions, coastal, inland, and desert, San Diego County faces unique challenges in planning for extreme heat events. Residents in each of these climate regions have varying levels of acclimation to extreme heat, with desert residents having the highest acclimation and coastal residents having the lowest acclimation (Guiruis *et al*., 2018). Kim *et al.* (2021) found that cities with higher temperatures have a higher AC penetration than cooler cities, meaning it is likely that the desert region of San Diego County's higher acclimation is at least partly tied to higher AC saturation. The total AC saturation in San Diego County is 43% for central AC and 13% for room

AC (Guiruis *et al.*, 2018). In addition to having drastically different climate zones, parts of San Diego also experience the heat island effect, which causes more built-up areas of the city to experience higher temperatures than greener parts of the city or rural areas. Therefore, a successful emergency heat response plan will require an alert system informed by different within-city temperature thresholds during heat emergencies (Guirguis *et al.*, 2018). A varied alert system, with lower temperatures triggering the alert in more vulnerable communities, will allow residents without AC adequate time to prepare for extreme heat before temperatures become dangerous or even deadly.

Despite access to AC being the top indicator of health outcomes during heat emergencies, increasing access to AC for individual households is not feasible for several reasons. One of the reasons is that San Diego's energy grid is already strained during extreme heat days. This was exemplified by the heatwave in September 2022 when rolling blackouts were narrowly avoided by an alert asking residents to reduce all non-essential energy use. In the heat wave of August 2020, several hundred thousand California residents lost power due to rolling blackouts caused by too much energy use (Powell & Hubler, 2022). With energy use in San Diego County expected to increase by 6-27% in the next 50 years (Kalansky *et al.*, 2018), the grid will be increasingly strained if nothing is done to reduce emissions, reinforce the grid, and transition to renewable energy.

Because ACs require a high amount of energy, and the number of high-heat days is expected to increase, if individual household ACs are the only solution, energy use due to high heat will increase in quantity and duration. Additionally, increasing energy use increases GHG emissions, which further exacerbates the climate conditions causing EHEs in the first place. The already expected increase in energy demand could increase energy costs by 10-24% in the same period, making energy costs associated with AC use even less accessible (The Risky Business Project, 2014). For these reasons, extreme heat response strategies need to focus on maximizing equitable access to places with AC for residents while minimizing the stress on the energy grid.

Existing Heat Action Plans and Policy Actions

In a KPBS, San Diego Public Broadcasting, interview, an Escondido resident passing out waters to unhoused people during the September 2022 EHE, mentions that two of the three Cool Zones in Escondido were closed that Sunday despite it being the hottest day of that week, and that most of the unhoused people he encountered were unaware of the existence of Cool Zones or that a heat emergency had even been declared (Thorne, 2022). While San Diego County provides information regarding EHEs on social media and through news alerts, efforts to reach people without access to the internet or televisions, like unhoused people, are clearly falling short. The California State plan for extreme heat directly mentions cooling centers as a necessary mitigations strategy (State of California, 2022) as does the Climate Resilient SD report; successful implementation of cooling centers will require coordinated efforts across city, county, and state governments.

San Diego County has an Excessive Heat Response Plan (County of San Diego, 2021), however only the "consumer version" is available for public viewing. It is a 16 page document with limited information on the dangers of heat exposure, covid safety protocols during EHEs, and a brief outline of the county alert system. It states that the level of response plan activation is determined by the NWS threat system. The means of communicating emergency information to the public laid out in the *Excessive Heat Response Plan* include sharing information on "different County departmental websites, social media and news outlets, mobile applications, 2-1-1 San Diego, and others." Information on designated Cool Zones is described as being shared with the public in the ways mentioned above, and a definition of Cool Zones is given in the final section of the document. No part of the "consumer version" of the plan mentions outreach to unhoused people or any other type of door to door outreach services.

San Diego County's Climate Action Plan (CAP) mentions the need to maintain an updated Heat Response Plan (County of San Diego, 2018). Chapter 4 mentions heat resiliency along with other climate threats like increased flood events, increased wildfire events, and the threat of sea-level rise. Minimal space is given to discussing EHEs and only one paragraph of suggested "action items" is included in the CAP. The action items include strategies to help address heat-related impacts. Some of the strategies mentioned are mapping critical infrastructure, educating disadvantaged communities on heat-related risks, and several other strategies (Appendix B).

The California State government has a much more comprehensive Heat Response Plan (State of California, 2022). This 72 page document highlights the importance of being prepared for EHE and lays out clear goals for how the State plans to mitigate health and other impacts of EHEs. San Diego County should utilize the State plan for EHE response to build its own more comprehensive Excessive Heat Response Plan. The California Heat Response Plan directly mentions cooling centers in three of its established actions and in one of its recommended actions. The established actions relevant to cooling centers include Track A - Goal 1, E1, Track C - Goal 1, E1, and Track C - Goal 2, E2. Track A - Goal 1 focuses on increasing public awareness and implementing existing actionable items prioritizing outreach to vulnerable communities. Track C - Goal 1, E1 prioritizes protecting energy systems from the impacts of extreme heat through the commercialization of microgrids to ensure power stays on for critical infrastructures like cooling centers. Trac C - Goal 2, E2 focuses on improving access to cooling facilities that are energy efficient and low-cost, and directing the three large electric utility companies to include funding for cooling centers in their

General Rate Cases. The recommended action is Track B - Goal 2, R3 stresses the need to work with local and tribal governments to increase protections for unhoused people during EHEs including by increasing access to cooling centers. The exact wording for each of these actions can be found in Appendix B.

These measures are important first steps, however San Diego County would benefit from a more comprehensive heat response plan that provides measurable actions focused on aiding the most vulnerable populations.

Project Objectives

Access to AC is the top indicator for health outcomes during extreme heat events (Barreca *et al.*, 2016; Guirguis *et al.*, 2018). However, accessing household AC is not a viable option for many community members. AC is only needed for a small, but increasing, number of days out of the year in San Diego. This, combined with the high initial costs of purchasing an AC, and the high cost of energy required for operation, make accessing AC impractical or impossible for many individuals. This study aims to inform decision makers on how to improve Cool Zone operations and increase their accessibility for the most vulnerable community members, so the high cost of household AC doesn't prevent people from accessing this life-saving ability to cool down. In order to make targeted recommendations I first determined a vulnerability score for communities around existing Cool Zones, then created a profile of those communities to highlight community needs.

Methods

Study Area

The general study area includes all the Cool Zones within San Diego County. A 0.8 mile radius around each Cool Zone was chosen as the service area. This is to closely examine the communities that already have the easiest access to each Cool Zone so resource recommendations can be specified to community needs.

Data

The data utilized in this project fall into three categories: social vulnerability data, temperature and impervious surface data, and San Diego County geospatial data. In order to understand the demographics of the communities surrounding existing Cool Zones, demographic data were retrieved from the Living Atlas: American Community Survey (ACS) and clipped to the 0.8 mile service area around each Cool Zone. ACS data is collected by the U.S. Census Bureau as a way to maintain a continuous collection of community based data. Surveys for the ACS are sent out to a predetermined number of addresses based on a random sample that provides the best geographical coverage for a given area. The surveys are not meant to target specific individuals, but rather focus on ensuring the best geographical coverage. The data is stored by census block. Description of the variables used to determine the level of social vulnerability can be found in Table 1 below. This clipped data was used to perform Principal Component Analysis (PCA), which is explained in more details below. The demographic data used in the study were selected based on a literature review of social factors that are found to increase heat susceptibility (see Procedures and Methods section).

The geospatial data were retrieved from San Diego Geographic Information Source (SANGIS) and were used to identify the spatial boundaries of San Diego, the different climate regions, and the Cool Zone locations. SANGIS is a Joint Powers Authority between the City and County of San Diego responsible for maintaining and gathering regional GIS data. The MTA transit stop data was used to create a more robust accessibility analysis that takes into account Cool Zone access through public transportation.

The temperature and impervious surface data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) and the Living Atlas: USA National Land Cover Database (NLCD) Impervious Surface Time Series respectively. NOAA monitors oceanic and atmospheric conditions to provide robust data for oceanic and atmospheric research. The NLCD operates under the U.S. Geological Survey to produce current and nationally consistent land cover data. Temperature data was downloaded for the month of September 2022, and reduced to temperatures from the hottest day of September 2022 EHE, September 5, 2022. Once imported the temperature data was uploaded as a feature class. The impervious surface data was downloaded as raster data to be used in conjunction with temperature data for predictive heat mapping.

Layers	Format	Data Source	Purpose of data layer	Comments
ACS: Access to Vehicle	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of population without access to a vehicle
ACS: Disability data	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of population with a reported disability
ACS: Educational attainment	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of population whose highest education is less than a high school diploma
ACS: Fertility data	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of women aged 15-50 who have given birth in the past 12 months
ACS: Population Variables	Feature class	Living Atlas ACS	Used to construct vulnerability index	Sub-selection: Percent of population aged 0-4
ACS: Context for senior well-being	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of population 65 and older
ACS: Poverty data	Feature class	Living Atlas: ACS	Used to construct vulnerability index	Sub-selection: Percent of the population whose income in the past 12 months was below poverty level
Impervious surface data	Raster	Living Atlas: USA NLCD Impervious Surface Time Series	Used for EBK predictive temperature map	Pulled from the Living Atlas
SD County Boundary	Shape file	SANGIS	Study area	Study extent- all data was clipped to the county level before being clipped into Cool Zone Service Areas
SD County climate regions	Shape file	SANGIS	Highlights the climatic variety in SD County	SD County has 4 distinct climates- creating highly variable levels of adaptation to high heat
SD County Cool Zone locations	Shape file	SANGIS	Used to create buffer for more targeted study area	Focus of the study
Temperature data	Excel	NOAA	Used for EBK predictive temperature map	Temperature data was pulled for the entire month of September 2022. Data was reduced to maximum temperature on September 3, 2022 to make maps.

Methods

The use of a 0.8 mile radius was based on the literature , which indicates that 0.8 miles is a walkable distance within 15 minutes for the average person (Kisner et al., 2012), and people should not be exerting themselves for longer than 15 minutes during extreme heat events (Kisner et al., 2012). In order to determine if the 0.8 mile service areas were actually walkable in 15 minutes the Drive Time tool was used to create a polygon of the actual area surrounding each Cool Zone that is walkable in 15 minutes. The 0.8 mile buffer and the polygon of distance walkable in 15 minutes based on the GIS tool were then compared in a map (Figure 3).

In order to determine what resources are most useful for the populations in their service area, the first step was understanding the population demographics of the surrounding communities and to assess their level of vulnerability to extreme heat. Seven vulnerability factors were chosen to create a social vulnerability index through a principal component analysis (PCA). A PCA standardizes the variables by reducing the dimensionality, resulting in a single vulnerability score for each census tract. These The social vulnerability factors utilized in this study were: percent of the population with a disability, percent of the population whose income was below poverty level in the past 12 months, percent of the population with access to a vehicle, percent of the population whose highest educational attainment is less than a high school diploma, and percent of women aged 15-50 who have given birth in the past 12 months. These factors were identified in the literature as important determinants of heat susceptibility (Bradford et al., 2015; Kisner et al., 2012). The seven variables selected were deemed to be relevant in the context of SD County, however, this should not be considered to be a comprehensive list of factors affecting heat vulnerability. Once the variables were selected, relevant ACS demographic data was found and clipped to the 0.8 mile buffer area around each Cool Zone (Appendix C). The clipped data was then used to perform the PCA using the Principal Component spatial analyst tool in ArcGIS Pro. The PCA results helped determine to what extent the social vulnerability factors interact in any given Cool Zone Service Area.

After computing a vulnerability index through PCA, the communities where the 96 Cool Zones were located were then divided into three equally sized groups, indicating low, medium, and high vulnerability scores. Figure 2 shows a distribution of the population demographics for each group. Some patterns can be observed in the data, with populations in the low vulnerability group characterized by low poverty levels, low share of people who are uneducated, live with a disability or have no vehicle access, among other factors.

Radar charts were used to visualize the vulnerable populations served by each Cool Zone. The "ggplot2" package in the programming language R was used to create the radar charts. The codes used for the analysis are available upon request.

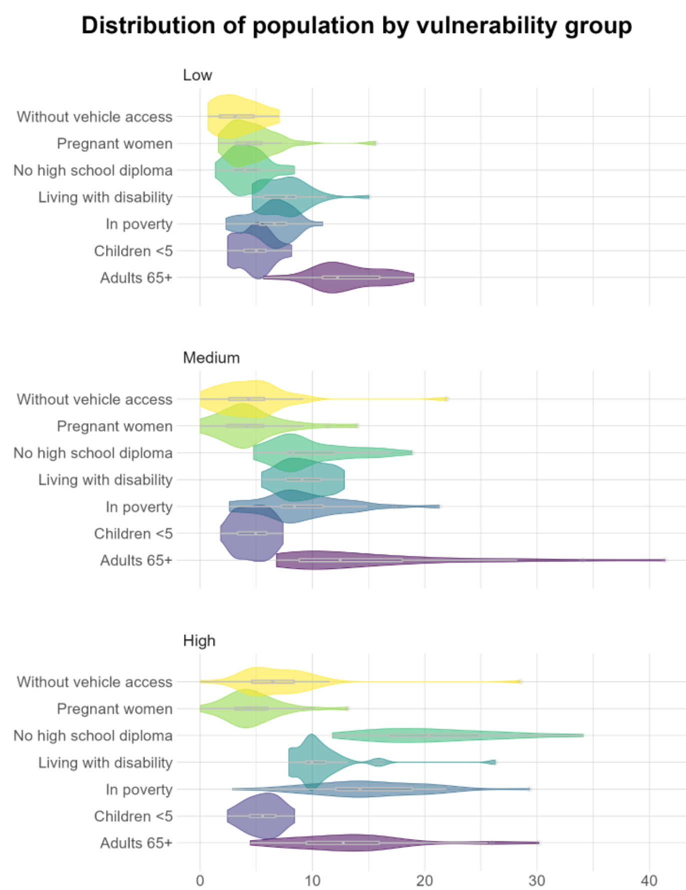


Figure 2. The distribution of populations by vulnerability group shown for the low, medium, and high vulnerability scores. The distribution is shown as % of the population in each vulnerability group for each category.

Finally, the temperature and impervious surface data were used with the Geostatistical Wizard tool to run an empirical Bayesian kriging (EBK) prediction to visualize the distribution of maximum temperatures (t-max) during an EHE. I chose to use temperatures from the hottest day of the September 2022 heat wave (September 3, 2022), then removed all temperature data that was not from that day. The data were derived from all NOAA weather stations throughout San Diego County, however, about half of the 92 stations were missing t-max values. Since the focus was extreme heat t-max values were used instead of average daily temperature. In order to account for the interactions between heat and impervious surfaces, impervious surface data from the NLCD was included.

Results

<u>Cool Zone Accessibility</u>

Walking times to the Cool Zones were evaluated based on existing literature that states 0.8 miles is a walkable distance in 15 minutes for the average person. ArcGIS Drive Time analysis tool , which uses ESRI Service Area data to account for available walking paths when determining the distance walkable from each Cool Zone in 15 minutes. The pre-set walking speed is 3.1 miles per hour and cannot be changed. The results in Figure 3 show that none of the 0.8 mile Service Areas utilized contain space that is entirely walkable in 15 minutes. In most cases, only a small subset of the population living in a 0.8 miles radius from a Cool Zone can walk there in 15 minutes. There is a higher density of Cool Zones in the southwest corner of the county where the City of San Diego and other urban areas are located, which suggests better access for residents living there. However, in East County the distance between Cool Zones is much greater, reducing walkability.

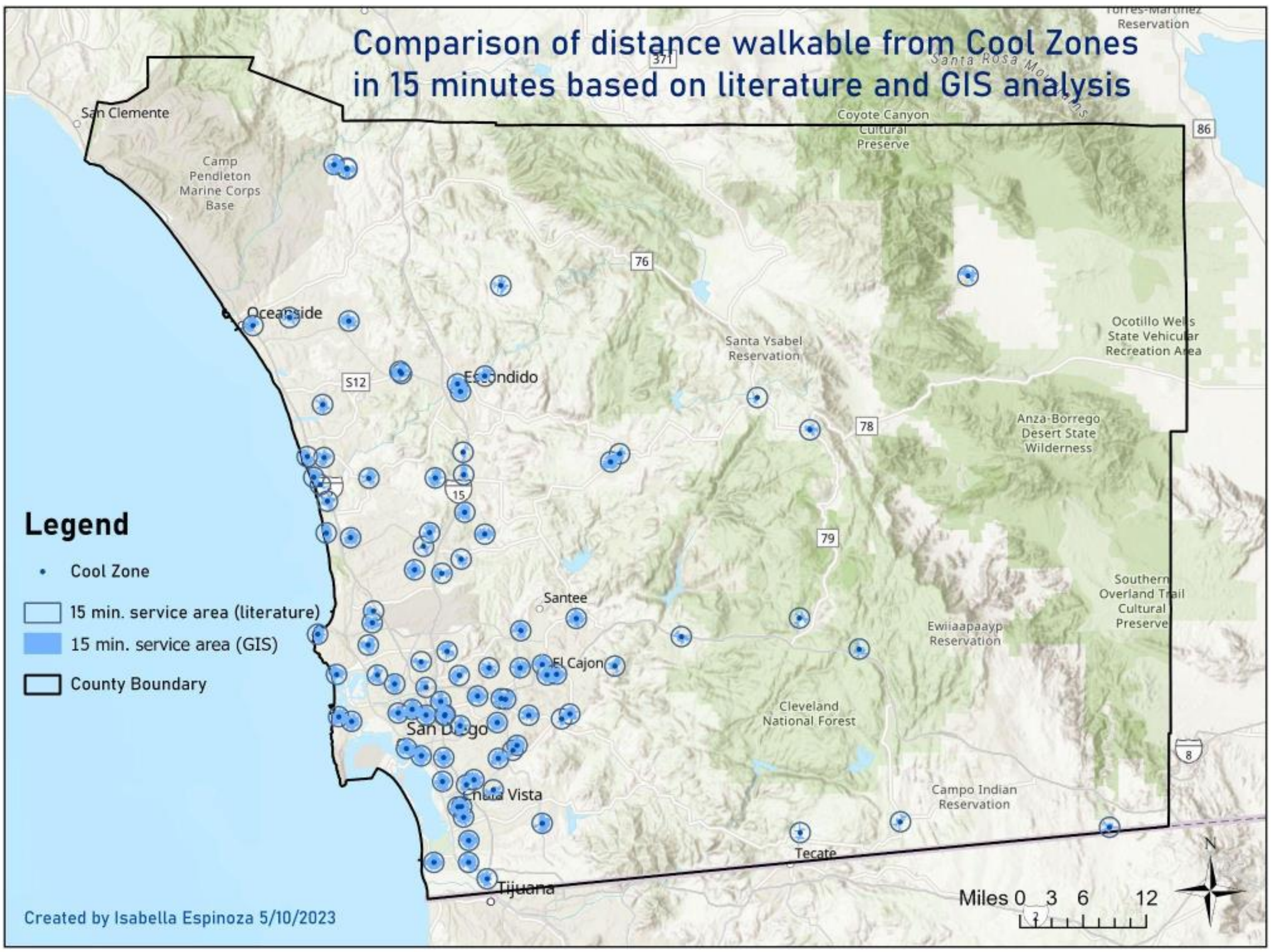


Figure 3. The results of the ArcGIS Pro Drive Time analysis on area walkable in 15 minutes compared to the 15 minute service area created using a 0.8 mile buffer suggested by literature. The filled in blue represents the area that can be walked in 15 minutes around each Cool Zone, while the blue circle around each Cool Zone indicates the 0.8 mile buffer. A blue dot is used to represent individual Cool Zones.

Social Vulnerability and Cool Zone Scorecards

The Principle Component Analysis (PCA) combined the seven social vulnerability factors identified in the analysis into a single social vulnerability index: vehicle access, disability, pregnant woman, educational attainment, poverty, and populations ≤5 and ≥65. The neumeric results for the PCA can be found in Appendix D.

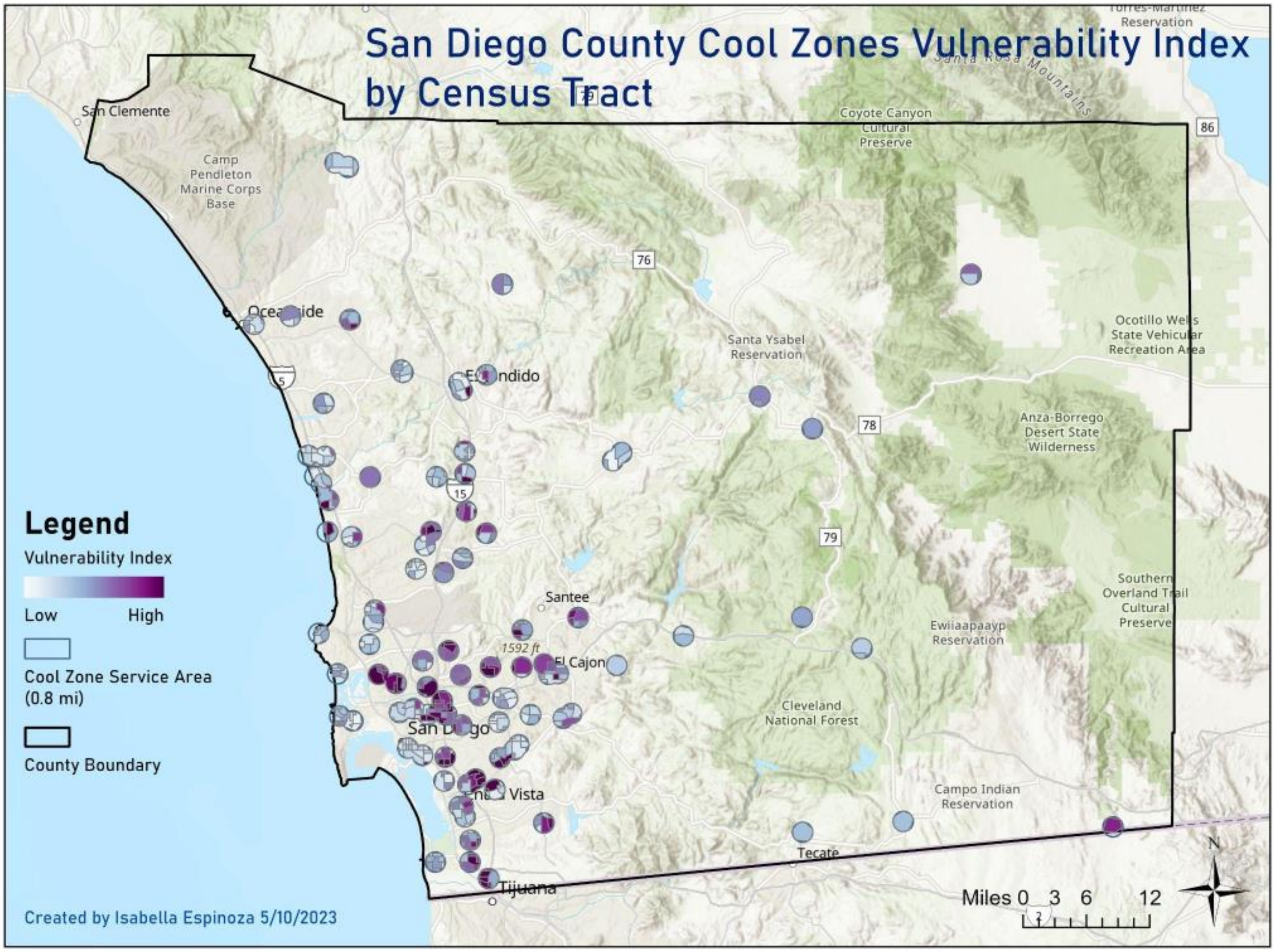


Figure 4. The results of the Principal Component Analysis (PCA) that was completed using ACS data on disability, poverty, vehicle access, educational attainment, population ≤5 and ≥65, and fertility. Darker purple indicates higher social vulnerability.

The social vulnerability index from the PCA was used to split the communities serviced by the Cool Zones into three equally sized groups characterized by low, medium and high vulnerability. Low and medium scoring communities serviced by the Cool Zones are evenly spread across the County, whereas communities characterized by high vulnerability scores are located primarily in the south west corner of the County where there is a higher amount of urbanization.

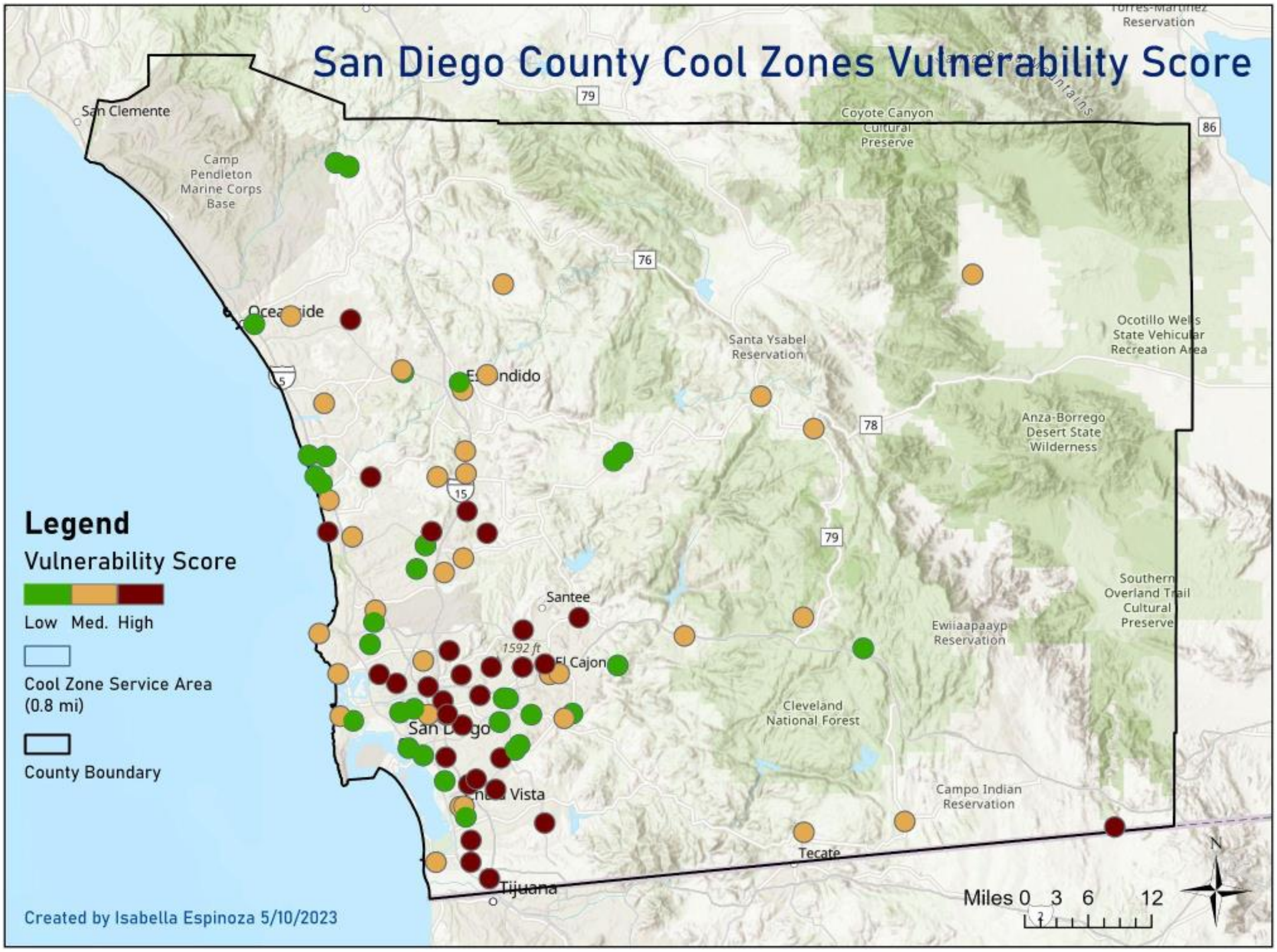


Figure 5. San Diego County Cool Zones based on their vulnerability score. Communities serviced by the Cool Zones were characterized by either low, medium, or high vulnerability.

Radar charts were created for each Cool Zone showing the overall vulnerability score (low, medium, or high) and the prevalence of individual vulnerability factors which characterize the surrounding communities. There are 96 radar charts in total, all of which can be found in Appendix E. The radar chart shows the variable with the highest percent of the population experiencing it for that Cool Zone in the top left portion of the circle, then lists the remaining variables from highest to lowest counterclockwise around the circle. An example of a radar chart for a high, medium, and low scoring Cool Zone are shown in Figure 5 below.

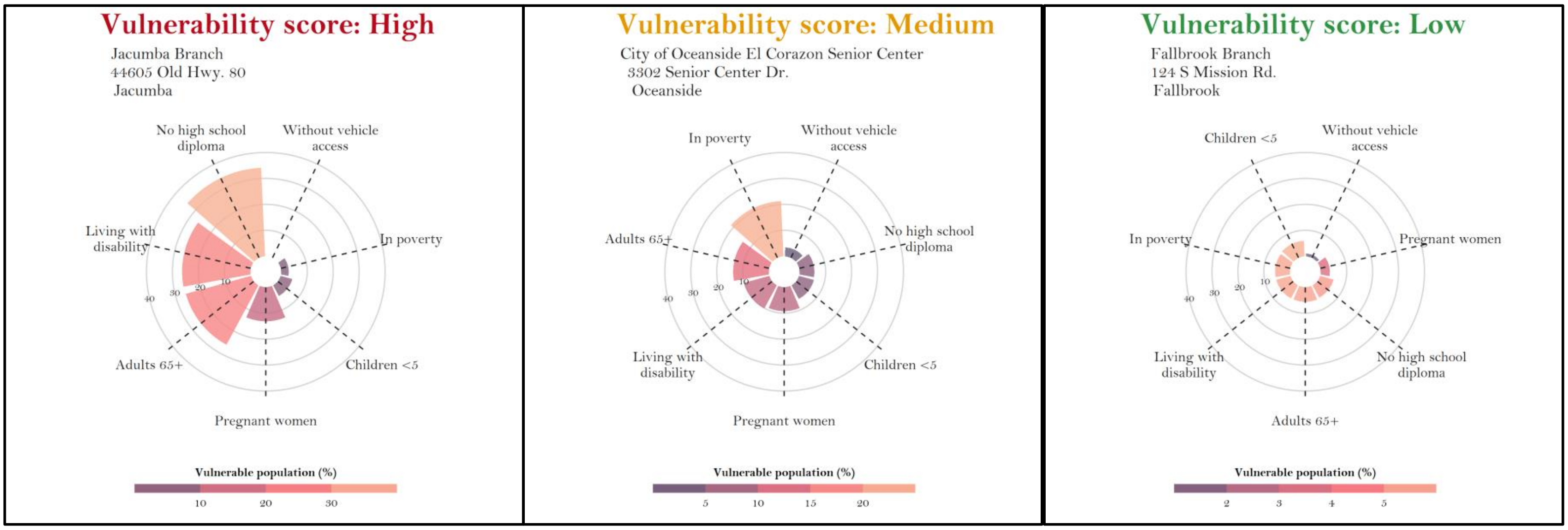


Figure 6. Radar charts for three different Cool Zones showing a high, medium, and low vulnerability score.

Out of 8 Cool Zone location categories, libraries constitute the vast majority, with 77% of Cool Zones being libraries (Figure 7). Senior centers and recreation centers make up 7% of Cool Zones each (Figure 7). The other categories are 3% or less.

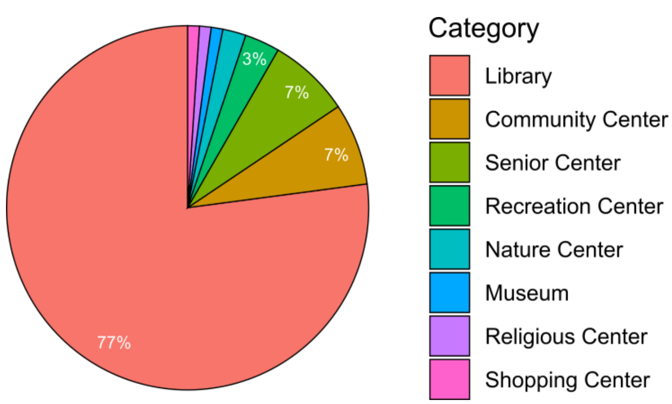


Figure 7. Cool Zones by Category.

Extreme Heat and Social Vulnerability

The results of the Empirical Bayesian Kriging analysis incorporating impervious surface data shows the hottest temperatures occurring in more urbanized areas. Moreover, Cool Zones servicing communities with high vulnerability scores are found in areas with higher temperatures, primarily in the southwest corner of the County (Figure 8). Though there are many Cool Zones already in the southwest corner, there are notable gaps in coverage for areas with high temperature in that section of the County. The area surrounding Escondido also lacks coverage in high temperature locations. San Diego's distinct climate zones impact the temperature modeling, however by incorporating impervious surface data an unexpected distribution occurs with higher temperature happening along the coastal region. Temperature data gathered at higher elevations also resulted in the unexpected pattern of cooler temperatures further inland.

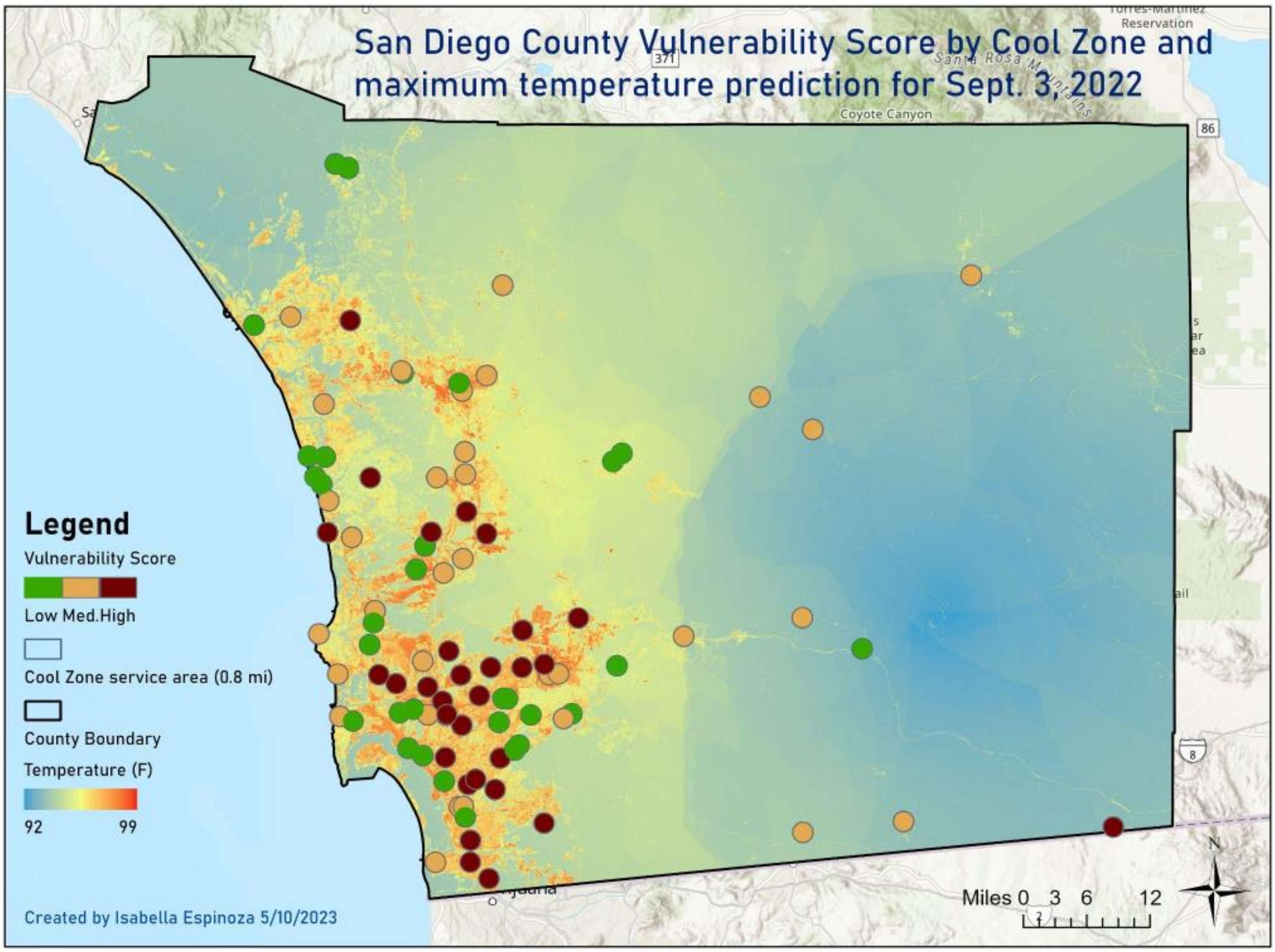


Figure 8. San Diego County vulnerability scores overlaid with a temperature prediction map from the hottest day of the September 2022 heat wave.

Discussion

Interpretation

The results presented in this paper provide insights on the geographical distribution of heat-vulnerable communities and the extent to which they are exposed to extreme heat, providing an indication for where efforts to improve Cool Zone access and utilization should be prioritized. The walkability analysis provides important insight into which portions of the community need to be the focus of ensuring adequate transportation options. Visually, the results show that only a portion of the population living in the Cool Zone service areas (0.8 miles) can access the facility within a 15 minute walk. To derive accurate estimates, the age profile of the population needs to be considered as well. The walking speed used in the ArcGIS Drive Time tool assumes a 3.1 mph walking speed, however, on average, adults >65 were found to walk at 2.1 mph (Alves *et al.,* 2020). This implies that in areas with a high proportion of elderly people, accessibility may be even lower than what this study shows. Additionally, Obuchi *et al.* (2021) found that higher temperatures decrease walking speed. Therefore, the distances walkable in 15 minutes in Figure 3 are over-estimates of what is actually walkable in 15 minutes during an EHE. The walkability of each Cool Zone should not be considered an indicator of vulnerability, but rather, should be used to understand current accessibility. The more information that can be gathered about the existing Cool Zones, their surrounding populations, and their accessibility options, the more effective and impactful recommendations for improvement can be. Future research should include more detailed walkability analysis and incorporate public transit stops when assessing overall accessibility.

The most vulnerable populations were primarily found along the coastline from the northern part of the City of San Diego, through Chula Vista, National City, and Imperial Beach all the way to San Ysidro along the Mexican border. Cool Zones in Escondido and El Cajon also serve highly vulnerable populations. These locations are known to experience highly-concentrated poverty, which is defined as an area where more than 20% of the population is living with an income below the poverty level (Concentrated Poverty in San Diego County). This aligns high vulnerability scores found in the spatial analysis (Figure 5). Communities with higher rates of poverty often have fewer resources available to them, which means that they should be prioritized for receiving support. The PCA analysis used in this study demonstrates one method that can identify vulnerable communities in order to create targeted solutions in heat action plans. The vulnerability scorecards provide the information needed to specialize resources to the needs of each vulnerable community.

The communities highlighted above as having the most vulnerable populations all fall into the coastal or near coastal/transitional climate categories. Guirguis et al. (2018) found that because people who live near the coast are more adapted to mild temperature conditions and cooling ocean breezes, private households and public facilities are less likely to have AC. As heat waves become more prevalent and continue occurring later in the year, having an updated more targeted heat response plan with a multi-faceted approach will be necessary. In August of 2017 over 70 schools in San Diego had to release students early because high heat conditions combined with the lack of AC and proper ventilation made the schools unsafe for staff and students (San Diego Tribune, 2017). Events like this will become more common unless SD County starts preparing now by not only improving the existing Cool Zones, but also by increasing AC penetration throughout county facilities. Figure 8 shows a clear pattern of highly vulnerable communities overlapping with higher temperature locations due to the prevalence of impervious surfaces in those areas. An effective heat response plan will not only involve improving the Cool Zone system, but will also require adapting the built environment to include more green spaces, cool roofs, cool pavement, and deploying a host of other heat mitigation and adaptation strategies concurrently.

The threat of rising temperatures posed by climate change is no longer a warning for the future. Extreme heat events are increasing in frequency and intensity across the globe, and are responsible for more weather-related mortalities than all other natural disasters combined (Shindell *et al.*, 2020; NWS). Despite being preventable with adequate interventions, heat-related mortalities present a major challenge for policy-makers and the public. Cool Zones have the potential to be a valuable adaptation strategy in response to extreme heat events. In their study on heat vulnerability and adaptive solutions, Bradford et al. (2015) found that Cool Zones are proven to be effective in mitigating negative heat-related outcomes for vulnerable populations, but emphasized that, in order for them to be effective, planners must understand the spatial variability of heat-related vulnerabilities. This study provides the information necessary to build the understanding needed to make Cool Zones an effective heat adaptation strategy by assessing the spatial distribution of vulnerable communities relative to existing Cool Zones in San Diego County. The vulnerability scorecards increase the utility of this information by breaking down the community composition and indicating which Cool Zones should be highest priority when dispersing resources. An interactive web-tool can be found at this link for further exploration of San Diego Cool Zones and their scorecards.

<u>Policy Implications</u>

The State of California recently announced its Community Resilience Center Program, which will fund neighborhood level resilience centers aimed at providing shelter and other necessary resources during climate emergencies (Community Resilience Centers - Strategic Growth Council). The idea is that these Community Resilience Centers will operate year round, allowing community members to build relationships and trust in these government offered programs. As these Community Resilience Centers are rolled out, comparative studies on their utilization and Cool Zone utilization should be conducted to determine how to shelter the most significant number of the most vulnerable community members. Information from this study could inform decision makers on which communities should be prioritized when determining where to pilot Community Resilience Centers in San Diego County.

Chief Heat Officers were developed and piloted by Arsht-Rock and and the Extreme Heat Resilience Alliance (EHRA) as a way to unify efforts across local governments in their efforts to combat extreme heat (Arsht-Rock, 2023). Ideally, as more cities and municipalities start hiring CHOs, a network of heat response professionals will be able to collaborate to develop and implement effective heat response strategies, while ensuring heat response efforts do not get forgotten by the governments charged with implementing them. Los Angeles has become the second city in the United States to appoint a Chief Heat Officer. Across the globe, seven local governments have developed CHO positions. San Diego County could benefit from appointing a CHO, especially considering the collaboration potential given the close proximity of the Los Angeles based CHO.

San Diego already operates a fan distribution and energy rebate program to get fans into people's homes during EHEs and to alleviate the burden of increased energy bills. This program is a necessary first step, however, distribution should be expanded to include people who work labor-intensive jobs or other jobs that prevent them from being able to stay cool at work or from being able to access Cool Zones due to their limited operating hours. Other vulnerable populations for consideration are populations with low mobility like people 65 or over and people with disabilities that limit their mobility. These populations are better suited for AC distribution and energy rebate programs, combined with community networks designed to check on older people and people with disabilities during heat emergencies. Cool Zones are an important resource that have potential to have a positive impact on the communities they serve, but they are not a one-size-fits-all solution.

Recommendations

A primary objective of this project was to gather information to make recommendations on how to improve Cool Zones for vulnerable populations. Despite being well-documented that spending even a few hours in a cooling center decreases the chance of heat-related illness (Widerynski *et al.*, 2017), very few people know about cooling centers or feel like they need to use them even if they fall into a vulnerable classification. These recommendations will focus on how to increase awareness, accessibility, and utilization, as well as on what can be done to standardize operations.

Increasing Awareness

Develop targeted community outreach plans with relevant information on what causes heat vulnerability and where people should go for the necessary resources. This includes more robust efforts to inform and aid unhoused people, who are often unaware that a heat emergency has been declared, during EHEs. Unhoused people face unique challenges that require more involved solutions. Additionally, programming is needed to increase awareness for outdoor workers who are unable to stay home during EHEs. Outdoor workers often exert themselves for long periods of time putting them at an increased risk for heat-related illness and mortality. Early warning systems triggered by regional and evidence-based temperature thresholds should start going out before temperatures become life-threatening. These warning systems should include information on Cool Zones and the life-saving impacts of spending time in AC.

Increasing Access and Utilization

San Diego County should pilot providing free public transportation during EHEs. This provides multiple benefits by not only making it easier for people to get to Cool Zones, but also by providing people the opportunity to cool off while they travel to their destinations. People in vulnerable communities are less likely to be able to take time off of work and might avoid taking public transit due to cost restrictions. By making public transit free during EHEs the aforementioned individuals would be able to find some respite during their commute. San Diego County should also pilot partnering with rideshare companies like Uber or Lyft to increase transportation options for people with limited mobility or who lack public transit access. Increasing accessibility is necessary to increase utilization, however, unless data is gathered on why people are not using Cool Zones, it will be difficult to make necessary improvements. The County should track Cool Zone utilization and survey residents on why they don't use Cool Zones and what would make them more likely to do so. Providing relevant programming like skills classes or entertainment could be an important first step.

Standardizing Operations

The minimum operating standards for Cool Zones should be expanded from the existing nine requirements (Appendix A) to include provisions about supplying water, snacks, social services, and other relevant resources. Additionally, all Cool Zones should be required to have backup generators so they continue to provide cooling services in the event of a power outage. Programming should be required at all Cool Zones, but the type of programming should depend on population needs.

Limitations and pitfalls

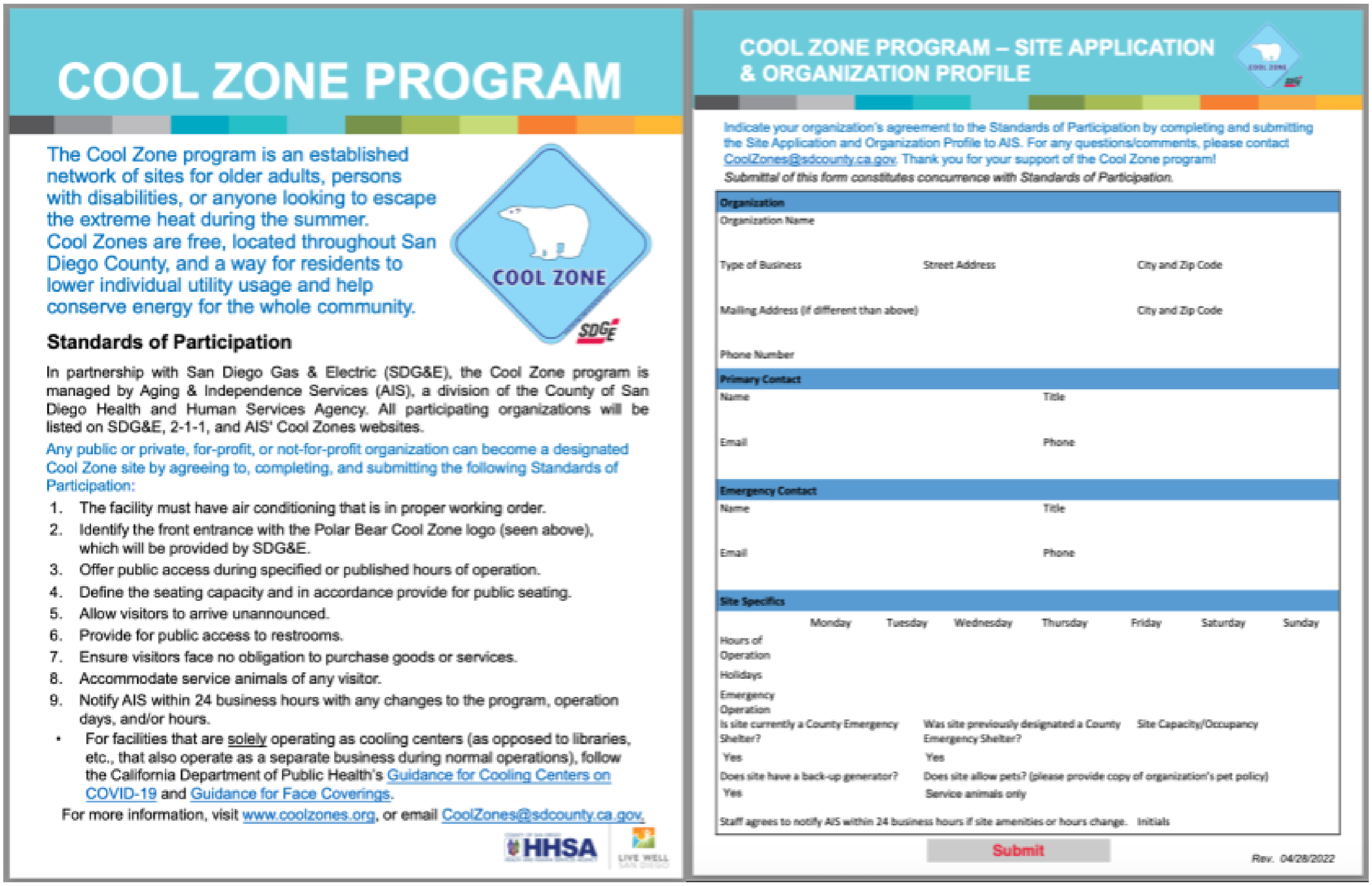
Social vulnerabilities are correlated with negative health outcomes during extreme heat exposure (Conlon *et al.* 2020; Bradford *et al.* 2015; Kisner *et al.* 2012). However, creating a social vulnerability analysis has limitations. Running a PCA reduces the dimensionality of the data making comparison easier, but important information can be lost in the process. Some of this was overcome by creating the scorecards highlighting the percentage of each vulnerability population at every Cool Zone. The vulnerability factors chosen for this study are not exhaustive. Utilizing specific health outcomes based on hospitalizations would provide better insights into which populations are most vulnerable. The temperature data used to create the predictive heat map was limited. This led to impervious surface data dominating the prediction, which is helpful in visualizing where heat islands could occur, but still skews the predictive temperature map. Neighborhood level microclimate research would provide more detailed maps creating a better visualization of how temperatures vary throughout different urban spaces. Due to time constraints, this study was unable to focus on how health outcomes vary by temperature thresholds, which is necessary information for developing heat response plans.

Conclusions

This project improves the understanding of the spatial distribution of vulnerable populations in San Diego County, in relation to the existing cooling centers intended to serve those populations. The results highlight the locations of the most vulnerable populations, provide a visualization of how different areas of SD County are impacted by extreme heat, and create a stepping off point for further accessibility analysis. The lack of AC penetration in coastal communities makes targeted community adaptation measures, like Cool Zones, necessary as extreme heat events become more common. The high energy utilization of AC is another reason to focus on having community based cooling locations rather than just passing out ACs and energy rebates to vulnerable community members. San Diego's grid is already strained during heat emergencies which was exemplified by the alert sent out by San Diego Gas & Electric during the September 2022 heat wave asking consumers to immediately reduce energy consumption in order to avoid rolling blackouts (Powell and Hubler, 2022). Until the energy grid runs off of cleaner energy and can provide more reliable distribution during extreme heat events, improving Cool Zones should be considered a top priority in order to cool down as many SD County residents as possible while putting the least amount of strain on the grid. Improving access to Cool Zones not only needs to involve equitable distribution, but also requires improving the way existing Cool Zones operate and increasing public awareness around the positive impact of utilizing Cool Zones.

Appendix A

The existing Cool Zone application with current requirements and application for an organization to become a Cool Zone in San Diego County. Pulled from the San Diego County Cool Zone page.



COOL ZONE PROGRAM

The Cool Zone program is an established network of sites for older adults, persons with disabilities, or anyone looking to escape the extreme heat during the summer. Cool Zones are free, located throughout San Diego County, and a way for residents to lower individual utility usage and help conserve energy for the whole community.

Standards of Participation

In partnership with San Diego Gas & Electric (SDG&E), the Cool Zone program is managed by Aging & Independence Services (AIS), a division of the County of San Diego Health and Human Services Agency. All participating organizations will be listed on SDG&E, 2-1-1, and AIS' Cool Zones websites.

Any public or private, for-profit, or not-for-profit organization can become a designated Cool Zone site by agreeing to, completing, and submitting the following Standards of Participation:

1. The facility must have air conditioning that is in proper working order.
2. Identify the front entrance with the Polar Bear Cool Zone logo (seen above), which will be provided by SDG&E.
3. Offer public access during specified or published hours of operation.
4. Define the seating capacity and in accordance provide for public seating.
5. Allow visitors to arrive unannounced.
6. Provide for public access to restrooms.
7. Ensure visitors face no obligation to purchase goods or services.
8. Accommodate service animals of any visitor.
9. Notify AIS within 24 business hours with any changes to the program, operation days, and/or hours.

- For facilities that are solely operating as cooling centers (as opposed to libraries, etc., that also operate as a separate business during normal operations), follow the California Department of Public Health's Guidance for Cooling Centers on COVID-19 and Guidance for Face Coverings.

For more information, visit www.coolzones.org, or email CoolZones@sdcounty.ca.gov.

HHSA

LIVE WELL SAN DIEGO

COOL ZONE PROGRAM – SITE APPLICATION & ORGANIZATION PROFILE

Indicate your organization's agreement to the Standards of Participation by completing and submitting the Site Application and Organization Profile to AIS. For any questions/comments, please contact CoolZones@sdcounty.ca.gov. Thank you for your support of the Cool Zone program!

Submittal of this form constitutes concurrence with Standards of Participation.

Organization

Organization Name

Type of Business | Street Address | City and Zip Code

Mailing Address (if different than above) | City and Zip Code

Phone Number

Primary Contact

Name | Title

Email | Phone

Emergency Contact

Name | Title

Email | Phone

Site Specifics

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Hours of Operation							
Holidays							
Emergency Operation							

Is site currently a County Emergency Shelter? Yes | Was site previously designated a County Emergency Shelter? Yes | Site Capacity/Occupancy

Does site have a back-up generator? Yes | Does site allow pets? (please provide copy of organization's pet policy) Service animals only

Staff agrees to notify AIS within 24 business hours if site amenities or hours change. Initials

Submit

Rev. 04/28/2022

Appendix B

Existing heat action plans and policy actions pulled from San Diego County's Climate Action Plan and the California Heat Response Plan.

San Diego County's Climate Action Plan

"The following strategies can help the County address heat-related impacts:

- Collaborate with regional partners on temperature and extreme heat preparedness initiatives, such as:
    - Mapping of critical infrastructure vulnerable to extreme heat events;
    - Outreach programs for outdoor workers and others susceptible to extreme heat;
    - Education of disadvantaged communities on heat-related risk and methods to prevent heat related illness;
    - Updates to the Excessive Heat Response Plan prepared by the Health and Human Services Agency;
    - Research on the effects of a warmer climate on the agricultural industry; and
    - Understanding the tolerance of current crop mixes to withstand increased temperatures.

State of California Heat Response Plan

TRACK A - GOAL 1, E1: Implement existing actionable and targeted public awareness campaigns, prioritizing outreach to communities most vulnerable to heat impacts.

> "The Office of Emergency Services maintains the 2014 Contingency Plan for Excessive Heat Emergencies (currently being updated as part of the draft Extreme Temperature Response Plan) and the 2020 Electric Power Disruption Toolkit for Local Government. Both documents contain information on public awareness campaigns and information on cooling centers."

TRACK C - GOAL 1, E1: Protect energy systems from the impacts of extreme heat.

> “Microgrid rulemaking: Initiated by SB 1339 (Stern, 2018) to create a policy framework to facilitate the commercialization of microgrids, can support local resiliency by ensuring the power stays on for critical services, such as cooling centers, even if the larger grid is unable to function due extreme heat or other emergencies. The Microgrid Incentive Program provides $200M for microgrid development in vulnerable and disadvantaged communities in California.”

TRACK C - GOAL 2, E2: Review and improve access to and use of air conditioning and other indoor cooling strategies, including passive cooling techniques and other alternate methods that are energy efficient, low-cost, and do not rely on high global warming potential refrigerants. Address obstacles to the use of air conditioning and other cooling strategies for vulnerable populations.

> “Decision D.16-11-022: directed the three large electric utilities to include funding for cooling centers in their General Rate Cases. These cooling center locations include government-run senior centers, community centers, parks and recreation sites, and public buildings. The funding is approximately $200,000 per year to support 400 cooling centers across the state within the large electric utilities’ jurisdictions”

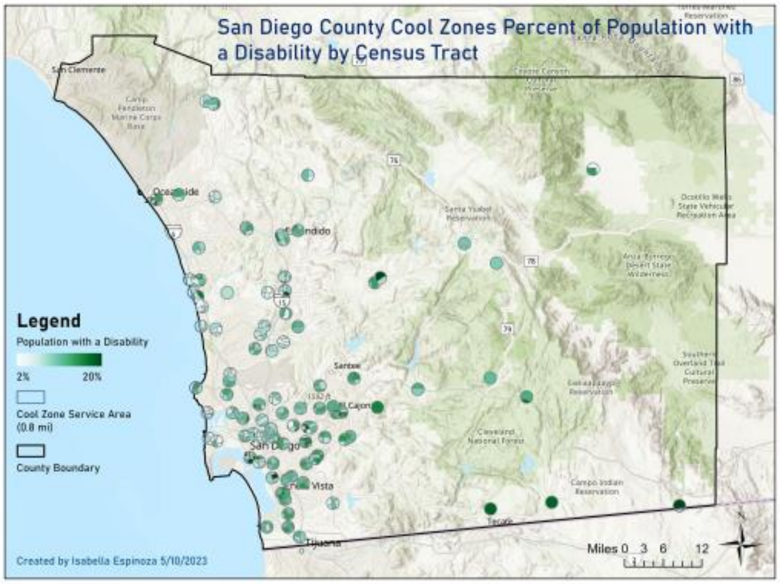
The recommended action is:

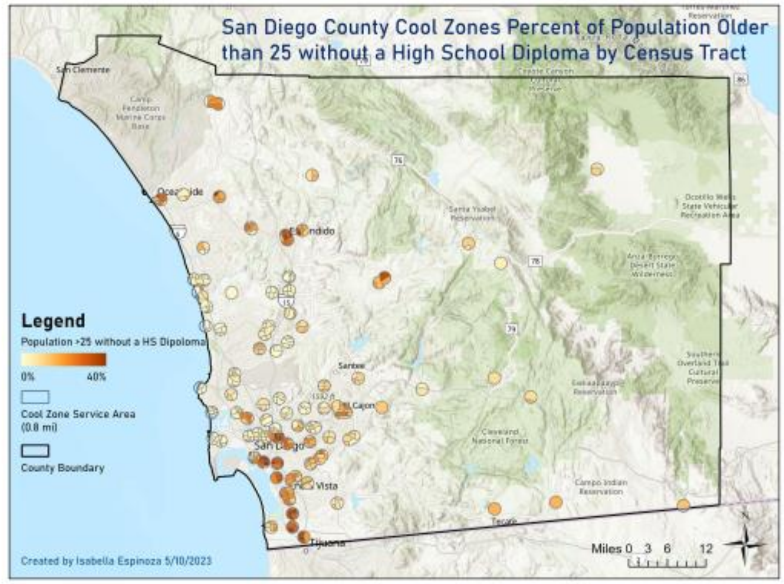
TRACK B - GOAL 3, R3: Work with tribal and local governments, and community-based organizations to bolster protections for unhoused populations during extreme heat events.

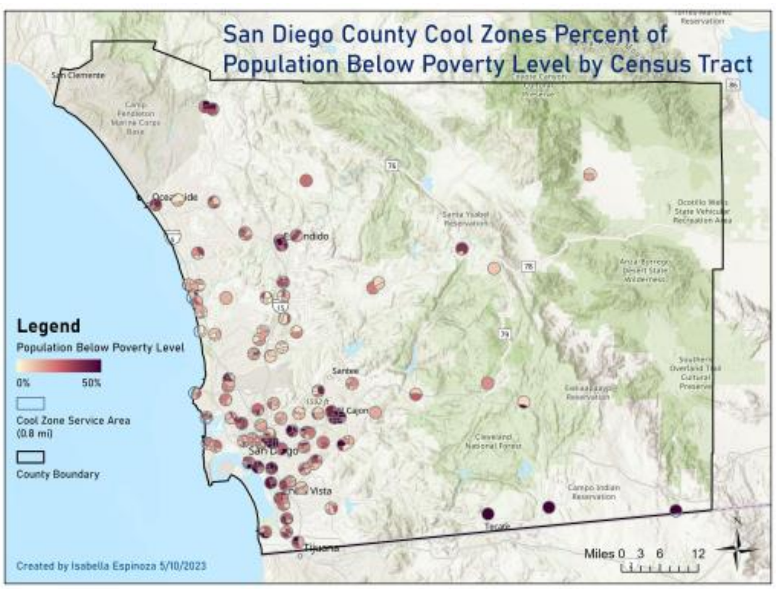
> “Work with local governments and local Continuums of Care to support local plans containing provisions for supporting people who are medically vulnerable, including providing access to resilience centers and/or cooling centers in the event of power shutoffs.”

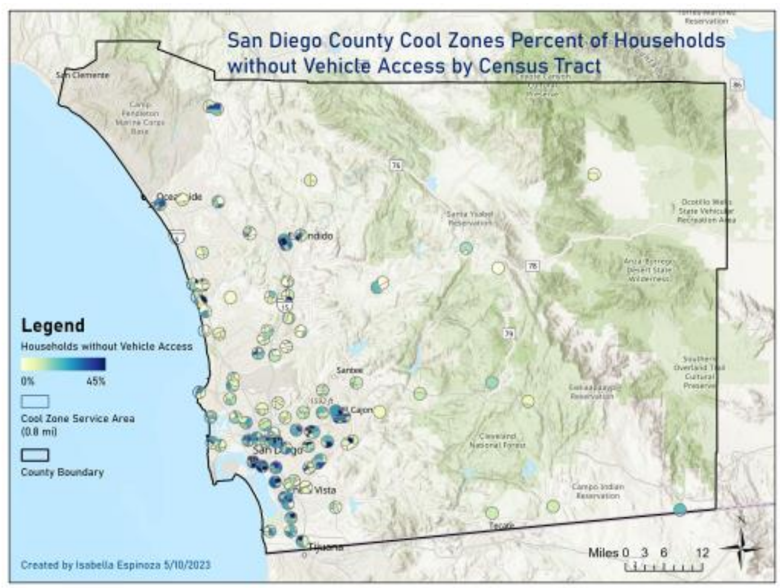
Appendix C

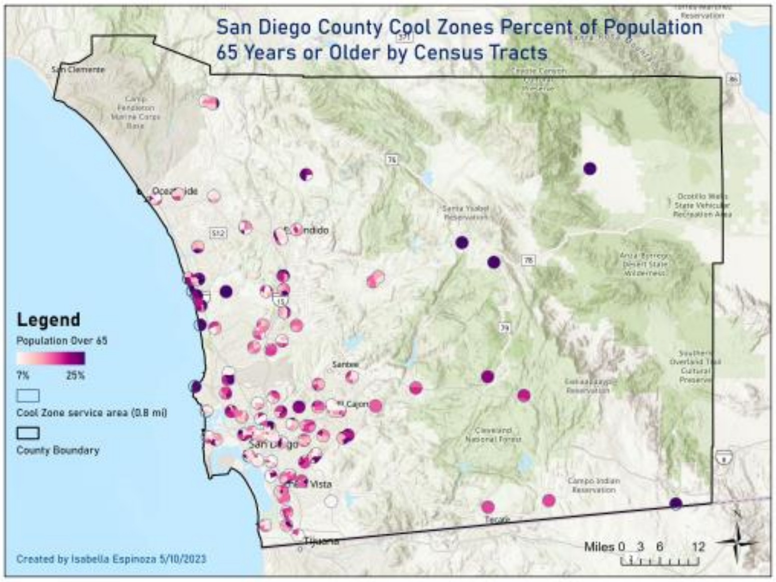
Maps of clipped American Community Survey data for the seven variables used to perform the PCA.

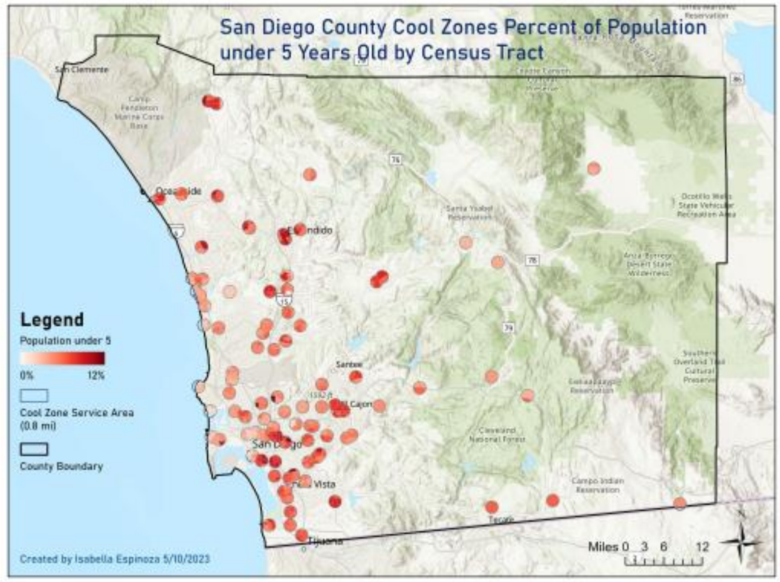


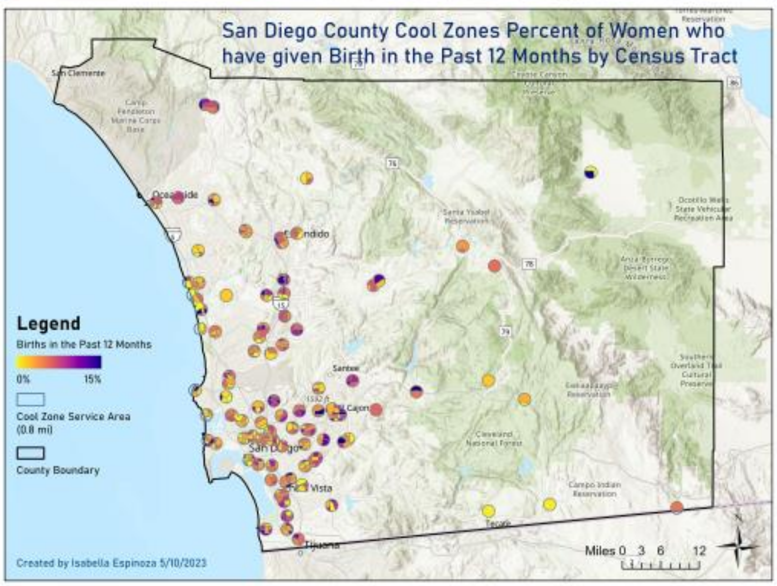







San Diego County Cool Zones Percent of Population
65 Years or Older by Census Tracts
Legend
Population Over 65
7%
25%
Cool Zone service area (0.8 mi)
County Boundary
Created by Isabella Espinoza 5/10/2023
Miles 0 3 6 12


San Diego County Cool Zones Percent of Population
under 5 Years Old by Census Tract
Legend
Population under 5
0%
12%
Cool Zone Service Area
(0.8 mi)
County Boundary
Created by Isabella Espinoza 5/10/2023
Miles 0 3 6 12


San Diego County Cool Zones Percent of Women who
have given Birth in the Past 12 Months by Census Tract
Legend
Births in the Past 12 Months
0%
15%
Cool Zone Service Area
(0.8 mi)
County Boundary
Created by Isabella Espinoza 5/10/2023
Miles 0 3 6 12

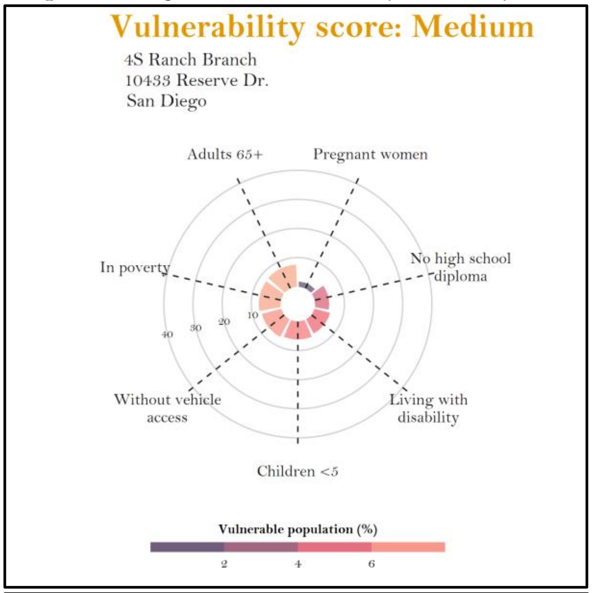
Appendix D

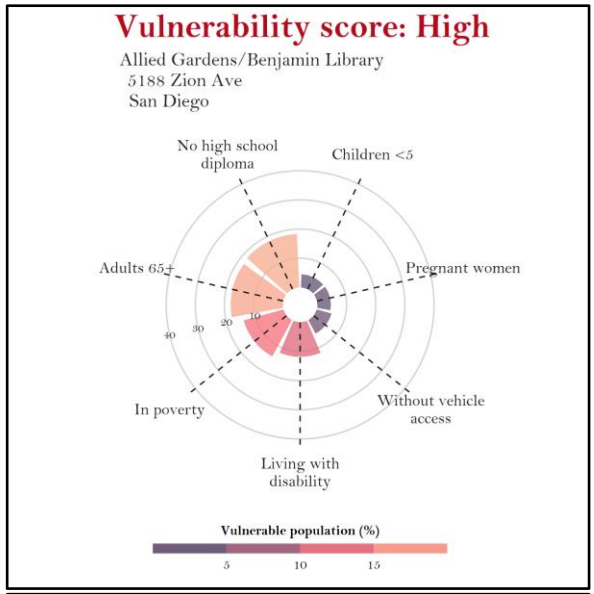
Numerical results from the Principal Component Analysis performed with ArcGIS Pro.

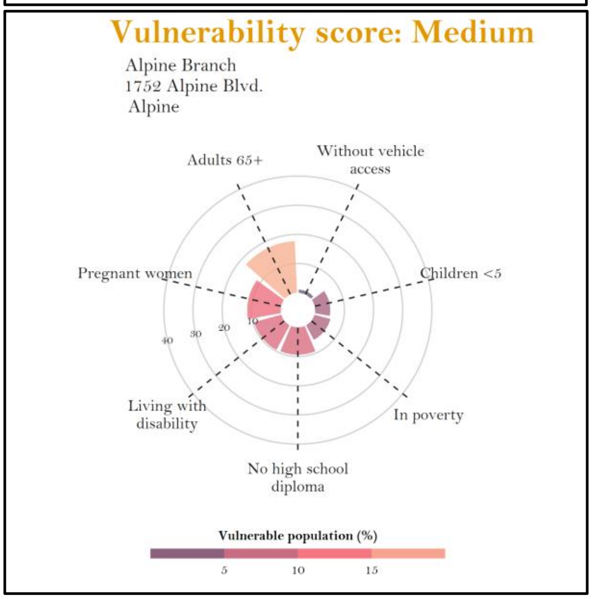
```
#                  COVARIANCE MATRIX

#    Layer           1             2             3             4             5             6             7
#   ---------------------------------------------------------------------------
        1          0.72605       0.45248       0.06992       0.21302       0.18909      -0.01410       0.36956
        2          0.45248       4.94342      -0.01203       0.15116       1.73369      -0.01472       0.83201
        3          0.06992      -0.01203       0.89322      -0.12466       0.02549       0.01889      -0.09924
        4          0.21302       0.15116      -0.12466       2.83060       0.00704      -0.36138       0.12937
        5          0.18909       1.73369       0.02549       0.00704       2.74980      -0.00838       0.97109
        6         -0.01410      -0.01472       0.01889      -0.36138      -0.00838       0.16222      -0.01866
        7          0.36956       0.83201      -0.09924       0.12937       0.97109      -0.01866       1.39969
#   ===========================================================================


#                  CORRELATION MATRIX

#    Layer           1             2             3             4             5             6             7
#   ---------------------------------------------------------------------------
        1          1.00000       0.23884       0.08682       0.14860       0.13383      -0.04107       0.36659
        2          0.23884       1.00000      -0.00572       0.04041       0.47023      -0.01644       0.31630
        3          0.08682      -0.00572       1.00000      -0.07840       0.01626       0.04962      -0.08875
        4          0.14860       0.04041      -0.07840       1.00000       0.00252      -0.53330       0.06500
        5          0.13383       0.47023       0.01626       0.00252       1.00000      -0.01255       0.49499
        6         -0.04107      -0.01644       0.04962      -0.53330      -0.01255       1.00000      -0.03915
        7          0.36659       0.31630      -0.08875       0.06500       0.49499      -0.03915       1.00000
#   ===========================================================================


#               EIGENVALUES AND EIGENVECTORS

# Number of Input Layers      Number of Principal Component Layers
            7                               7
# PC Layer           1             2             3             4             5             6             7
#   ---------------------------------------------------------------------------
# Eigenvalues
                   6.26689       2.90301       2.00448       1.03357       0.91074       0.47261       0.11371

# Eigenvectors
# Input Layer
        1          0.10297       0.08581       0.03570       0.44452       0.37497       0.80108      -0.02882
        2          0.83117      -0.04101      -0.55006      -0.00102      -0.02766      -0.06445      -0.00068
        3         -0.00409      -0.06170      -0.01486      -0.26234       0.92184      -0.27809       0.00089
        4          0.05415       0.98111       0.01391      -0.11594       0.01741      -0.05168       0.13371
        5          0.48381      -0.07916       0.71827      -0.45024      -0.06149       0.19299       0.00239
        6         -0.00688      -0.13002      -0.00632       0.02416       0.00732       0.03390       0.99057
        7          0.24798       0.03739       0.42402       0.71891       0.06856      -0.48551       0.00791
#   ===========================================================================

#               PERCENT AND ACCUMULATIVE EIGENVALUES

# PC Layer    EigenValue    Percent of EigenValues    Accumulative of EigenValues
        1       6.26689            45.7270                  45.7270
        2       2.90301            21.1821                  66.9091
        3       2.00448            14.6259                  81.5350
        4       1.03357             7.5415                  89.0766
        5       0.91074             6.6453                  95.7219
        6       0.47261             3.4484                  99.1703
        7       0.11371             0.8297                 100.0000
#   ===========================================================================
```

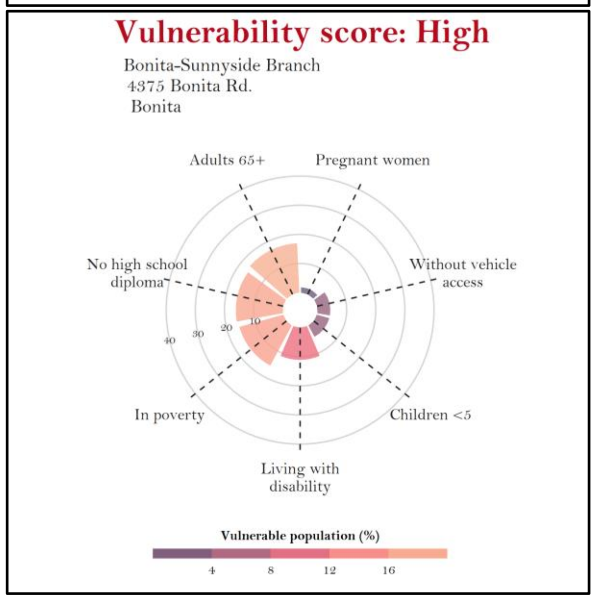
Appendix E

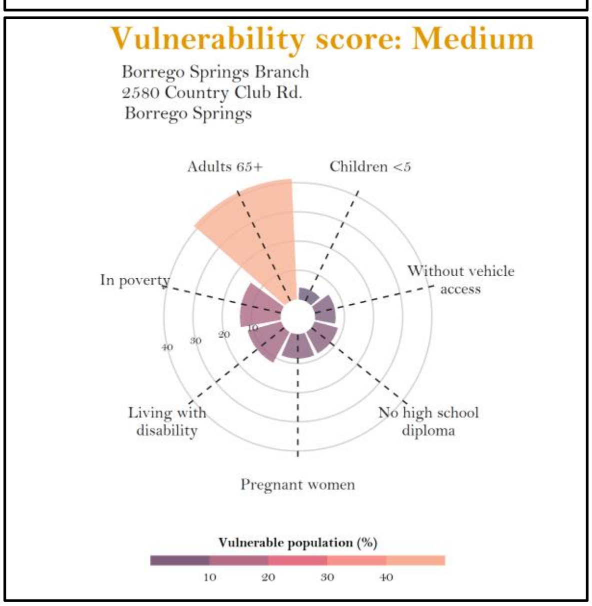
Radar charts for all 96 Cool Zones in San Diego County. Showing the percent of the population experiencing each vulnerability for every Cool Zone service area.

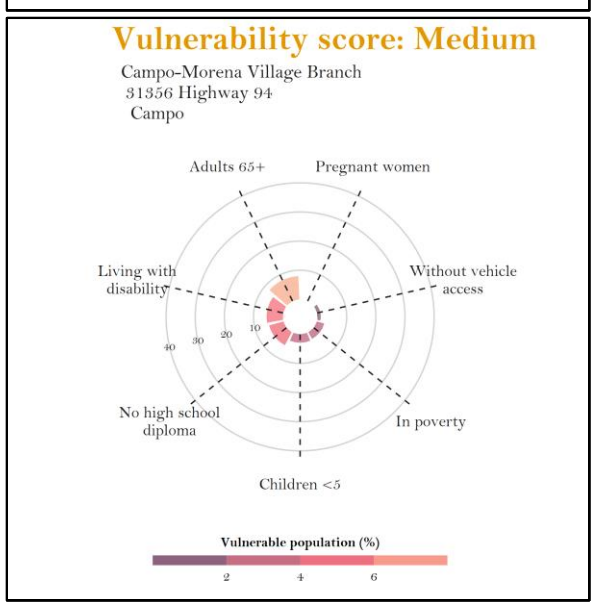






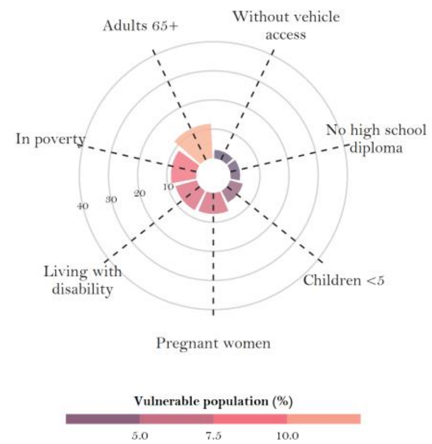






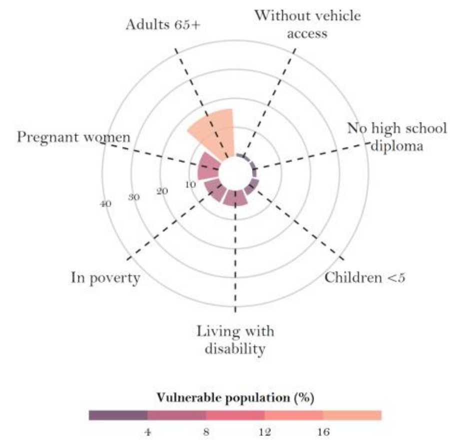
Vulnerability score: Low

Canyonside Recreation Center
12350 Black Mtn Rd
San Diego



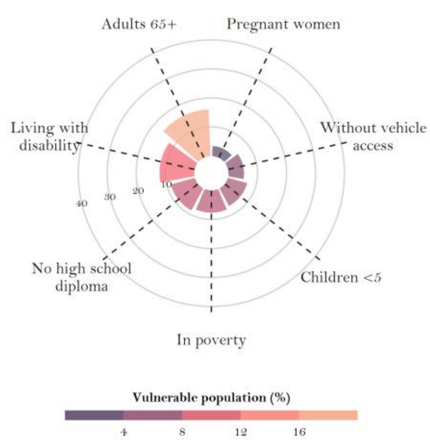
Vulnerability score: Low

Cardiff-by-the-Sea Branch
2081 Newcastle Ave.
Cardiff-by-the-Sea



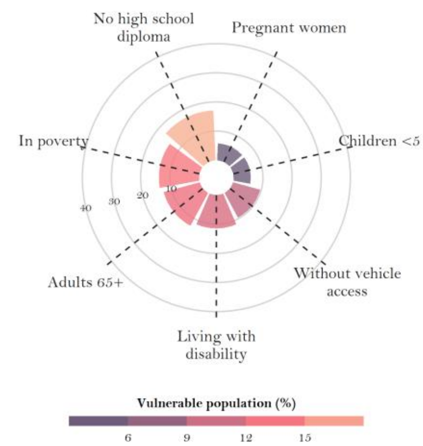
Vulnerability score: Medium

Carlsbad City Library
1775 Dove Lane
Carlsbad



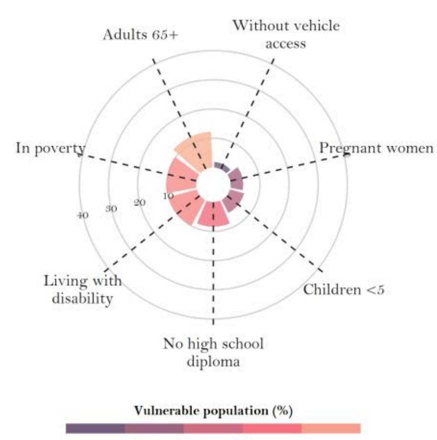
Vulnerability score: High

Carmel Mountain Ranch Library
12095 World Trade Dr
San Diego



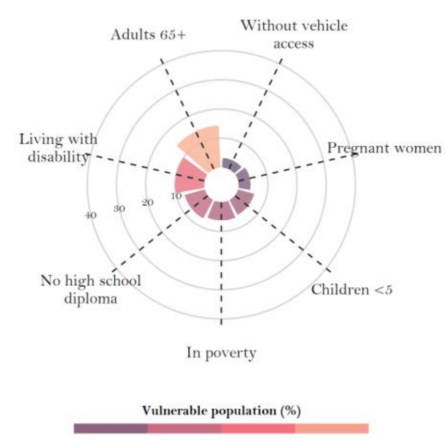
Vulnerability score: Medium

Carmel Valley Branch Library
3919 Townsgate Drive
San Diego



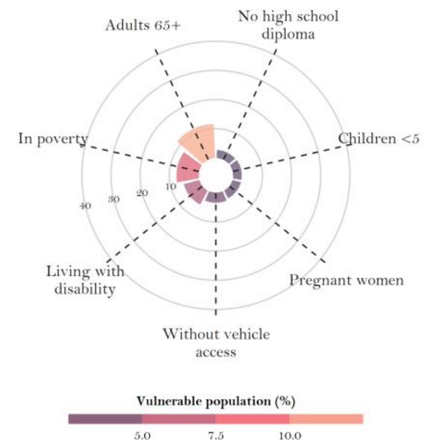
Vulnerability score: Low

Casa De Oro Branch
9805 Campo Rd. #180
Spring Valley



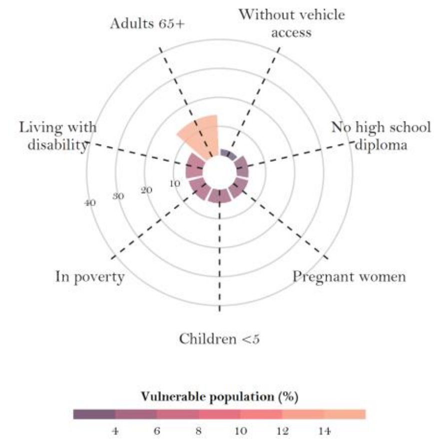
Vulnerability score: Low

Central Branch Library
330 Park Blvd.
San Diego



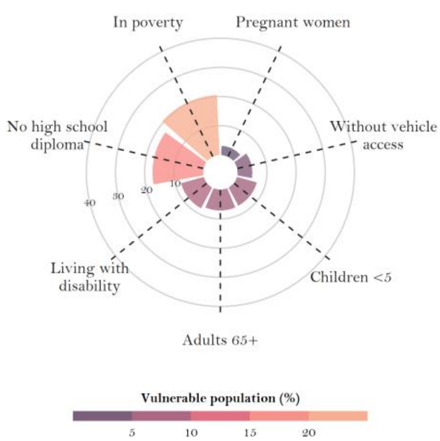
Vulnerability score: Low

Christian Science Reading Room
8370 La Mesa Blvd
La Mesa



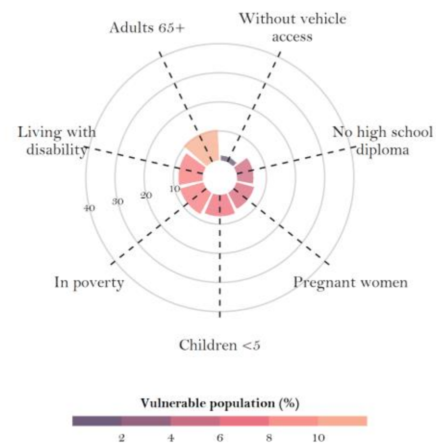
Vulnerability score: High

City Heights/Weingart Library
3795 Fairmount Ave
San Diego



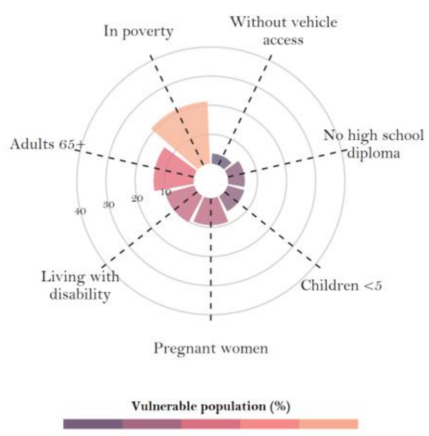
Vulnerability score: Low

City of Oceanside Country Club Senior Center
455 Country Club Ln.
Oceanside



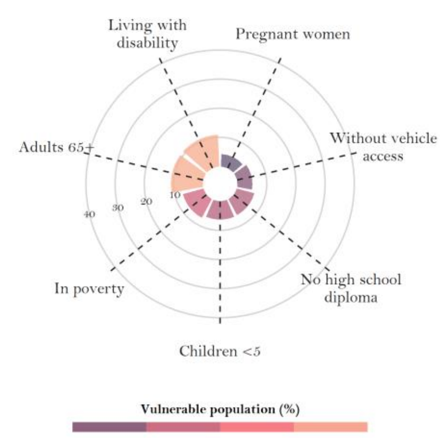
Vulnerability score: Medium

City of Oceanside El Corazon Senior Center
3302 Senior Center Dr.
Oceanside



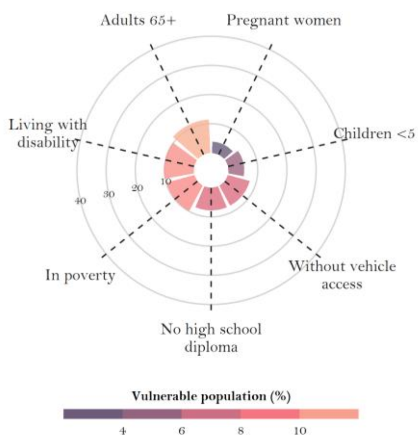
Vulnerability score: Medium

City of San Marcos Senior Activity Center
111 Richmar Ave.
San Marcos



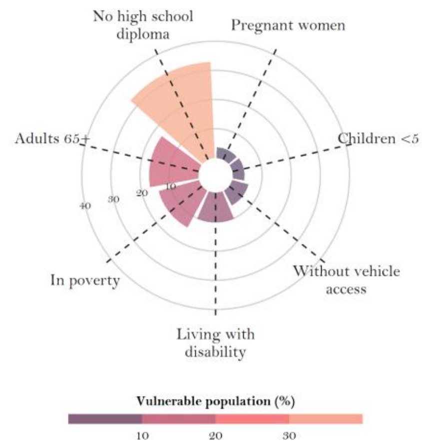
Vulnerability score: Medium

Civic Center Branch Library
365 F St.
Chula Vista



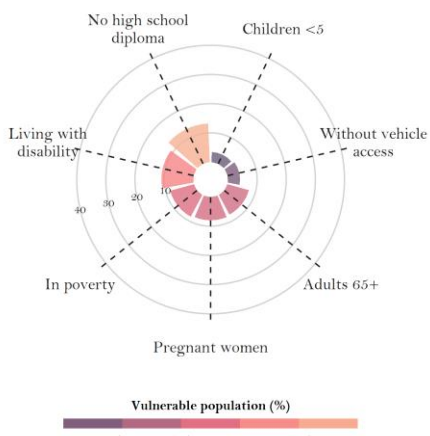
Vulnerability score: High

Clairemont Library
2920 Burgener Blvd
San Diego



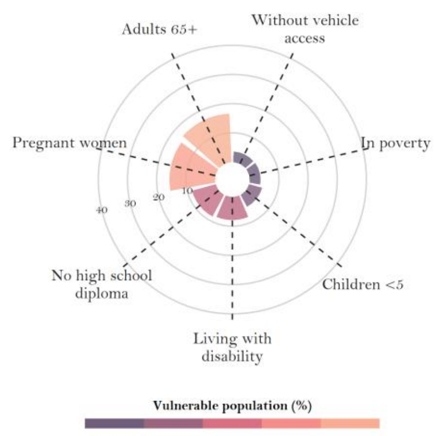
Vulnerability score: High

College-Rolando Library
6600 Montezuma Rd.
San Diego



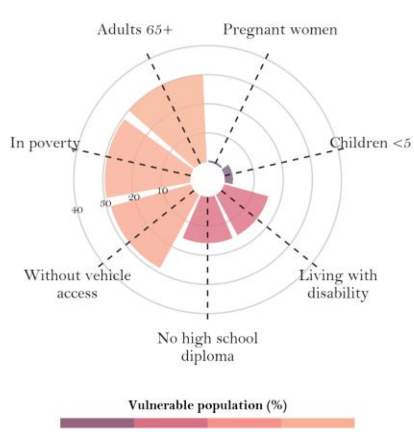
Vulnerability score: Low

Crest Branch
105 Juanita Ln.
El Cajon



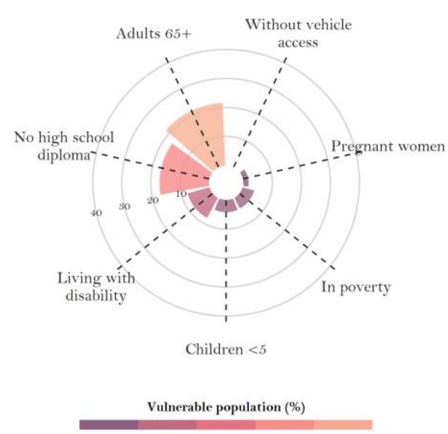
Vulnerability score: High

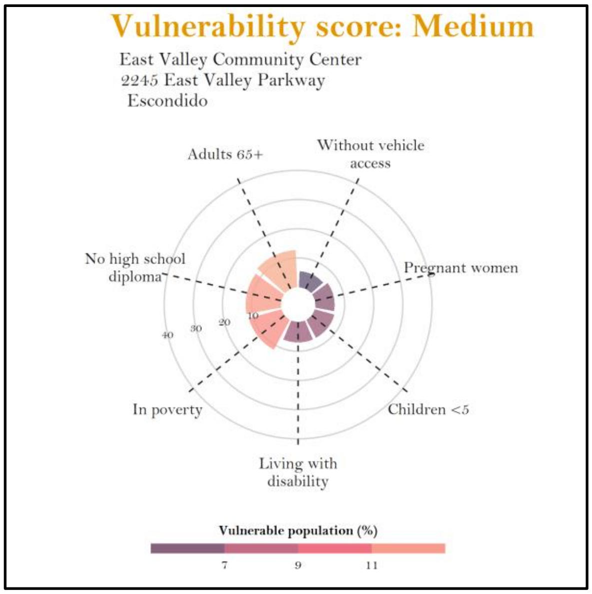
Del Mar Branch
1309 Camino Del Mar
Del Mar

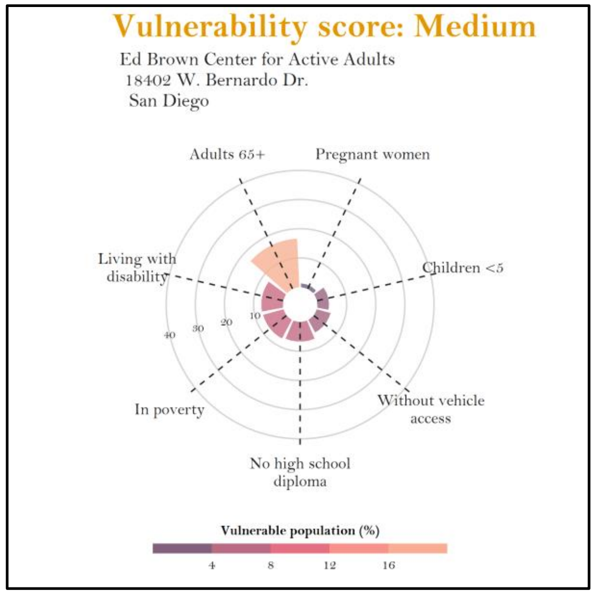


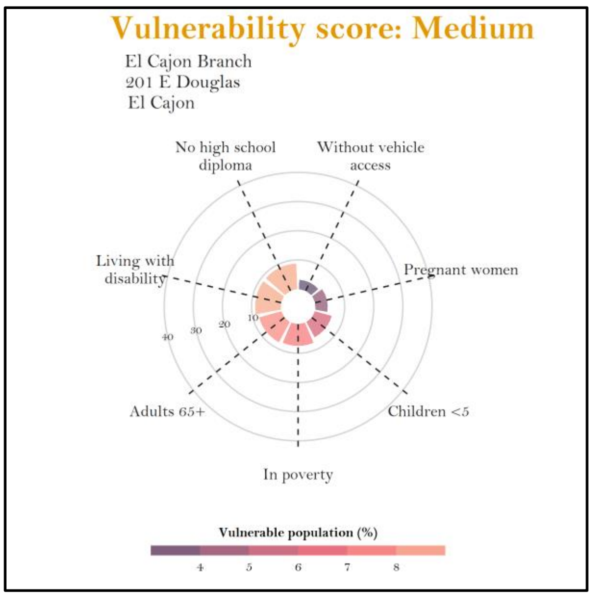
Vulnerability score: Medium

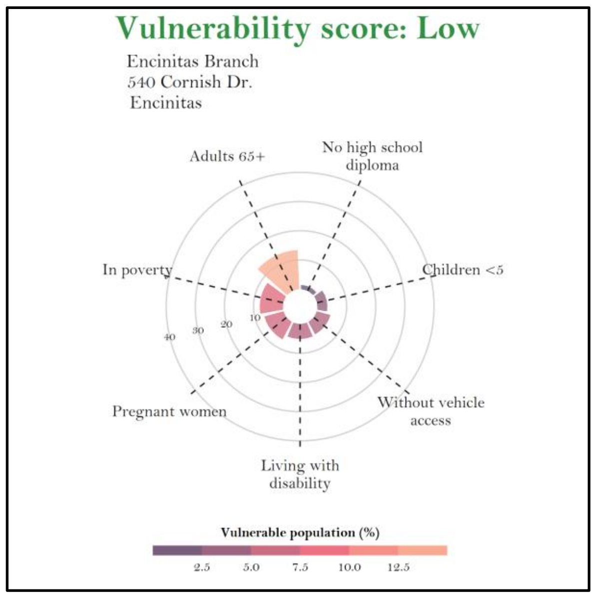
Descanso Branch
9545 River Dr.
Descanso

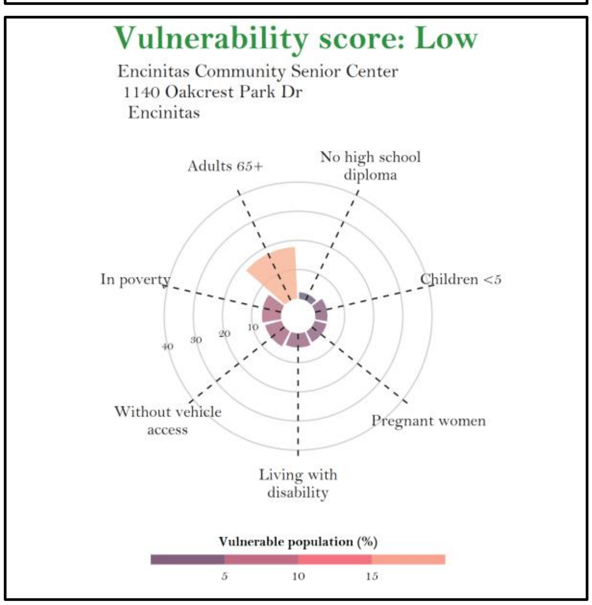


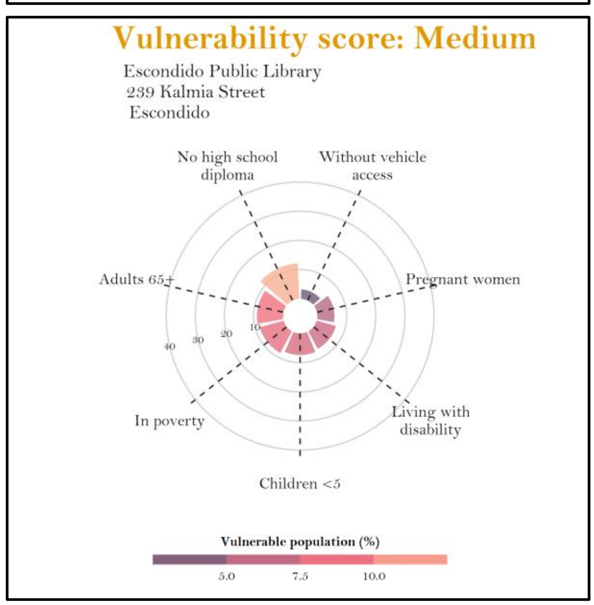

Vulnerability score: Medium
East Valley Community Center
2245 East Valley Parkway
Escondido
Adults 65+
Without vehicle access
Pregnant women
Children <5
Living with disability
In poverty
No high school diploma
40
30
20
10
Vulnerable population (%)
7
9
11


Vulnerability score: Medium
Ed Brown Center for Active Adults
18402 W. Bernardo Dr.
San Diego
Adults 65+
Pregnant women
Children <5
Without vehicle access
No high school diploma
In poverty
Living with disability
40
30
20
10
Vulnerable population (%)
4
8
12
16


Vulnerability score: Medium
El Cajon Branch
201 E Douglas
El Cajon
No high school diploma
Without vehicle access
Pregnant women
Children <5
In poverty
Adults 65+
Living with disability
40
30
20
10
Vulnerable population (%)
4
5
6
7
8

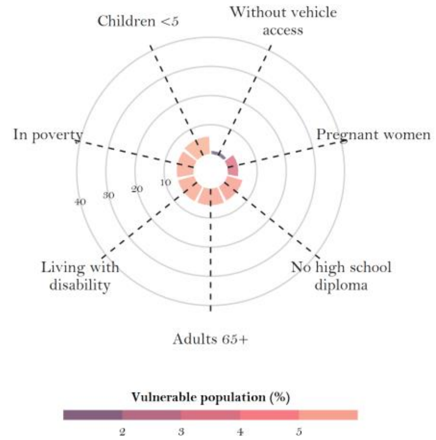

Vulnerability score: Low
Encinitas Branch
540 Cornish Dr.
Encinitas
Adults 65+
No high school diploma
Children <5
Without vehicle access
Living with disability
Pregnant women
In poverty
40
30
20
10
Vulnerable population (%)
2.5
5.0
7.5
10.0
12.5


Vulnerability score: Low
Encinitas Community Senior Center
1140 Oakcrest Park Dr
Encinitas
Adults 65+
No high school diploma
Children <5
Pregnant women
Living with disability
Without vehicle access
In poverty
40
30
20
10
Vulnerable population (%)
5
10
15


Vulnerability score: Medium
Escondido Public Library
239 Kalmia Street
Escondido
No high school diploma
Without vehicle access
Pregnant women
Living with disability
Children <5
In poverty
Adults 65+
40
30
20
10
Vulnerable population (%)
5.0
7.5
10.0

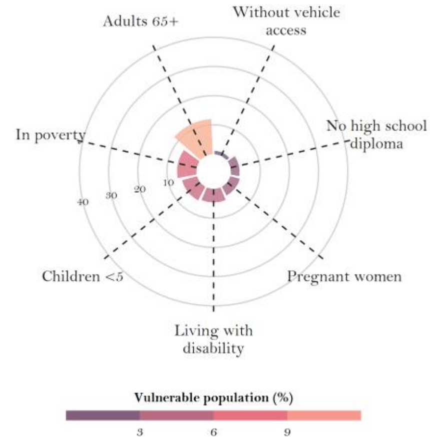
Vulnerability score: Low

Fallbrook Branch
124 S Mission Rd.
Fallbrook



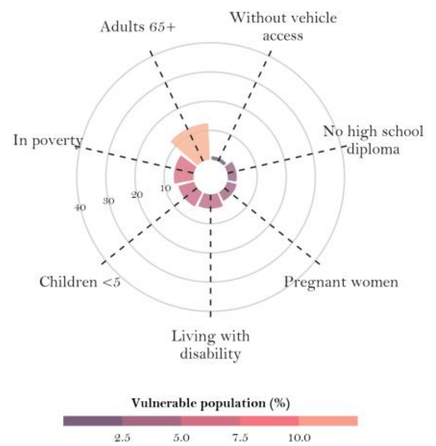
Vulnerability score: Low

Fallbrook Community Center
341 Heald Ln.
Fallbrook



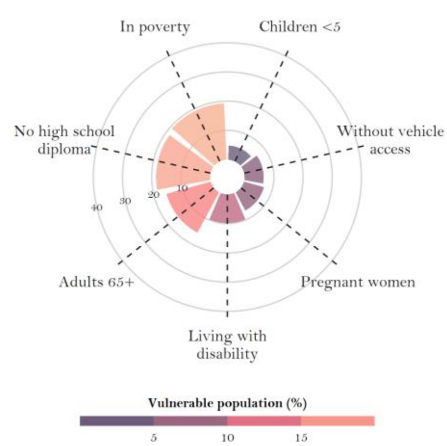
Vulnerability score: Low

Fallbrook Senior Center
399 Heald Lane
Fallbrook



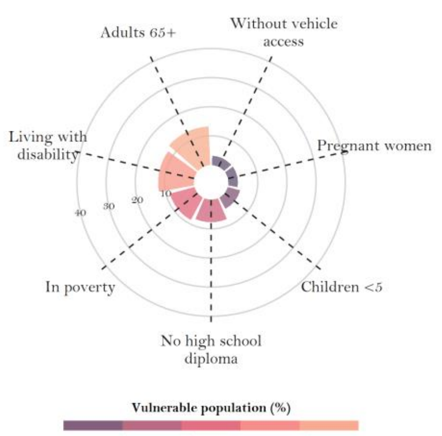
Vulnerability score: High

Fletcher Hills Branch
576 Garfield Ave.
El Cajon



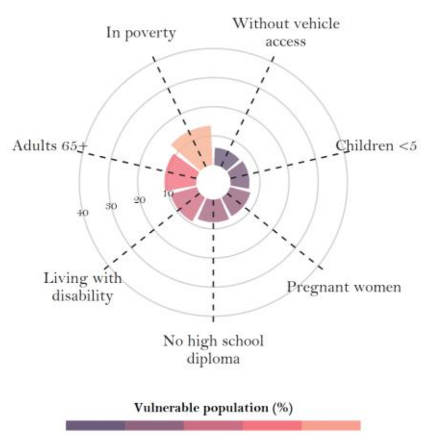
Vulnerability score: Medium

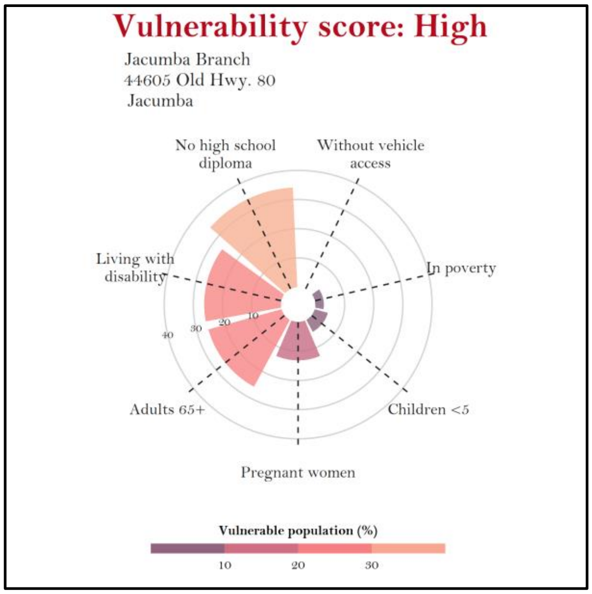
Heritage of the Americas Museum
12110 Cuyamaca College Dr W
El Cajon

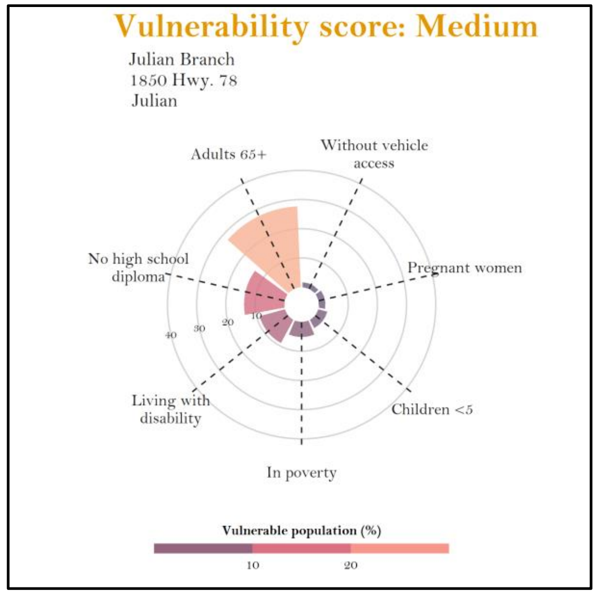


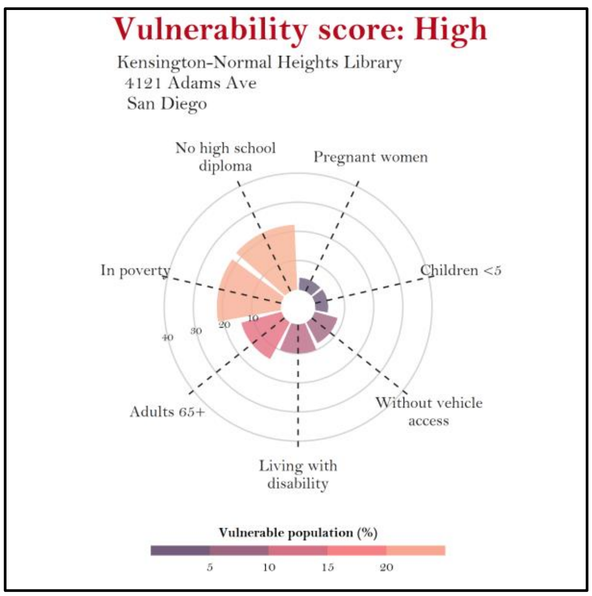
Vulnerability score: Medium

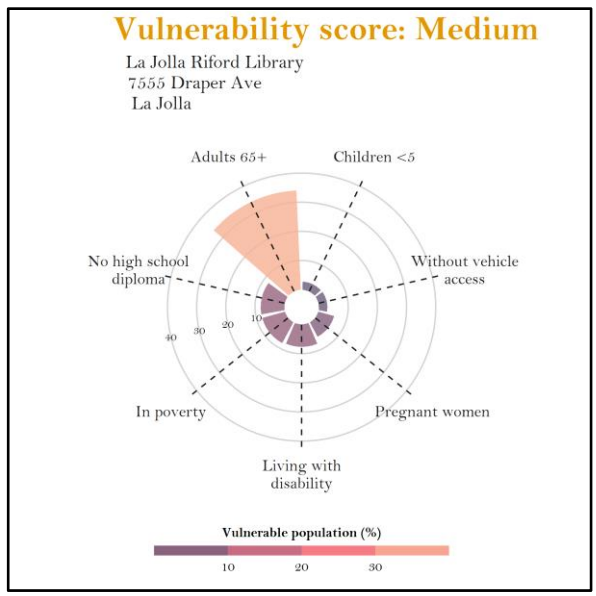
Imperial Beach Branch
810 Imperial Beach Blvd.
Imperial Beach

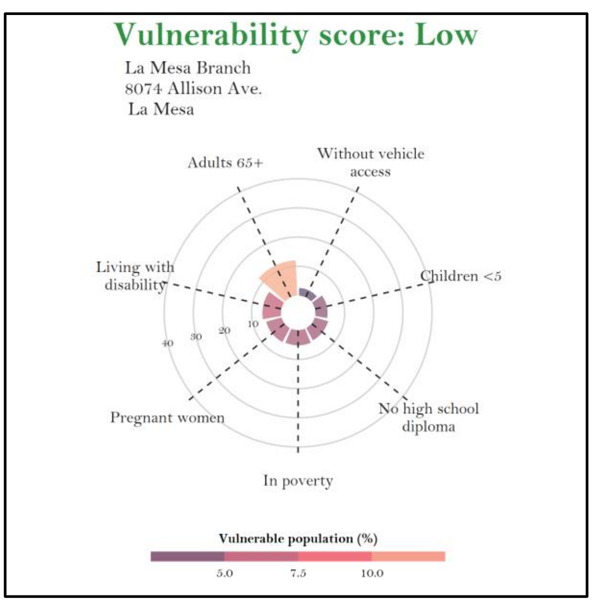


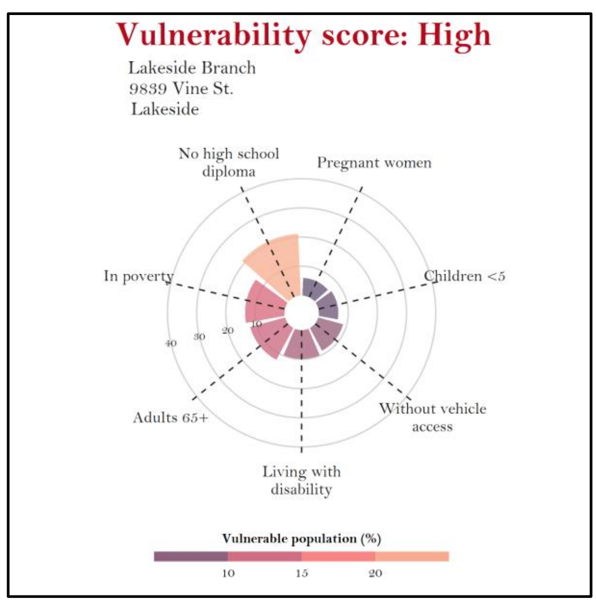

Vulnerability score: High
Jacumba Branch
44605 Old Hwy. 80
Jacumba
No high school diploma
Without vehicle access
Living with disability
In poverty
Adults 65+
Children <5
Pregnant women
10
20
30
40
Vulnerable population (%)
10 20 30


Vulnerability score: Medium
Julian Branch
1850 Hwy. 78
Julian
Adults 65+
Without vehicle access
No high school diploma
Pregnant women
Living with disability
Children <5
In poverty
10
20
30
40
Vulnerable population (%)
10 20


Vulnerability score: High
Kensington-Normal Heights Library
4121 Adams Ave
San Diego
No high school diploma
Pregnant women
In poverty
Children <5
Adults 65+
Without vehicle access
Living with disability
10
20
30
40
Vulnerable population (%)
5 10 15 20

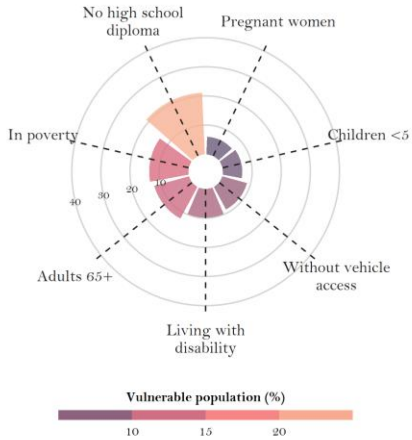

Vulnerability score: Medium
La Jolla Riford Library
7555 Draper Ave
La Jolla
Adults 65+
Children <5
No high school diploma
Without vehicle access
In poverty
Pregnant women
Living with disability
10
20
30
40
Vulnerable population (%)
10 20 30


Vulnerability score: Low
La Mesa Branch
8074 Allison Ave.
La Mesa
Adults 65+
Without vehicle access
Living with disability
Children <5
Pregnant women
No high school diploma
In poverty
10
20
30
40
Vulnerable population (%)
5.0 7.5 10.0


Vulnerability score: High
Lakeside Branch
9839 Vine St.
Lakeside
No high school diploma
Pregnant women
In poverty
Children <5
Adults 65+
Without vehicle access
Living with disability
10
20
30
40
Vulnerable population (%)
10 15 20

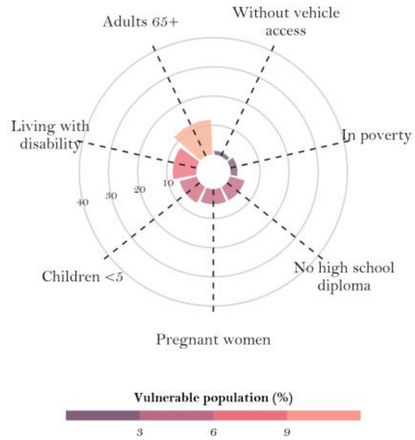
Vulnerability score: High

Lakeside Community Center and Teen Center
9841 Vine Street
Lakeside



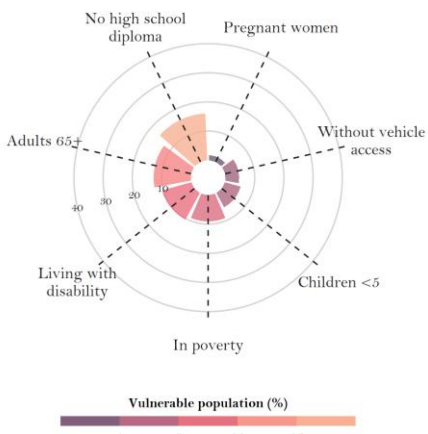
Vulnerability score: Low

Lemon Grove Branch
3001 School Ln.
Lemon Grove



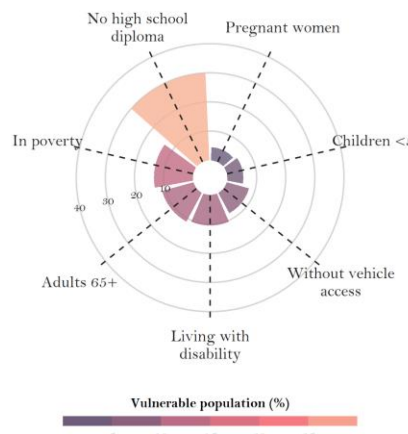
Vulnerability score: High

Lincoln Acres Branch
2725 Granger Ave.
National City



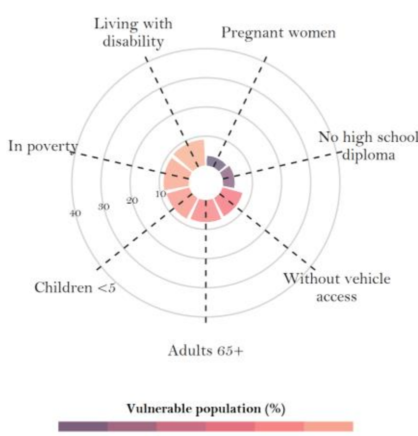
Vulnerability score: High

Linda Vista Branch Library
2160 Ulric St.
San Diego



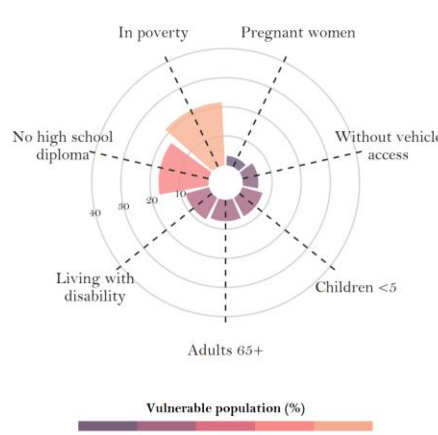
Vulnerability score: Low

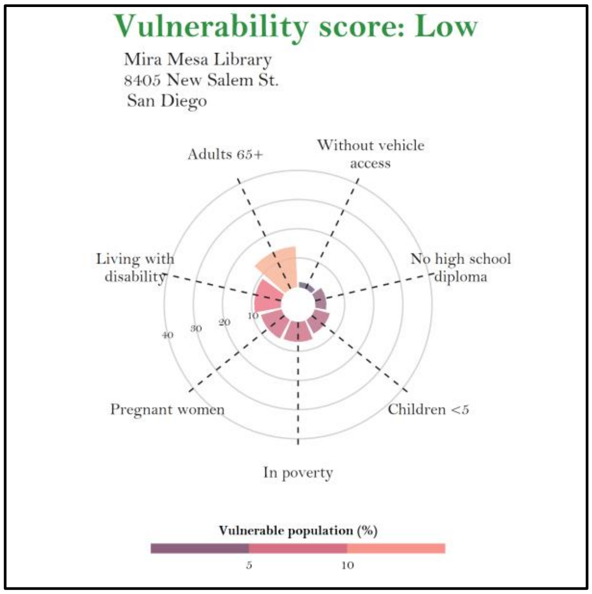
Logan Heights Branch Library
567 S 28th St
San Diego

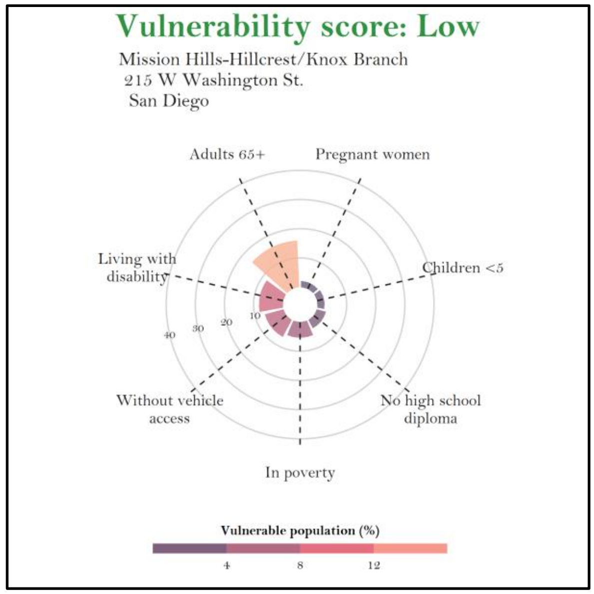


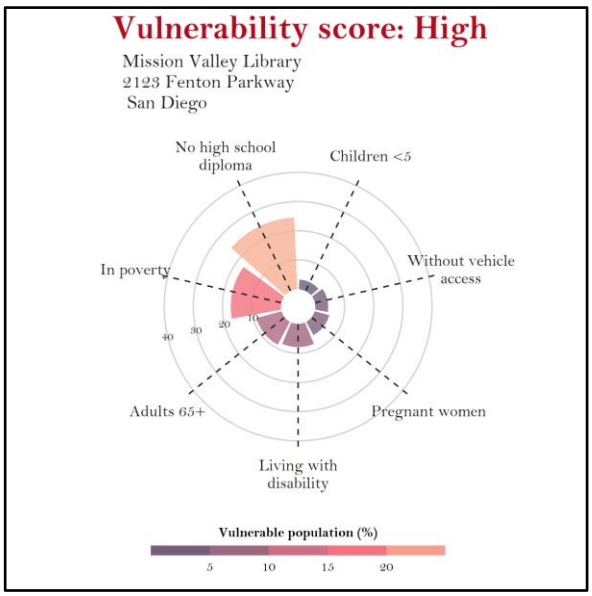
Vulnerability score: High

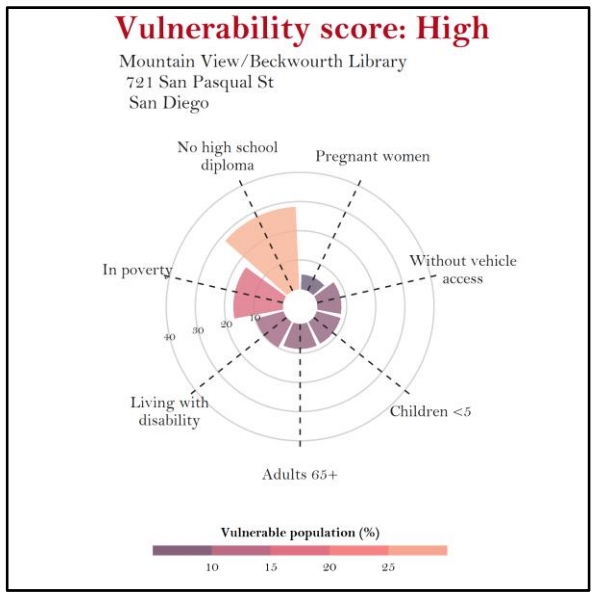
Mid-City Gymnasium
4302 Landis Street
San Diego

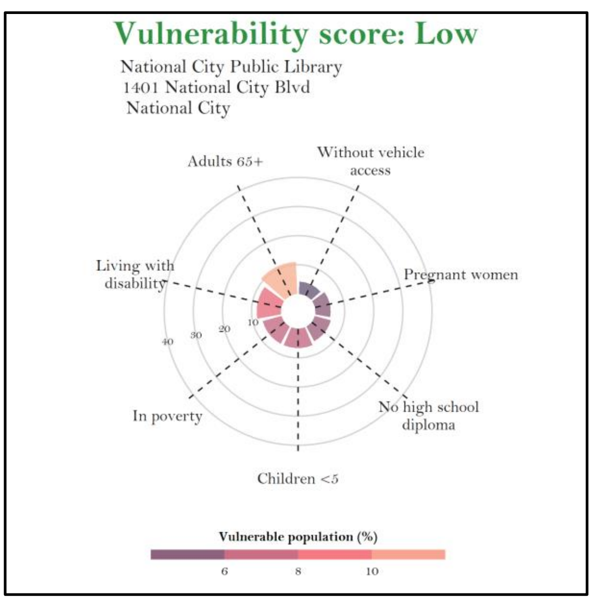


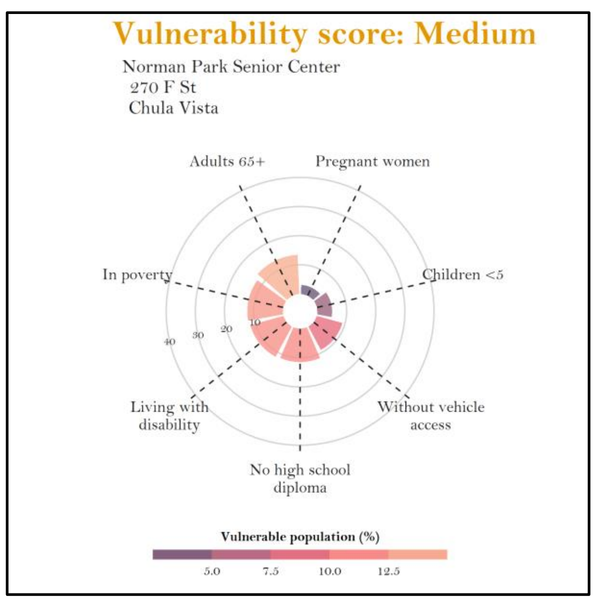

Vulnerability score: Low
Mira Mesa Library
8405 New Salem St.
San Diego
Adults 65+
Without vehicle access
No high school diploma
Children <5
In poverty
Pregnant women
Living with disability
Vulnerable population (%)
5
10

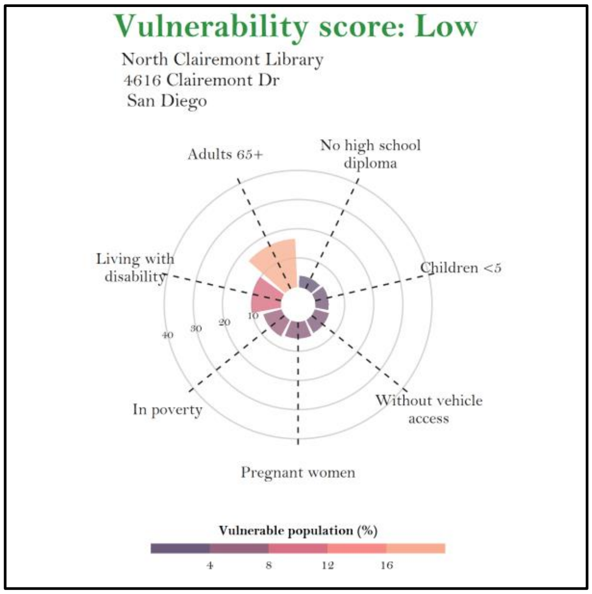

Vulnerability score: Low
Mission Hills-Hillcrest/Knox Branch
215 W Washington St.
San Diego
Adults 65+
Pregnant women
Children <5
No high school diploma
In poverty
Without vehicle access
Living with disability
Vulnerable population (%)
4
8
12

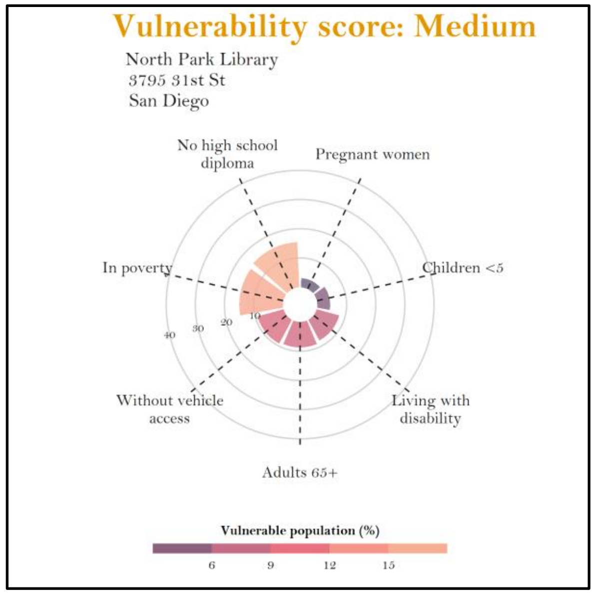

Vulnerability score: High
Mission Valley Library
2123 Fenton Parkway
San Diego
No high school diploma
Children <5
Without vehicle access
Pregnant women
Living with disability
Adults 65+
In poverty
Vulnerable population (%)
5
10
15
20

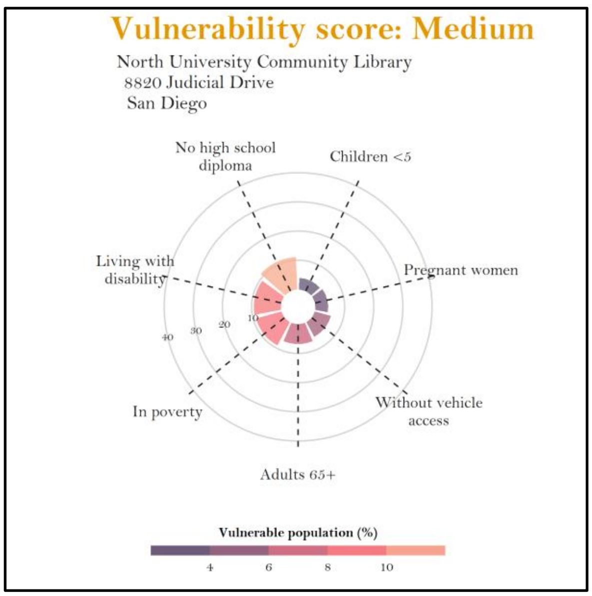

Vulnerability score: High
Mountain View/Beckwourth Library
721 San Pasqual St
San Diego
No high school diploma
Pregnant women
Without vehicle access
Children <5
Adults 65+
Living with disability
In poverty
Vulnerable population (%)
10
15
20
25

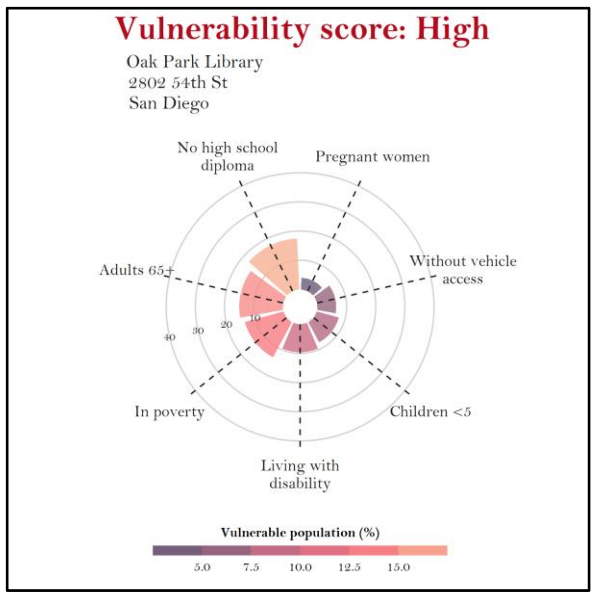

Vulnerability score: Low
National City Public Library
1401 National City Blvd
National City
Adults 65+
Without vehicle access
Pregnant women
No high school diploma
Children <5
In poverty
Living with disability
Vulnerable population (%)
6
8
10

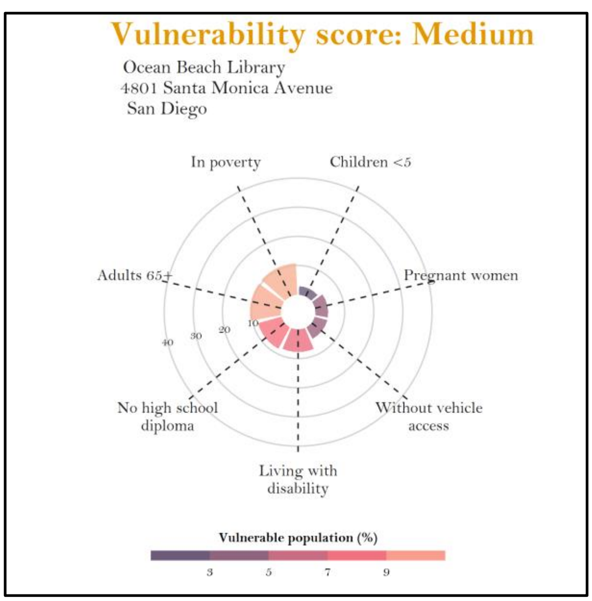

Vulnerability score: Medium
Norman Park Senior Center
270 F St
Chula Vista
Adults 65+
Pregnant women
Children <5
Without vehicle access
No high school diploma
Living with disability
In poverty
Vulnerable population (%)
5.0
7.5
10.0
12.5

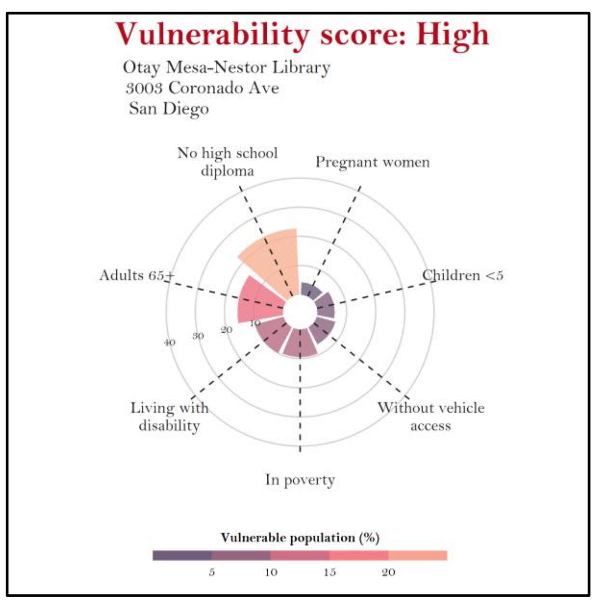

Vulnerability score: Low
North Clairemont Library
4616 Clairemont Dr
San Diego
Adults 65+
No high school diploma
Children <5
Without vehicle access
Pregnant women
In poverty
Living with disability
10
20
30
40
Vulnerable population (%)
4
8
12
16


Vulnerability score: Medium
North Park Library
3795 31st St
San Diego
No high school diploma
Pregnant women
Children <5
Living with disability
Adults 65+
Without vehicle access
In poverty
10
20
30
40
Vulnerable population (%)
6
9
12
15


Vulnerability score: Medium
North University Community Library
8820 Judicial Drive
San Diego
No high school diploma
Children <5
Pregnant women
Without vehicle access
Adults 65+
In poverty
Living with disability
10
20
30
40
Vulnerable population (%)
4
6
8
10

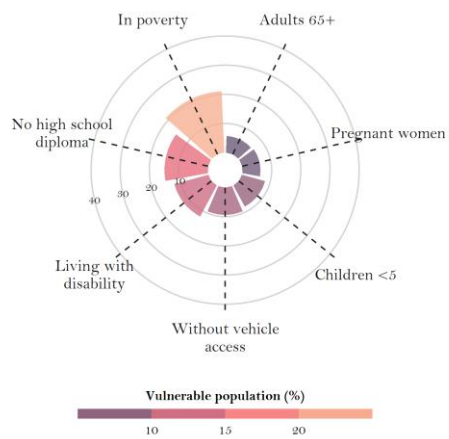

Vulnerability score: High
Oak Park Library
2802 54th St
San Diego
No high school diploma
Pregnant women
Without vehicle access
Children <5
Living with disability
In poverty
Adults 65+
10
20
30
40
Vulnerable population (%)
5.0
7.5
10.0
12.5
15.0


Vulnerability score: Medium
Ocean Beach Library
4801 Santa Monica Avenue
San Diego
In poverty
Children <5
Pregnant women
Without vehicle access
Living with disability
No high school diploma
Adults 65+
10
20
30
40
Vulnerable population (%)
3
5
7
9


Vulnerability score: High
Otay Mesa-Nestor Library
3003 Coronado Ave
San Diego
No high school diploma
Pregnant women
Children <5
Without vehicle access
In poverty
Living with disability
Adults 65+
10
20
30
40
Vulnerable population (%)
5
10
15
20

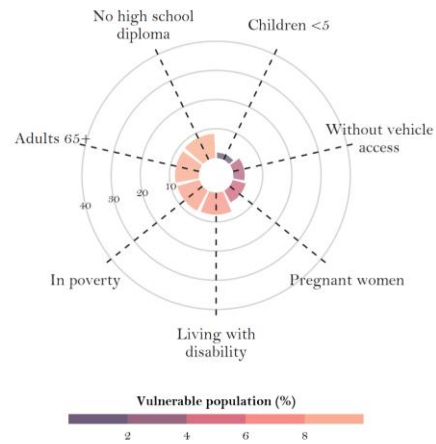
Vulnerability score: High

Otay Ranch Town Center Library
2015 Birch Rd, Suite 409
Chula Vista



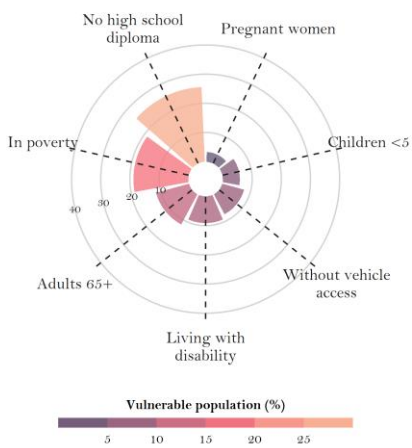
Vulnerability score: Medium

Pacific Beach/Taylor Library
4275 Cass St.
San Diego



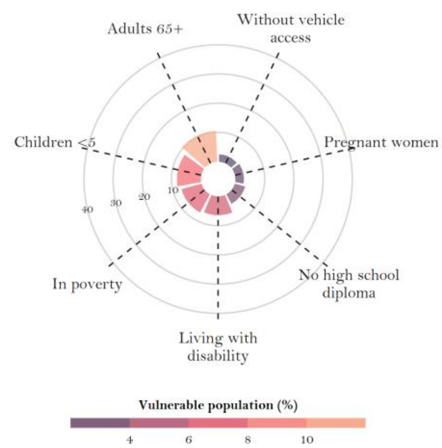
Vulnerability score: High

Paradise Hills Library
5922 Rancho Hills Dr.
San Diego



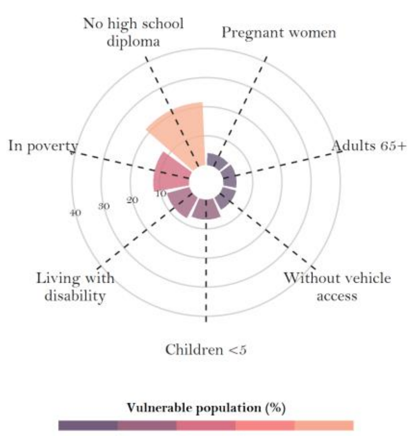
Vulnerability score: Low

Park Avenue Community Center
210 E. Park Avenue
Escondido



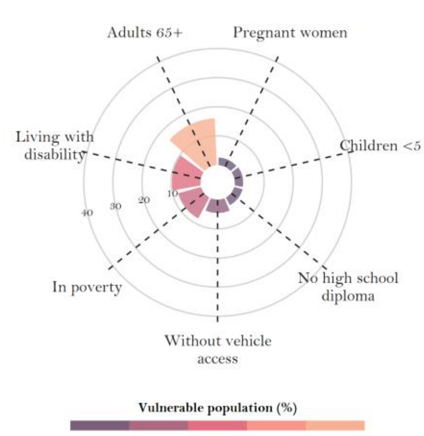
Vulnerability score: High

Parkway Plaza
415 Fletcher Parkway
El Cajon



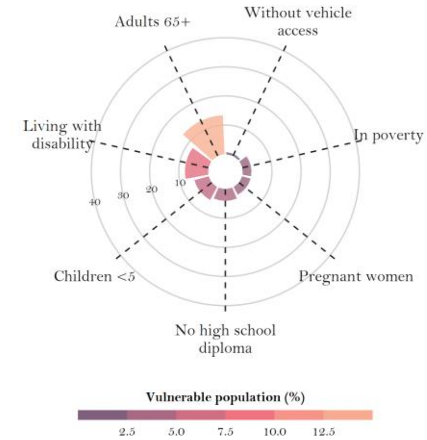
Vulnerability score: Low

Pine Valley Branch
28804 Old Hwy. 80
Pine Valley



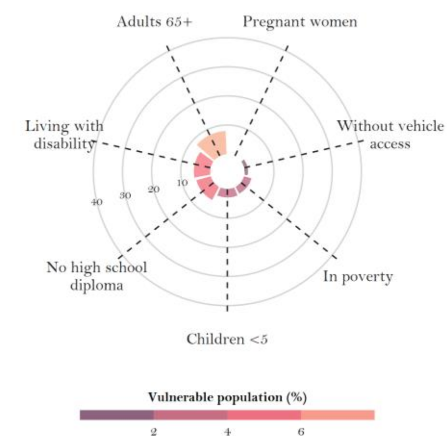
Vulnerability score: Low

Point Loma/Hervey Library
3701 Voltaire St
San Diego



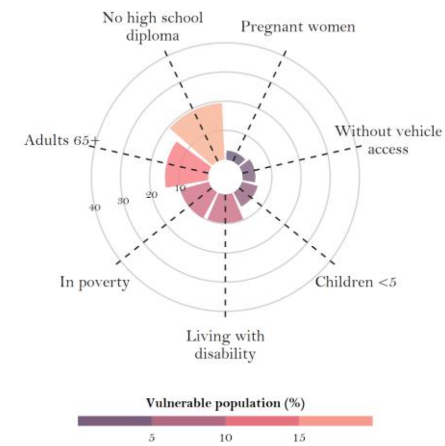
Vulnerability score: Medium

Potrero Branch
24883 Potrero Valley Rd.
Potrero



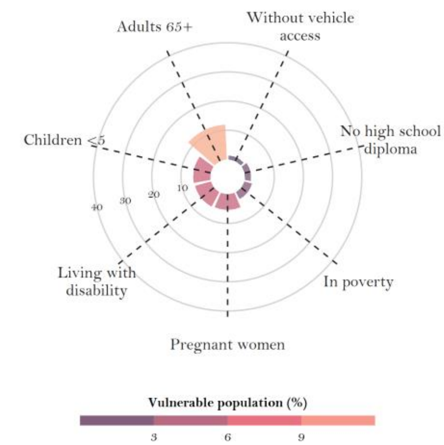
Vulnerability score: High

Poway Branch
13137 Poway Rd.
Poway



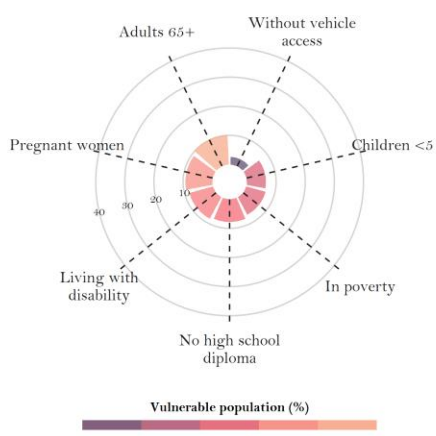
Vulnerability score: Low

Ramona Branch
1275 Main St.
Ramona



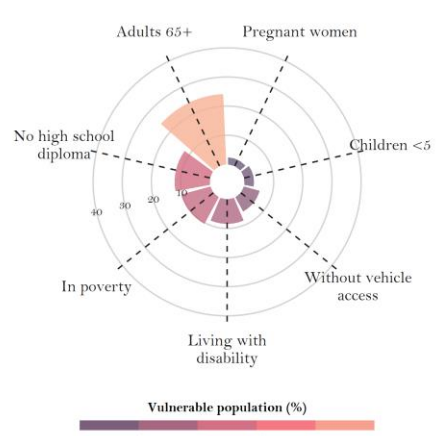
Vulnerability score: Low

Ramona Senior Center
434 Aqua Lane
Ramona



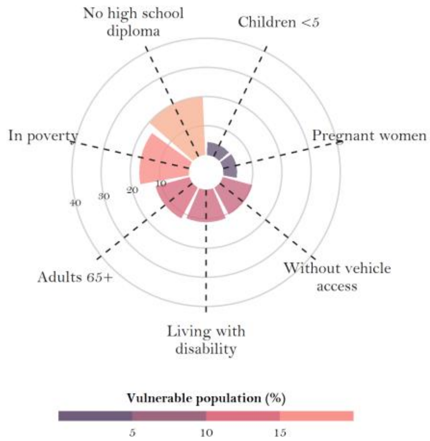
Vulnerability score: Medium

Rancho Bernardo Library
17110 Bernardo Center Dr
San Diego



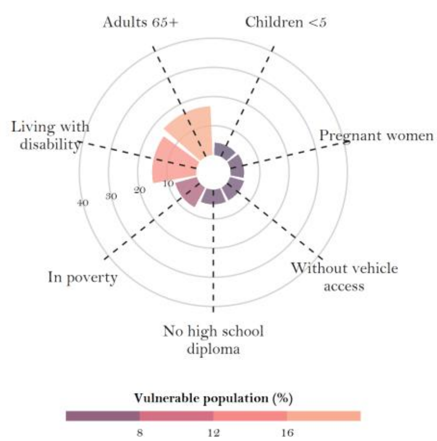
Vulnerability score: High

Rancho Penasquitos Library
13330 Salmon River Rd.
San Diego



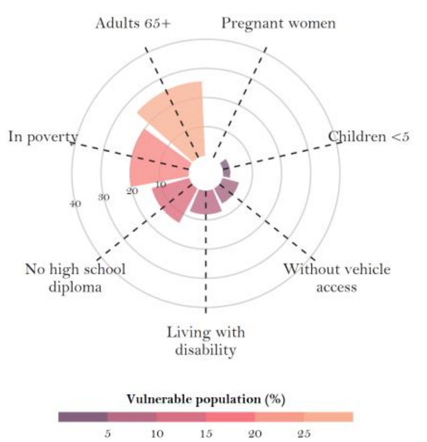
Vulnerability score: Low

Rancho San Diego Branch
11555 Via Rancho San Diego
El Cajon



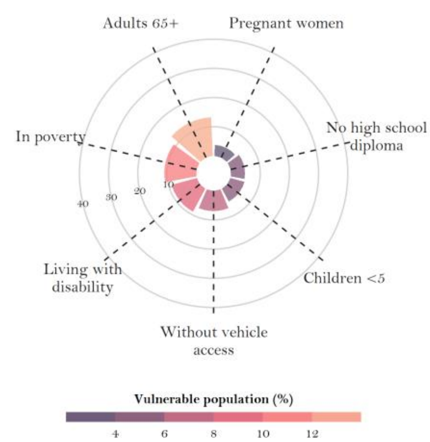
Vulnerability score: High

Rancho Santa Fe Branch
17040 Avenida de Acacias
Rancho Santa Fe



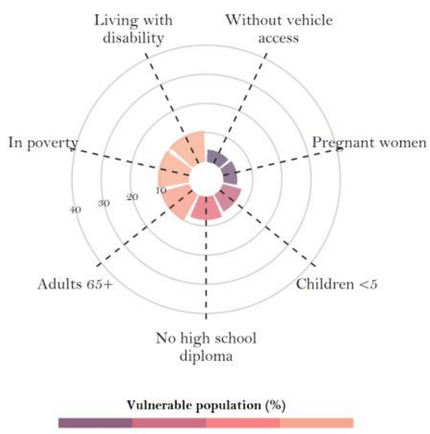
Vulnerability score: Low

Salvation Army Senior Dining & Social Center - Chula Vista
648 Third Ave
Chula Vista



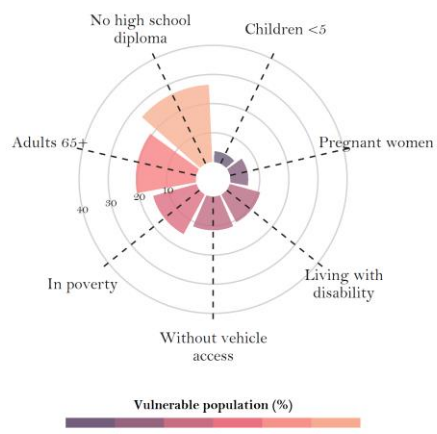
Vulnerability score: Medium

Salvation Army Senior Dining & Social Center - El Cajon
1011 E. Main St
El Cajon



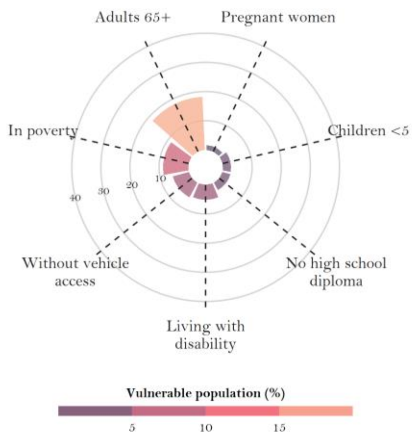
Vulnerability score: High

San Carlos Library
7265 Jackson Dr
San Diego



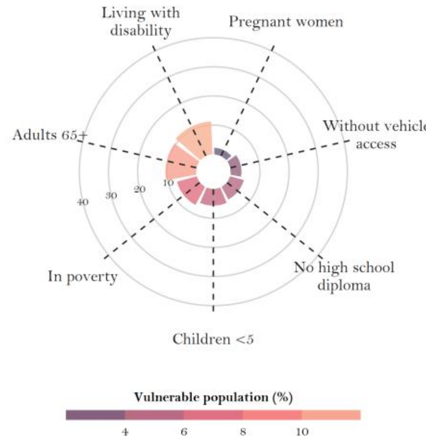
Vulnerability score: Low

San Elijo Lagoon
2710 Manchester Ave.
Cardiff By The Sea



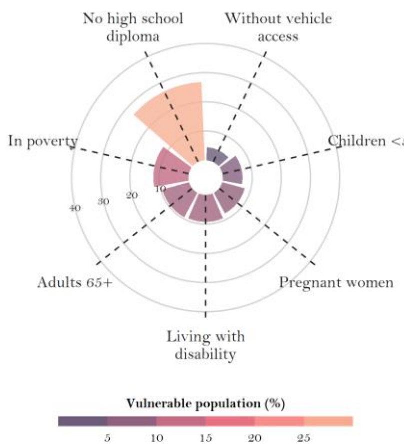
Vulnerability score: Low

San Marcos Branch
2 Civic Center Dr.
San Marcos



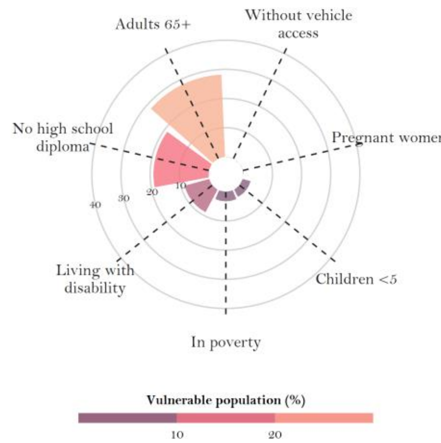
Vulnerability score: High

San Ysidro Library
4235 Beyer Blvd
San Diego



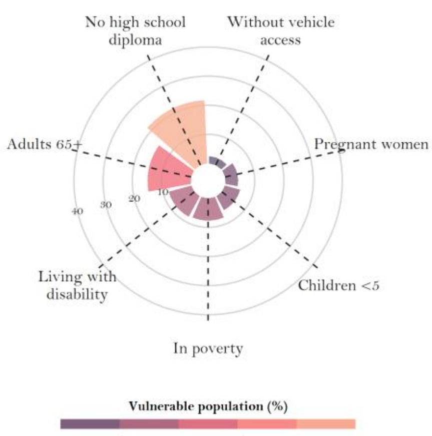
Vulnerability score: Medium

Santa Ysabel Nature Center
22135 Hwy. 79
Santa Ysabel



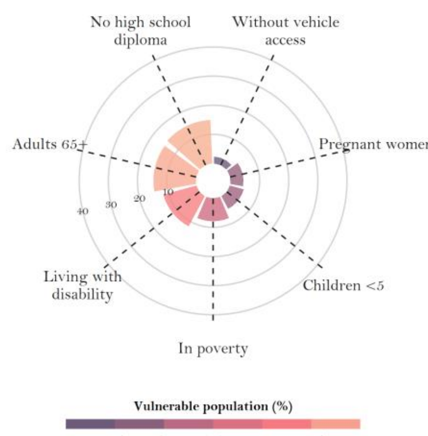
Vulnerability score: High

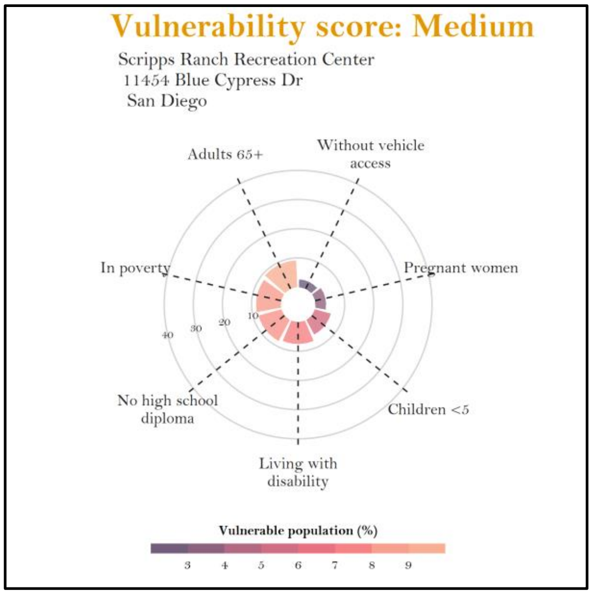
Santee Branch
9225 Carlton Hills Blvd. #17
Santee

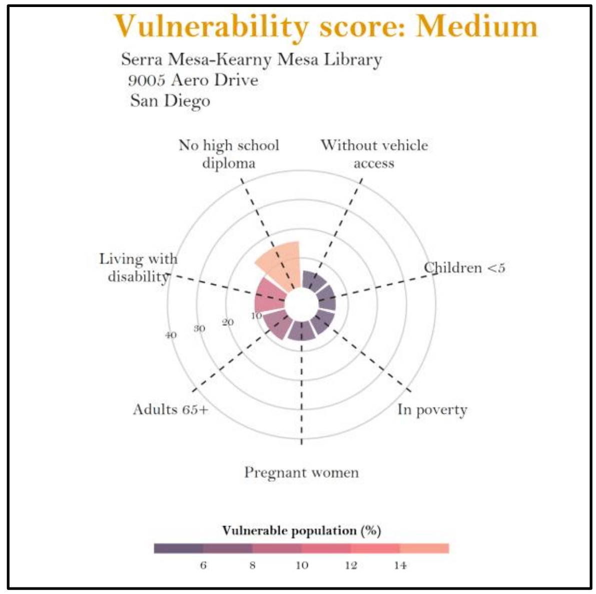


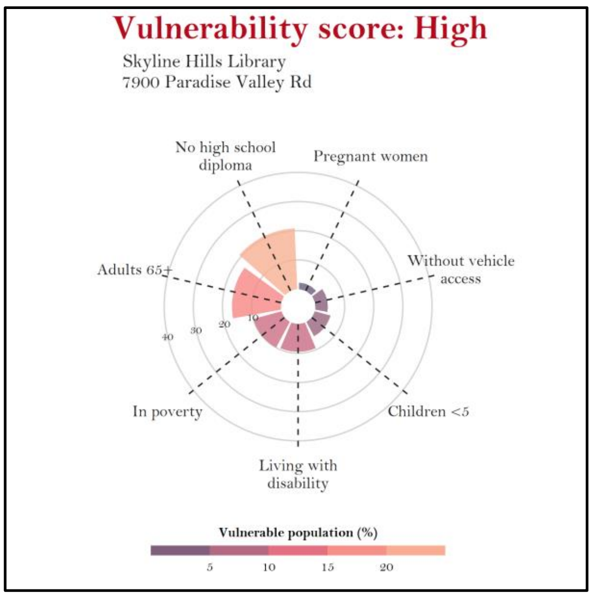
Vulnerability score: Medium

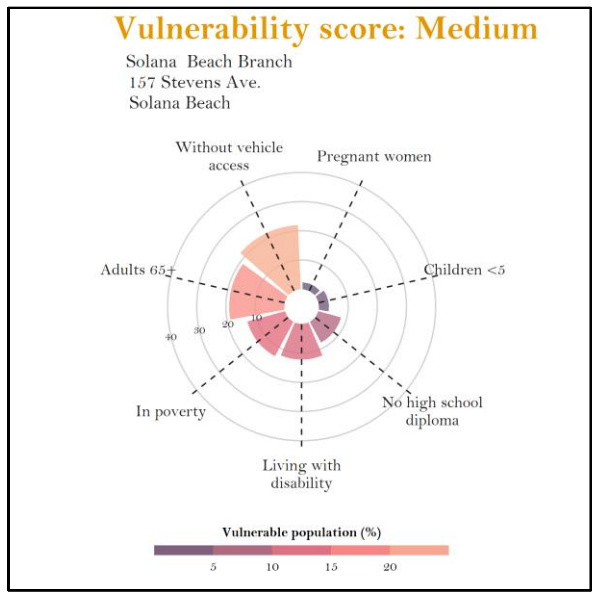
Scripps Miramar Ranch Library
10301 Scripps Lake Dr
San Diego

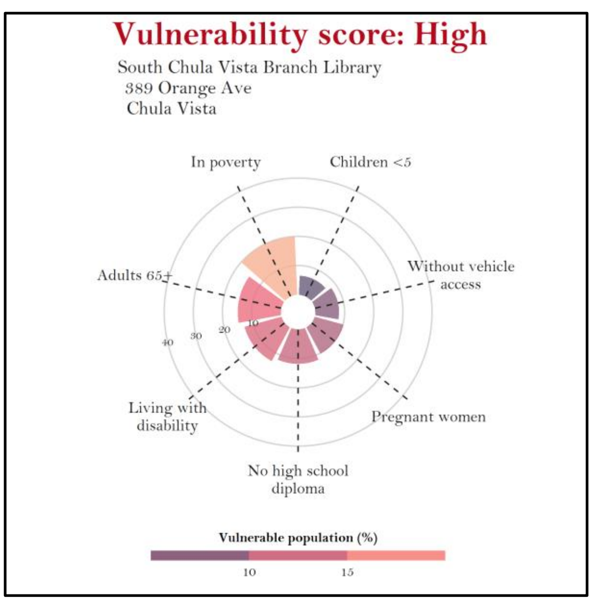


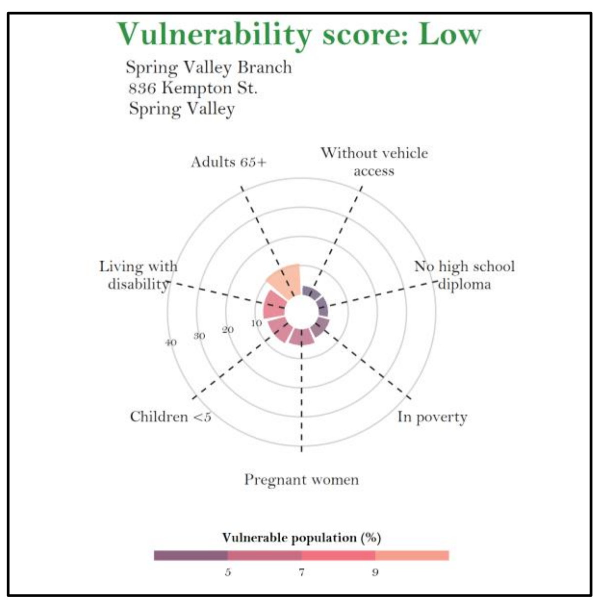

Vulnerability score: Medium
Scripps Ranch Recreation Center
11454 Blue Cypress Dr
San Diego
Adults 65+
Without vehicle access
Pregnant women
Children <5
Living with disability
No high school diploma
In poverty
10
20
30
40
Vulnerable population (%)
3 4 5 6 7 8 9


Vulnerability score: Medium
Serra Mesa-Kearny Mesa Library
9005 Aero Drive
San Diego
No high school diploma
Without vehicle access
Children <5
In poverty
Pregnant women
Adults 65+
Living with disability
10
20
30
40
Vulnerable population (%)
6 8 10 12 14


Vulnerability score: High
Skyline Hills Library
7900 Paradise Valley Rd
No high school diploma
Pregnant women
Without vehicle access
Children <5
Living with disability
In poverty
Adults 65+
10
20
30
40
Vulnerable population (%)
5 10 15 20

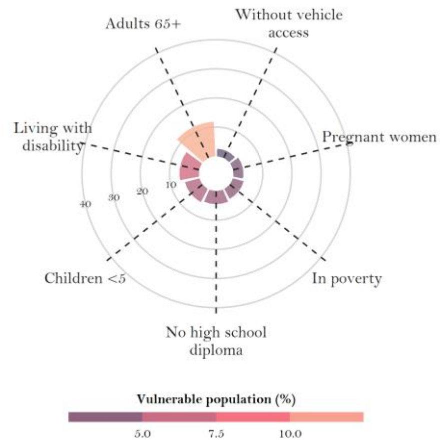

Vulnerability score: Medium
Solana Beach Branch
157 Stevens Ave.
Solana Beach
Without vehicle access
Pregnant women
Children <5
No high school diploma
Living with disability
In poverty
Adults 65+
10
20
30
40
Vulnerable population (%)
5 10 15 20


Vulnerability score: High
South Chula Vista Branch Library
389 Orange Ave
Chula Vista
In poverty
Children <5
Without vehicle access
Pregnant women
No high school diploma
Living with disability
Adults 65+
10
20
30
40
Vulnerable population (%)
10 15


Vulnerability score: Low
Spring Valley Branch
836 Kempton St.
Spring Valley
Adults 65+
Without vehicle access
No high school diploma
In poverty
Pregnant women
Children <5
Living with disability
10
20
30
40
Vulnerable population (%)
5 7 9

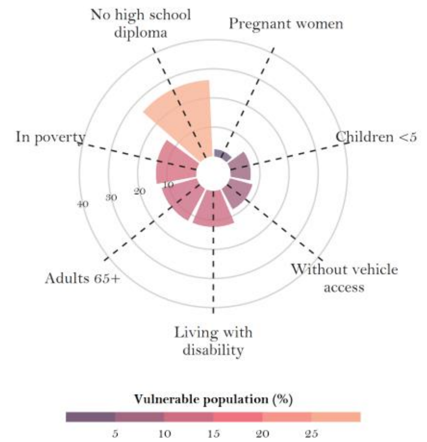
Vulnerability score: Low

Spring Valley Community Center
8735 Jamacha Blvd.
Spring Valley



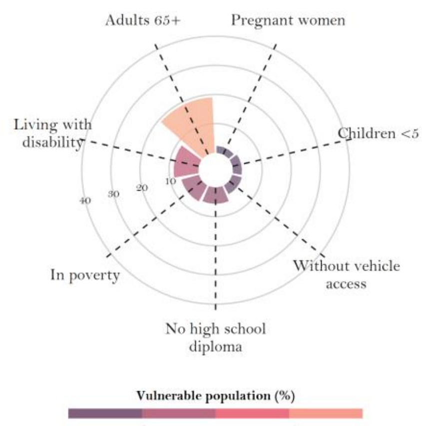
Vulnerability score: High

Tierrasanta Branch Library
4985 La Cuenta Dr.
San Diego



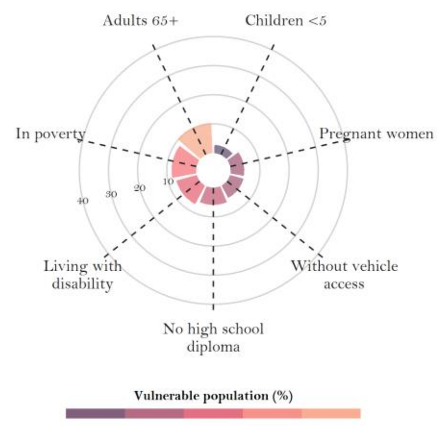
Vulnerability score: Low

University Community Branch Library
4155 Governor Dr
San Diego



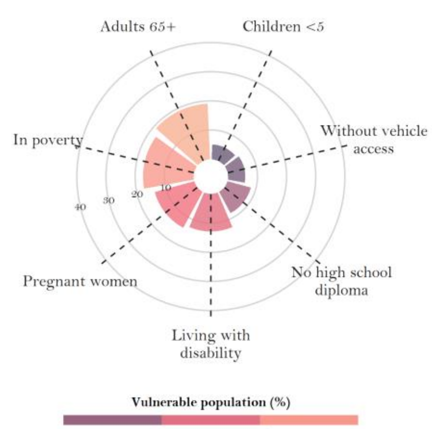
Vulnerability score: Low

University Heights Library
4193 Park Blvd
San Diego



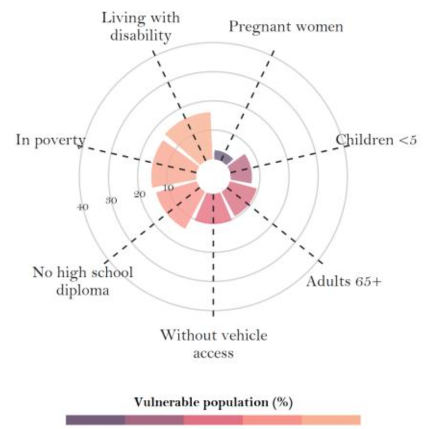
Vulnerability score: Medium

Valley Center Branch
29200 Cole Grade Rd.
Valley Center



Vulnerability score: High

Vista Branch
700 Eucalyptus Ave.
Vista



Literature Cited

Alves, Fernando & Santos Cruz, Sara & Ribeiro, Anabela & Silva, Ana & Martins, João & Cunha, Inês. (2020). Walkability Index for Elderly Health: A Proposal. Sustainability. 12. 7360. 10.3390/su12187360.

Atlantic Council's Adrienne Arsht Rockefeller Foundation Resilience Center. (2021). *Extreme Heat: The Economic and Social Consequences for the United States*. The Atlantic Council. Retrieved December 4, 2022, from https://www.atlanticcouncil.org/wp-content/uploads/2021/08/Extreme-Heat-Report-2021.pdf

Arsht-Rock. (2023, May 15). *Chief Heat Officers - Arsht-Rock*. https://onebillionresilient.org/project/chief-heat-officers/

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century. *Journal of Political Economy*, *124*(1), 105–159. https://doi.org/10.1086/684582

Bradford, K. L., Abrahams, L., Hegglin, M., & Klima, K. (2015). A Heat Vulnerability Index and Adaptation Solutions for Pittsburgh, Pennsylvania. *Environmental Science & Technology*, *49*(19), 11303–11311. https://doi.org/10.1021/acs.est.5b03127

Chamberlain, M. H. (2022). Heat Resilience Planning in San Diego: Local Plans, Barriers, and Tools to Facilitate Strategy Implementation. *UC San Diego: Climate Science and Policy*. Retrieved from https://escholarship.org/uc/item/0058k6q7

Community Resilience Centers - Strategic Growth Council. (n.d.). Retrieved December 6, 2022, from https://sgc.ca.gov/programs/community-resilience-centers

Conlon KC, Mallen E, Gronlund CJ, Berrocal VJ, Larsen L, O'Neill MS. Mapping Human Vulnerability to Extreme Heat: A Critical Assessment of Heat Vulnerability Indices Created Using Principal Components Analysis. *Environ Health Perspect.* 2020 Sep;128(9):97001. doi: 10.1289/EHP4030. Epub 2020 Sep 2. PMID: 32875815; PMCID: PMC7466325.

County of San Diego, Health and Human Services Agency, Public Health Services. 2021 Annual Excessive Heat Report. October 7, 2022.

County of San Diego. Climate Action Plan. February 2018.

DNV GL Energy Insights USA, Inc. 2020. 2019 California Residential Appliance Saturation Study. California Energy Commission. Publication Number: CEC-200-2020-XXX.

Foster, J. (2023). Invited Perspective: Cooling Centers and Heat Waves—Can Current Data Inform Guidance? *Environmental Health Perspectives*, *131*(6). https://doi.org/10.1289/ehp12830

Guirguis, K., Basu, R., Al-Delaimy, W. K., Benmarhnia, T., Clemesha, R. E. S., Corcos, I., Guzman-Morales, J., Hailey, B., Small, I., Tardy, A., Vashishtha, D., Zivin, J. G., & Gershunov, A. (2018). Heat, Disparities, and Health Outcomes in San Diego County's Diverse Climate Zones. *GeoHealth*, *2*(7), 212–223. https://doi.org/10.1029/2017gh000127

Kalansky, Julie, Dan Cayan, Kate Barba, Laura Walsh, Kimberly Brouwer, Dani Boudreau. (University of California, San Diego). 2018. San Diego Summary Report. *California's Fourth Climate Change Assessment.* Publication number: SUM-CCCA4-2018-009.

Kim, K., Jung, J., Schollaert, C., & Spector, J. T. (2021). A Comparative Assessment of Cooling Center Preparedness across Twenty-Five U.S. Cities. *International Journal of Environmental Research and Public Health*, *18*(9), 4801. https://doi.org/10.3390/ijerph18094801

Kisner, C., Mulder, K., & VanGessel, B. (2012). Assessing Heat Vulnerability and Access to Cooling Centers in Detroit, Michigan. *IMAGIN 2013 Student Geospatial Poster & Paper Competition*.

Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W., & Solomon, G. M. (2011). Six Climate Change–Related Events In The United States Accounted For About $14 Billion In Lost Lives And Health Costs. *Health Affairs*, *30*(11), 2167–2176. https://doi.org/10.1377/hlthaff.2011.0229

Lowe, D., Ebi, K. L., & Forsberg, B. (2011). Heatwave Early Warning Systems and Adaptation Advice to Reduce Human Health Consequences of Heatwaves. *International Journal of Environmental Research and Public Health*, *8*(12), 4623–4648. https://doi.org/10.3390/ijerph8124623

Meade, R. D., Notley, S. R., Akerman, A. P., McCormick, J. J., King, K. E., Sigal, R. J., & Kenny, G. P. (2023). Efficacy of Cooling Centers for Mitigating Physiological Strain in Older Adults during Daylong Heat Exposure: A Laboratory-Based Heat Wave Simulation. *Environmental Health Perspectives*, *131*(6). https://doi.org/10.1289/ehp11651

McElroy S, Schwarz L, Green H, Corcos I, Guirguis K, Gershunov A, Benmarhnia T. Defining heat waves and extreme heat events using sub-regional meteorological data to maximize benefits of early warning systems to population health. *Sci Total Environ*. 2020 Jun 15;721:137678. doi: 10.1016/j.scitotenv.2020.137678. Epub 2020 Mar 6. PMID: 32197289.

Mora, C., Counsell, C. W., Bielecki, C. R., & Louis, L. V. (2017). Twenty-Seven Ways a Heat Wave Can Kill You: *Circulation: Cardiovascular Quality and Outcomes*, *10*(11). https://doi.org/10.1161/circoutcomes.117.004233

National Weather Service. (2017). Heat: A Major Killer. Retrieved from

https://www.weather.gov/oax/heatsafety

Obuchi, S.P., Kawai, H., Garbalosa, J.C. *et al.* Walking is regulated by environmental temperature. *Sci Rep* 11, 12136 (2021). https://doi.org/10.1038/s41598-021-91633-1

Powell, M., & Hubler, S. (2022, September 6). California's Heat Wave Sets Records, and Stretches Power Grid. *The New York Times*.

https://www.nytimes.com/2022/09/05/us/california-heat-wave-record-labor-day.html

Schmeltz, M. T., Petkova, E. P., & Gamble, J. L. (2016). Economic Burden of Hospitalizations for Heat-Related Illnesses in the United States, 2001-2010. *International journal of environmental research and public health*, *13*(9), 894. https://doi.org/10.3390/ijerph13090894

Sherbakov, T., Malig, B.,Guirguis, K., Gershunov, A., Basu, R., Ambient temperature and added heat wave effects on hospitalizations in California from 1999 to 2009, *Environmental Research*, Volume 160, 2018, Pages 83-90, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2017.08.052.

Shindell D, Zhang Y, Scott M, Ru M, Stark K, Ebi KL. The Effects of Heat Exposure on Human Mortality Throughout the United States. *Geohealth.* 2020 Apr 1;4(4):e2019GH000234. doi: 10.1029/2019GH000234. PMID: 32258942; PMCID: PMC7125937.

State of California, California Natural Resource Agency. Protecting Californians From Extreme Heat: A State Action Plan to Build Community Resilience. April, 2022.

Stone B Jr, Mallen E, Rajput M, Gronlund CJ, Broadbent AM, Krayenhoff ES, Augenbroe G, O'Neill MS, Georgescu M. Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk. *Environ Sci Technol.* 2021 May 18;55(10):6957-6964. doi: 10.1021/acs.est.1c00024. Epub 2021 Apr 30. PMID: 33930272; PMCID: PMC9882910.

The Risky Business Project. (2014). RISKY BUSINESS: The Economic Risks of Climate Change in the United States. In *https://riskybusiness.org/report/national/*. Risky Business.

Retrieved November 28, 2022, from https://riskybusiness.org/site/assets/uploads/2015/09/RiskyBusiness_Report_WEB_09_08_14.pdf

Thorne, T. (2022, September 5). Advocates say "Cool Zones" not accessible in all parts of San Diego County. *KPBS Public Media*. https://www.kpbs.org/news/health/2022/09/02/advocates-say-cool-zones-not-accessible-in-all-parts-of-san-diego-county

Voelkel, J., Hellman, D., Sakuma, R., & Shandas, V. (2018). Assessing Vulnerability to Urban Heat: A Study of Disproportionate Heat Exposure and Access to Refuge by Socio-Demographic Status in Portland, Oregon. *International Journal of Environmental Research and Public Health*, *15*(4), 640. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph15040640

Widerynski, S., Schramm, P. J., Conlon, K. C., Noe, R. S., Grossman, E., Hawkins, M., Nayak, S. U., Roach, M., Hilts, A. S. (2017, August 7). *Use of cooling centers to prevent heat-related illness : summary of evidence and strategies for implementation*. https://stacks.cdc.gov/view/cdc/47657