Heat Vulnerability in Delta Communities

Delta Stewardship Council & UC Davis Environmental Policy and Management Policy Clinic Collaboration

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Background

Client
Delta Stewardship Council: Dan Constable, Cory Copeland, and Ron Melcer

Advisors
Dr. Eric Post (UC Davis Wildlife, Fish & Conservation Biology) and Dr. Frances Moore (UC Davis Environmental Science & Policy)

Policy Recommendation Guidelines
1. Develop a system for coordinating emergency health care services
2. Increase outreach to vulnerable communities

Abbreviations

Bay Delta	Sacramento San-Joaquin Bay Delta region
CD	Census Division
CDP	Census Designated Place
DSC	Delta Stewardship Council
PL	Place
RCP	Representative Concentration Pathway
IPCC	Intergovernmental Panel on Climate Change

List of Evaluated Bay Delta Communities (identified by DSC)

Antioch	Discovery Bay	Mountain House	Tracy
Antioch-Pittsburg	Freeport	Oakley City	Tracy City
Bay Point	Hood	Pittsburg City	Walnut Grove
Bethel Island	Isleton	Rio Vista	West Sacramento
Brentwood City	Isleton City	Rio Vista City	
Byron	Knightsen	Stockton	
Clarksburg	Lathrop City	Stockton City	
Country Club	Lincoln	Terminous	
Courtland	Lincoln Village	Thornton	

Introduction

As climate change continues, the negative effects on humans and the physical environment will intensify further. Earthquakes, subsidence and sea level rise are frequent topics of climate research; extreme heat and its varying consequences on human health, has been given less attention. This is particularly true in the Sacramento San-Joaquin Bay Delta region (Bay Delta). This region is located in Northern California at the confluence of the Sacramento and San Joaquin rivers. The Delta is heavily leveed to accommodate agricultural lands and communities; encompassing about fourteen cities and five counties (Water Education Foundation). By 2025, the California Delta and its watershed is projected to warm above late 20th century levels by another 1°C; by 2055, between 2°C and 2.5°C; and by 2085, between 3.5°C and 4°C (Dettinger, 2016). The health and welfare of communities within the Delta have a difficult future in the face of rising temperatures.

The Delta Stewardship Council is looking to primarily examine how heat vulnerability may affect the Delta communities. A main factor in this project will be identifying which Delta communities are most vulnerable to extreme heat events. Extreme heat is defined as a day in a year when the daily maximum/minimum temperature exceeds the 98th historical percentile of daily maximum/minimum temperatures based on observed historical data from 1961–1990 between April and October. This ranges from 101.9-103.9 F depending on the region (CalAdapt 2019). By assessing the climatic data and presenting a clearer understanding of the dangers present in extreme heat, the Delta Stewardship Council will ideally be able to use this information and research to contribute to their Climate Vulnerability Assessment for the state of California.

Common research questions in the reviewed literature center around how vulnerable groups are identified and who the vulnerable groups are (Duckers 2018). The relevant research used modified heat vulnerability indices that looked at a variety of variables such as: tree cover, air conditioning access, social isolation, age, socioeconomic status, race/ethnicity, and education. While we found that there is no standard for vulnerability indices, we used variables identified by the California Department of Public Health (CDPH). These variables were broken down into ‘Population Sensitivity Domain’ and ‘Adaptive Capacity Domain’; we referred to these domains as social variables and physical variables, respectively. These variables were chosen due to data availability from CDPH and CalAdapt that could meet our chosen depth of analysis. We hypothesized that high poverty levels and minority populations within Bay Delta communities are disproportionately affected by extreme heat because they do not have equitable access to resources. We tested this hypothesis by aggregating the available data for each variable of interest per city and ranked the cities from least vulnerable to most vulnerable. Our research focused on assessing the vulnerability of Bay Delta communities based on social and physical variables.

Social Variables

We used variables identified by the California Department of Public Health labelled as Population Sensitivity Domain. Sensitivity was defined as the physiological and socio-economic factors which directly or indirectly affect the degree to which a population is impacted by climate-related changes (CDPH 2019). These variables were chosen through consideration of data availability and completeness in order to conduct an adequate analysis. These variables are listed below.

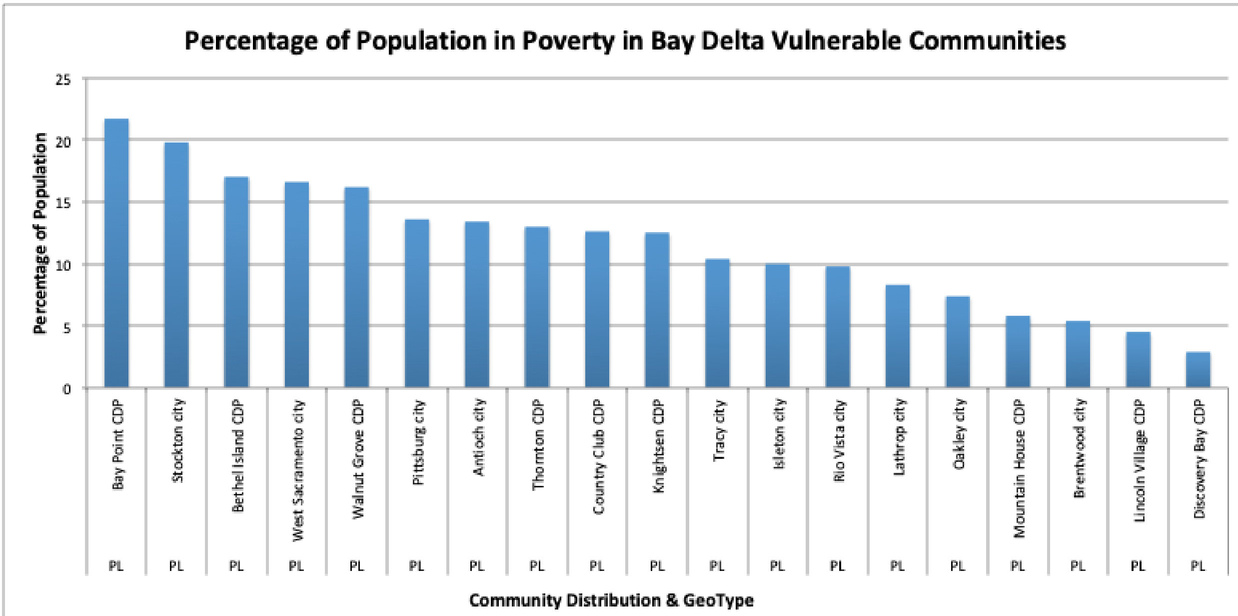
Percent of population who are considered children (<5 years old)
Percent of population who are considered elderly (>65 years old)
Population over 25 years old who have a high school education
Poverty rate of area
Percent of population made up of ethnic groups
Percent of population who are linguistically isolated
Percent of population living with one or more disabilities
Percent of population who have health insurance
Percent of population who own a vehicle
Percent of population who live on impervious surfaces

For brevity, we will be more closely examining ethnic groups, poverty rates, and linguistic isolation.

Poverty

Poverty is typically correlated with heat-related mortality. Of the fifteen communities who experienced the highest death rates in the Chicago 1995 heat wave, eleven of those contained the highest proportion of people living below the poverty line (Klinenberg, 1999). Unfortunately, these statistics are commonplace when it comes to heat wave events. Although it is difficult to ascertain why socioeconomic status is linked to heat-related deaths, we can speculate that those living below the poverty line have different livelihoods (i.e. work outdoors) and have less accessibility to healthcare and cooling centers (Green 2019). We determined the percentage of the population that fall below the poverty line within the Bay Delta communities (Figure 1). The five communities with the highest poverty rates are Bay Point CDP, Stockton City, Bethel Island CDP, West Sacramento City, and Walnut Grove CDP, ranging from about 16 to 22 percent of the population below the poverty line.

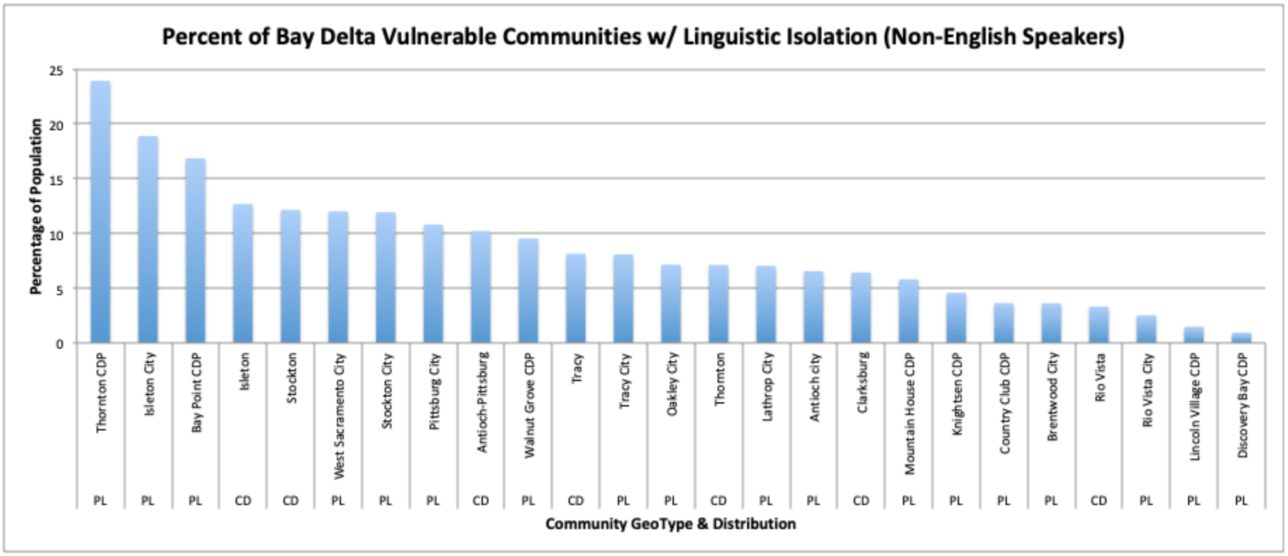
Figure 1: Percentage of Population Below Poverty Line in Bay Delta Vulnerable Communities



Linguistic Isolation

A key social variable in examining vulnerability is linguistic isolation (Duckers 2018). Linguistic isolation is a term used to describe households in which no one aged 14 or over speaks English or only speaks another language in the home (CDPH 2019). In this case, our team was able to locate the percentage of population that are non-English speakers by community, using data from the California Department of Public Health. Our findings (Figure 2 below) indicate that the top five Delta communities that are linguistically isolated are Thornton, Isleton City, Bay Point, Isleton and Stockton.

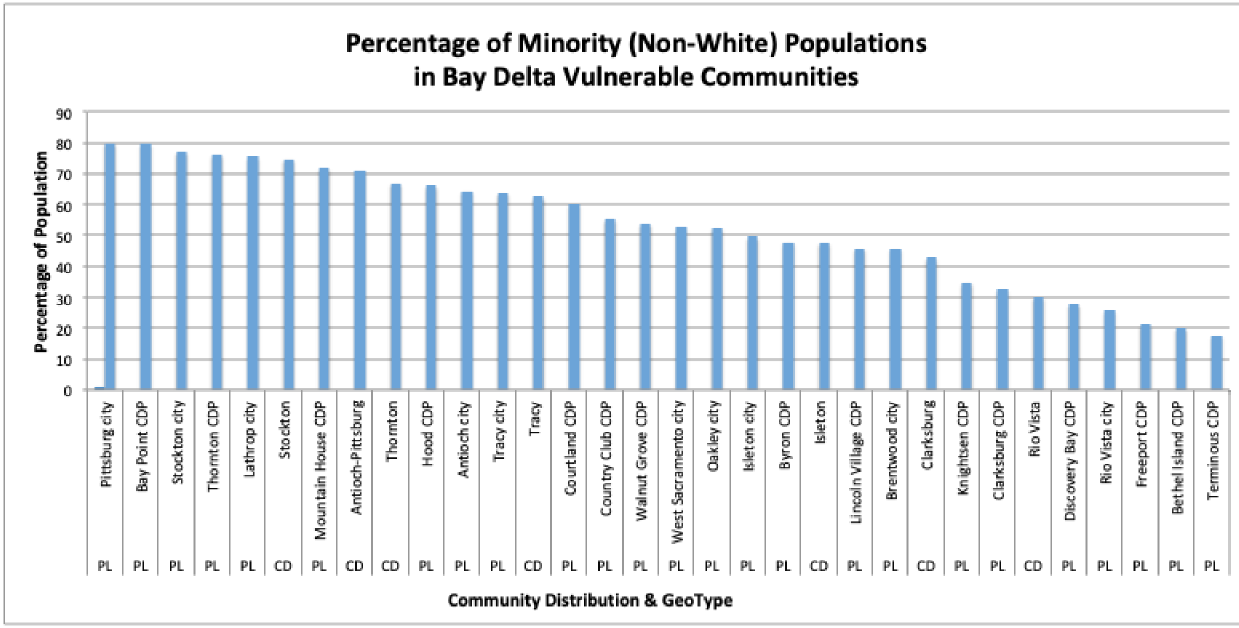
Figure 2: Percentage of Non-English Speakers (Linguistic Isolation) in Bay Delta Vulnerable Communities



Ethnic Groups

Non-white ethnic groups (often referred to as minority groups) are often identified as vulnerable populations to extreme heat (Maier 2014; Mayrhuber 2018; Nayak 2018; Voelkel 2018). We can speculate that minority populations are more vulnerable to extreme heat because typically, they are spatially isolated relative to white ethnic groups (Voelkel 2018). Although this is not a direct determinant of vulnerability, this isolation increases the likelihood that non-white populations experience similar living conditions (i.e. less tree cover, amplified urban heat effects). The five Delta communities with the highest percentage of non-white populations were Pittsburg City, Bay Point, Stockton City, Thornton, and Lathrop City.

Figure 3: Percentage of Minority (Non-White) Populations in Bay Delta Vulnerable Communities



Physical/Environmental Variables

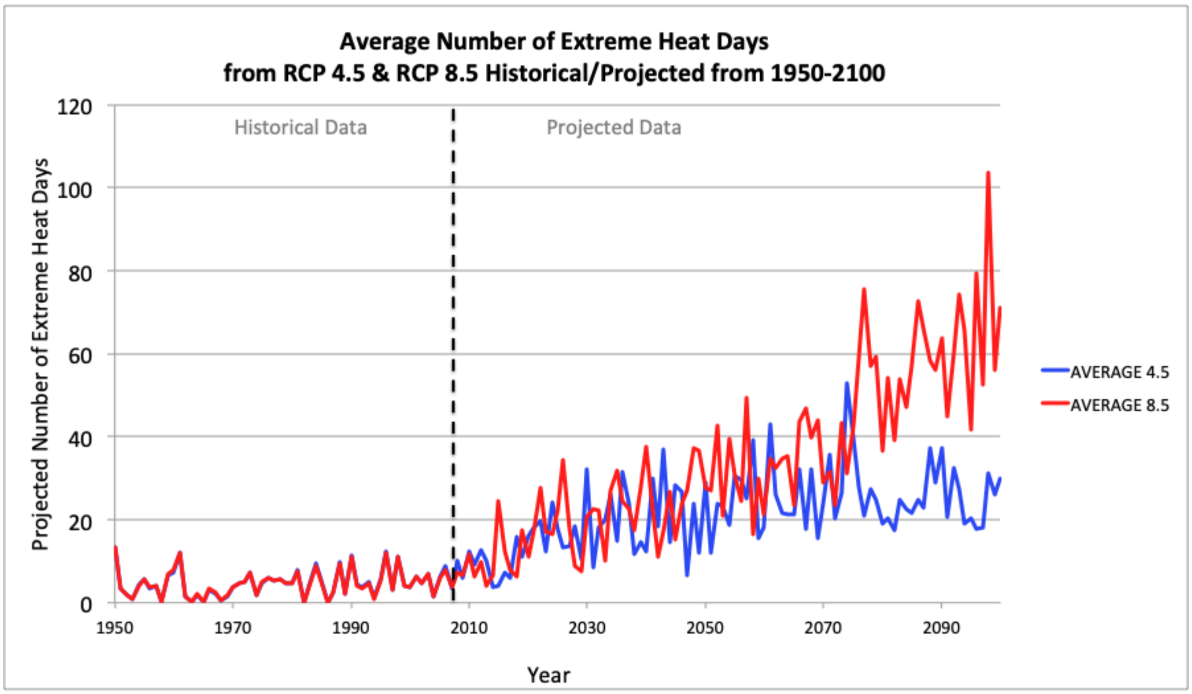
For these physical variables, we looked at three indicators: number of extreme heat days, percentage of area of the region that is considered to be an impervious surface, and the percentage of the population that works in outdoor environments. Impervious surface and outdoor worker data was pulled from the CDPH database, labelled as ‘Adaptive Capacity Domain’. Adaptive capacity was defined as the broad range of responses and adjustments to the impacts of climate change, including the capacity to moderate potential damages, take advantage of opportunities, and cope with the consequences (CDPH 2019). Percentage of population that works in outdoor environments is not strictly physical, but neither is it purely social, thus it was decided to include it within the physical factors.

Number of Extreme Heat Days

We used two different projections for greenhouse gas emission rates to visualize the extreme heat days in the future. A Representative Concentration Pathway (RCP) is a trajectory for greenhouse gas emissions that was initially adopted by the Intergovernmental Panel on Climate Change (IPCC) to project various scenarios based on different global emissions pathways. In our analysis, we examined both RCP 4.5 and RCP 8.5 data for each of the communities using CanESM2 modeling data as a central point. This data was chosen as it was the average model for warm days and nights.

RCP 4.5 assumes emission increases until 2040, then plateauing through the rest of the century, implying immediate and effective climate change action through behavioral and policy changes. RCP 8.5 assumes emissions rising throughout the century until 2100, the “do-nothing” scenario. In Figure 4, the extreme heat days from each projection up to 2100 and from the historical data (1950-2006) were averaged to give expected changes. If policy makers do not take drastic changes to combat climate change, approximately ⅓ of the year will consist of extreme heat days by the end of the 21st century.

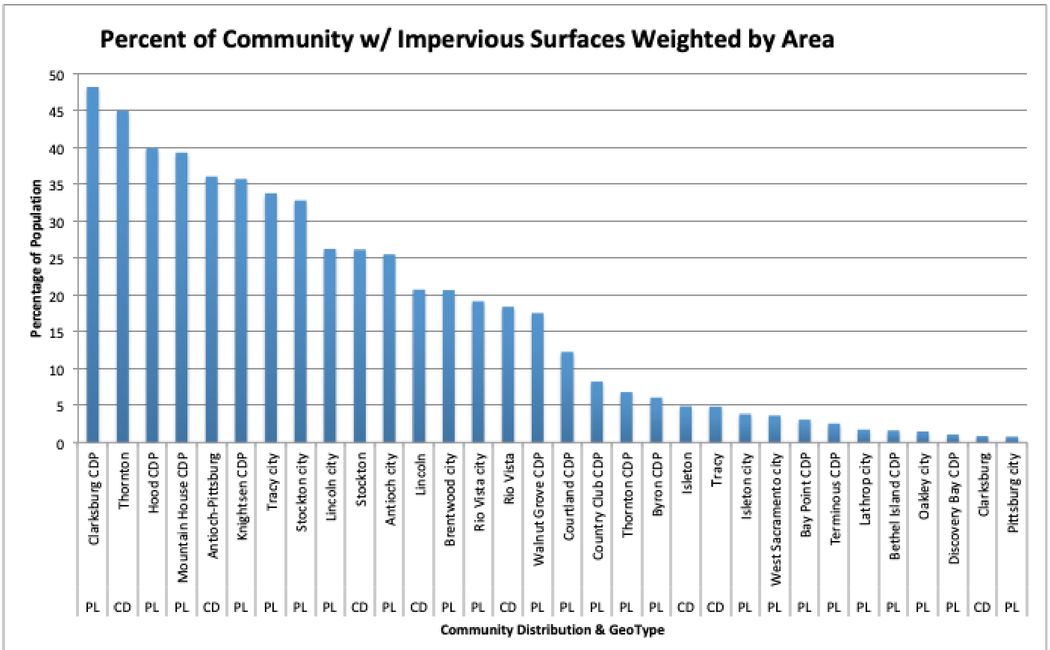
Figure 4: Average Number of Extreme Heat Days from RCP 4.5 and RCP 8.5 over the Historical and Projected Period from (1950-2100)



Impervious Surfaces for Area

An impervious surface is defined as an area where water is unable to pass through. The California Department of Public Health data used two different variations of impervious surface data, population and area. The population data described areas of impervious surfaces where people are residing, while the area data represented the percentage of total surface area that is impervious in a region (CDPH 2019). In an extreme heat event, regions where water cannot permeate will trap heat on the surface and become potentially dangerous for vulnerable individuals. Figure 5 below identifies the most vulnerable communities based on the impervious surface area data, the top 5 being Clarksburg, Thornton, Hood, Mountain House, and Antioch-Pittsburg.

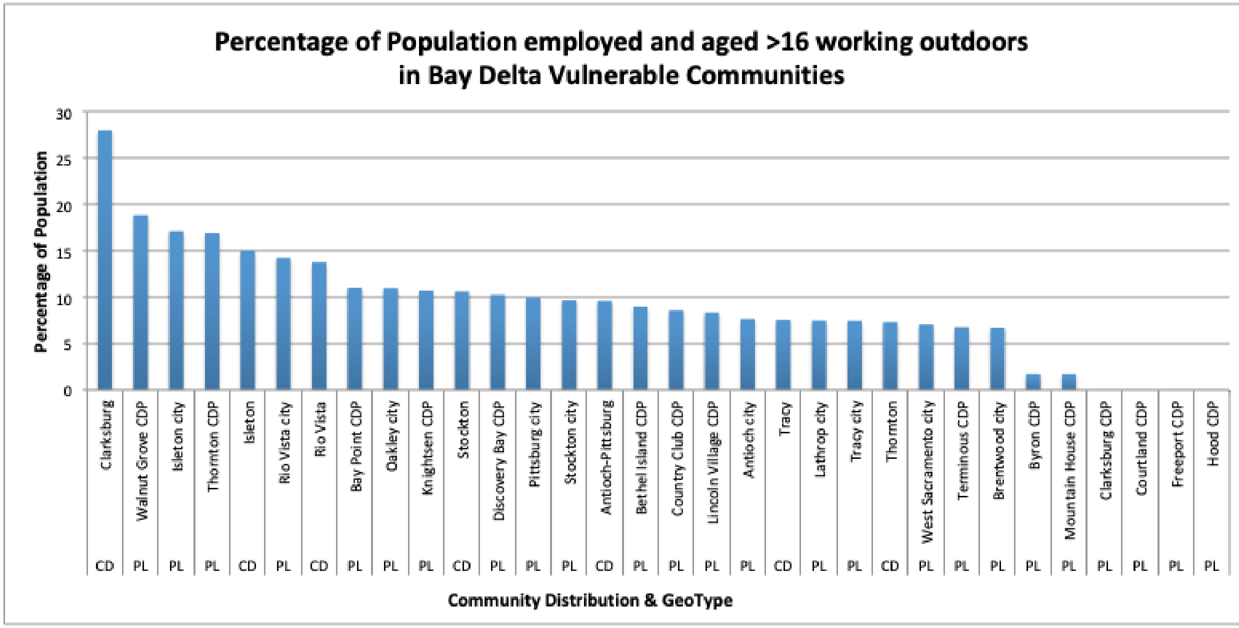
Figure 5: Percentage of Community w/ Impervious Surfaces Weighted by Area in Bay Delta Vulnerable Communities



Outdoor Workers

The number of outdoor workers in a region is an important heat indicator because it reveals the percentage of each community's population that will be directly exposed to the elements. In an extreme heat event, outdoor workers are much more likely to suffer from heat-related illnesses (Voelkel 2018). In the Bay Delta, the majority of outdoor workers are those working in agriculture and doing manual labor. Without proper shade and access to cool areas, extreme heat events are very dangerous to vulnerable communities. The top 5 communities in the Delta with outdoor workers include: Clarksburg, Walnut Grove, Isleton City, Thornton, and Isleton.

Figure 6: Percentage of Population Over 16 Years-Old Working Outdoors in Bay Delta Vulnerable Communities



Ranking & Evaluation of Regions

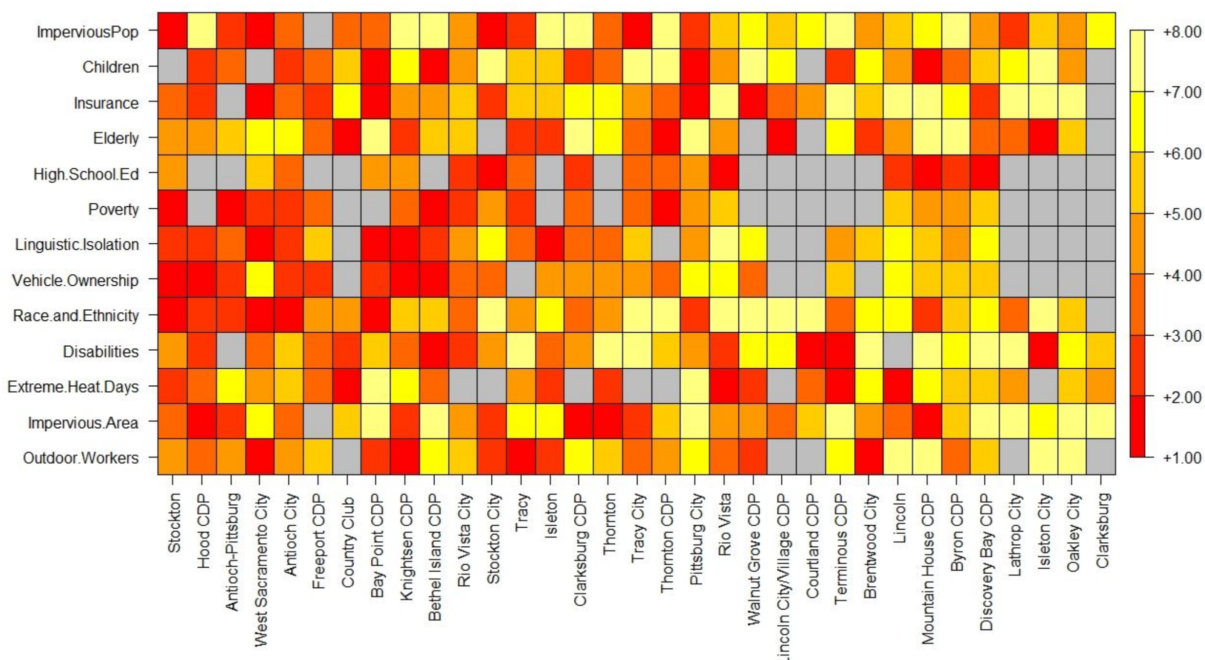
To help identify how vulnerable each identified community in the Bay Delta is based on the variables identified for both social and physical factors, a ranking system was developed to find consistencies between regions. The full methodology, detailed in Appendix A, pg. 14, sought to organize the communities into groupings from most to least vulnerable in order to present a clear picture of areas that policy makers should focus their attentions on. Based on our data analysis, the following groups were found to be most vulnerable:

Physical Top Group	**Social Top Group**	**Combined Group**
Stockton City	Stockton	Stockton
Hood	Antioch-Pittsburg	Hood
Tracy City	Bay Point	Antioch-Pittsburg
Rio Vista	Hood	West Sacramento
Thornton	West Sacramento	Antioch
Walnut Grove	Antioch	Country Club
Country Club	Bethel Island	Bay Point
Knightsen	Freeport	Knightsen
Stockton	Rio Vista City	Bethel Island
Isleton	Country Club	Rio Vista City

Vulnerability Ranking Matrix

An aggregate index matrix is useful when visualizing how each identified variable affects the vulnerability of a community. One insight from this visualization is that low high school completion rates do not correlate with high vulnerability for other variables. The matrix also clearly displays where the data gaps are, represented in gray. It may be useful to note that a majority of the missing data coincides with the communities that we ranked as the least vulnerable, this highlights the need for more data to better evaluate vulnerability.

Figure 7: Vulnerability ranking of Bay Delta communities



Spatial Relationships of Communities

Looking at the maps from Appendix B, pg. 17, that detail the above rankings in the Bay Delta, there are some takeaways that can be made regarding the vulnerable regions.

1. Regions with high populations (>20,000) and high impervious surface levels tended to be the most vulnerable in the case of an extreme heat event (Stockton, West Sacramento, Antioch, Pittsburg)
2. Clustering of regions spatially in the Combined Group illustrate that vulnerable areas are often more contiguous, and could be targeted by policy makers
3. The largest proportion of vulnerable regions were found in Contra Costa County

4. Areas with very low populations (<4000) and small areas (ie Hood and Freeport) may not reflect accurate rankings of vulnerability

Policy Recommendations & Evaluation

System for coordinating emergency services

The legal Delta includes portions of six different counties (Sacramento, San Joaquin, Alameda, Contra Costa, Solano, and Yolo). The evaluated communities are spread across these counties, with the exception of Alameda County. There is currently no coordinated system to warn residents of extreme heat events and enable them to take the necessary precautions. An alert system for highly vulnerable areas may help alleviate confusion and prevent heat-related deaths.

Focus on outreach to vulnerable communities

Lower heat advisory thresholds could provide a time buffer for at-risk communities to react and find access to cooling centers. Phone alerts could be sent out if the lower threshold is reached. Public organizations should make an active effort to engage regions with high linguistic isolation and provide pamphlets or warnings about extreme heat events in both English and Spanish.

Future Research Applications

Improve data regarding cool areas

Improving access to cool areas can reduce the risks associated with extreme heat. Examples of cool areas include public libraries, planting more trees to provide more shade/tree canopy cover, and access to individual air conditioning units. Tree canopy and air conditioning data is currently available at a county-wide level, so it is difficult to assess individual community vulnerability. Increasing data availability on a community-wide level versus a county-wide level could help policy makers determine the physical needs of a region and implement strategies to overcome potential health risks.

Conclusion

Heat vulnerability literature offers data that can be used by climate scientists and politicians. An area of strength within this research is the sheer number of variables that can be considered in vulnerability indices. Data for physical and social variables for the Bay Delta communities were collected by Cal Adapt and the California Department of Public Health. This data helps demonstrate how the vulnerability of a community cannot be decided by one variable or indicator, but necessitates a wider range of information.

There are some weaknesses to the available data and research for this topic. For example, the variety of methods used in designating the Bay Delta communities make it difficult to formulate a complete picture of how these areas will react to increases in extreme heat. Some researchers view the region as a whole, which undermines the high level of variance that can be seen across these communities. Some places within the Bay Delta are mainly rural, while others are a mix of suburban, urban, and agricultural regions. Another weakness is evident by the lack of complete data for several factors. For instance, tree canopy data for Bay Delta communities was largely incomplete, preventing our group from being able to analyze this physical factor with any form of conclusivity. Additionally, we had hoped to examine the accessibility of these populations to air conditioning in their home. The available data was taken on a county-wide level, rather than by city or CDP, forcing us to remove this variable altogether because we could not adequately compare it to other factors. These problems represent an opportunity for further research. If data collection were to be done in a consistent method for all of the relevant heat indicators, these factors could be examined for future analysis.

Finally, an exploration of potential policy solutions to mitigate extreme heat events represents a critical area of study that should be continued. While it is crucial to identify key extreme heat variables, making policy decisions based upon these results is the next step that needs to be taken. Climate change and its impacts, such as increased extreme heat events, represent an unprecedented threat to everyone. Immediate action should be taken, through further research and policy solutions, in order to successfully mitigate this problem and decrease loss of life due to extreme heat events.

Acknowledgements

We would like to thank Dan Constable, Cory Copeland and Ron Melcer at the Delta Stewardship Council for their unwavering support throughout the duration of this project. Your timely responses to our emails did not go unnoticed.
We also extend our gratitude and appreciation to Fran Moore and Eric Post for your patience in dealing with us flaky graduate students by keeping us on track over the past six months.

Appendix A

Methodology of Ranking System

Step 1: We collected physical and social data from the CalAdapt and California Department of Public Health websites where it was aggregated into excel sheets. From each variable, the data was organized from most to least vulnerable, with the most vulnerable being the largest percentage of the population for that factor (ie highest percentage of impervious surfaces to lowest percentage of impervious surfaces).

geotype	Geoname	% Pop Surface
PL	Tracy city	60.00
PL	Stockton city	57.13
CD	Stockton	53.26
PL	West Sacramento city	53.06
CD	Antioch-Pittsburg	52.66
PL	Lathrop city	52.29
PL	Pittsburg city	52.27
CD	Tracy	51.90
CD	Thornton	51.55
PL	Bay Point CDP	51.54
PL	Antioch city	50.99
PL	Country Club CDP	50.49
PL	Discovery Bay CDP	49.99
PL	Brentwood city	49.22
PL	Oakley city	48.83

Most Vulnerable

Least Vulnerable

Step 2: Within each variable set, the ordered communities were assigned numbers from 1 to 24-32 depending on the availability of the data. Due to the large capacity of the data sets and the number of communities analyzed, not every variable had the same information present.

City Name	CalAdapt	Impervious Pop	Child Pop (<5yrs)	Insurance	Elderly Pop (>65)
Antioch city	20	11	13	17	20
Antioch-Pittsburg	22	5	9		19
Bay Point CDP	26	10	2	3	27
Bethel Island CDP	13	27	28	12	2
Brentwood city	23	14	14	27	13
Byron CDP	18	29	15	25	18
Clarksburg	15	22	22	18	6
Clarksburg CDP		25	21	11	3
Country Club CDP	3	12	12	7	9
Courtland CDP	10	24	18	24	4
Discovery Bay CDP	19	13	16	29	14

Step 3: In order to diminish the impacts of missing or arbitrary data, the rankings were put into subsets from 1-8, with each number given to 4 communities. For example, Rankings 1-4 = 1, Rankings 5-8 = 2, Rankings 9-12 = 3, etc. The number 8 was chosen as the variable with the least amount of data presented 24 cities and the complete data sets presented 32 cities, thereby both being divisible by 8 and easily categorized. The subset format was also utilized as it was difficult to uniquely identify one city as the most vulnerable when there are so many factors available for analysis. The most suitable choice would be to identify a range of most vulnerable to least.

City Name	CalAdapt
Rio Vista	1
Country Club CDP	2
Lincoln	3
Terminous CDP	4
Isleton	5
Thornton	6
Walnut Grove CDP	7
Stockton	8
Freeport CDP	9
Courtland CDP	10
Hood CDP	11
Bethel Island CDP	12

→

City Name	CalAdapt
Rio Vista	1
Country Club	1
Lincoln	1
Terminous CDP	1
Isleton	2
Thornton	2
Walnut Grove CDP	2
Stockton	2
Freeport CDP	3
Courtland CDP	3
Hood CDP	3
Bethel Island CDP	3

Step 4: The adapted rankings from all the vulnerability data sets were averaged to create an overall order. The categories were split based on social, physical, and combined factors. The final rankings were ordered numerically from the smallest average (most vulnerable) to the largest average (least vulnerable). The subsequent rankings were graphed to visualize the vulnerable regions.

City Name	Average
Bay Point CDP	2.600
Hood CDP	2.889
Stockton	2.900
Bethel Island CDP	3.111
Antioch-Pittsburg	3.111
Antioch city	3.273
Knightsen CDP	3.273
Country Club	3.333
Rio Vista City	3.400
Isleton	3.444

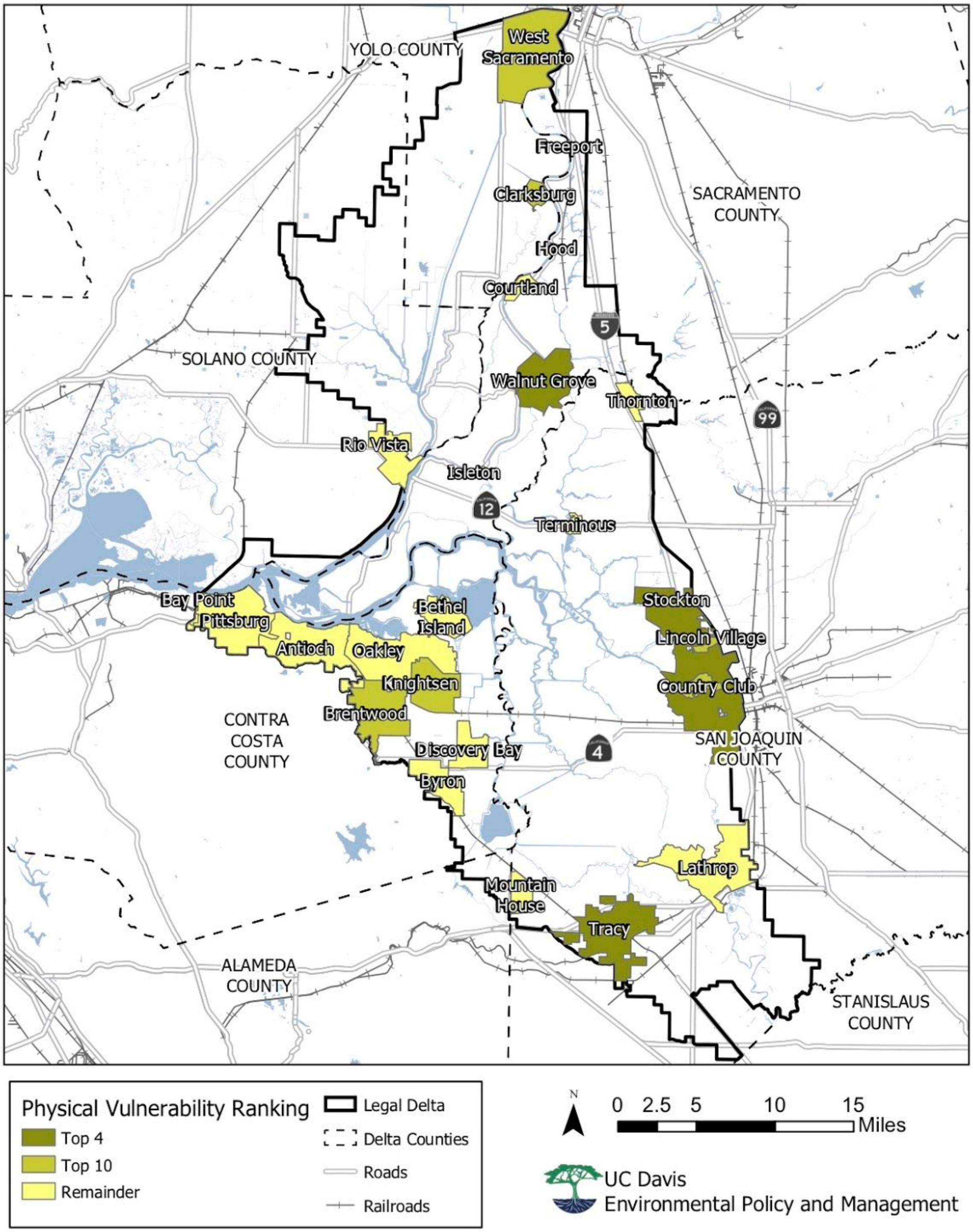
↑ Most Vulnerable

Least Vulnerable

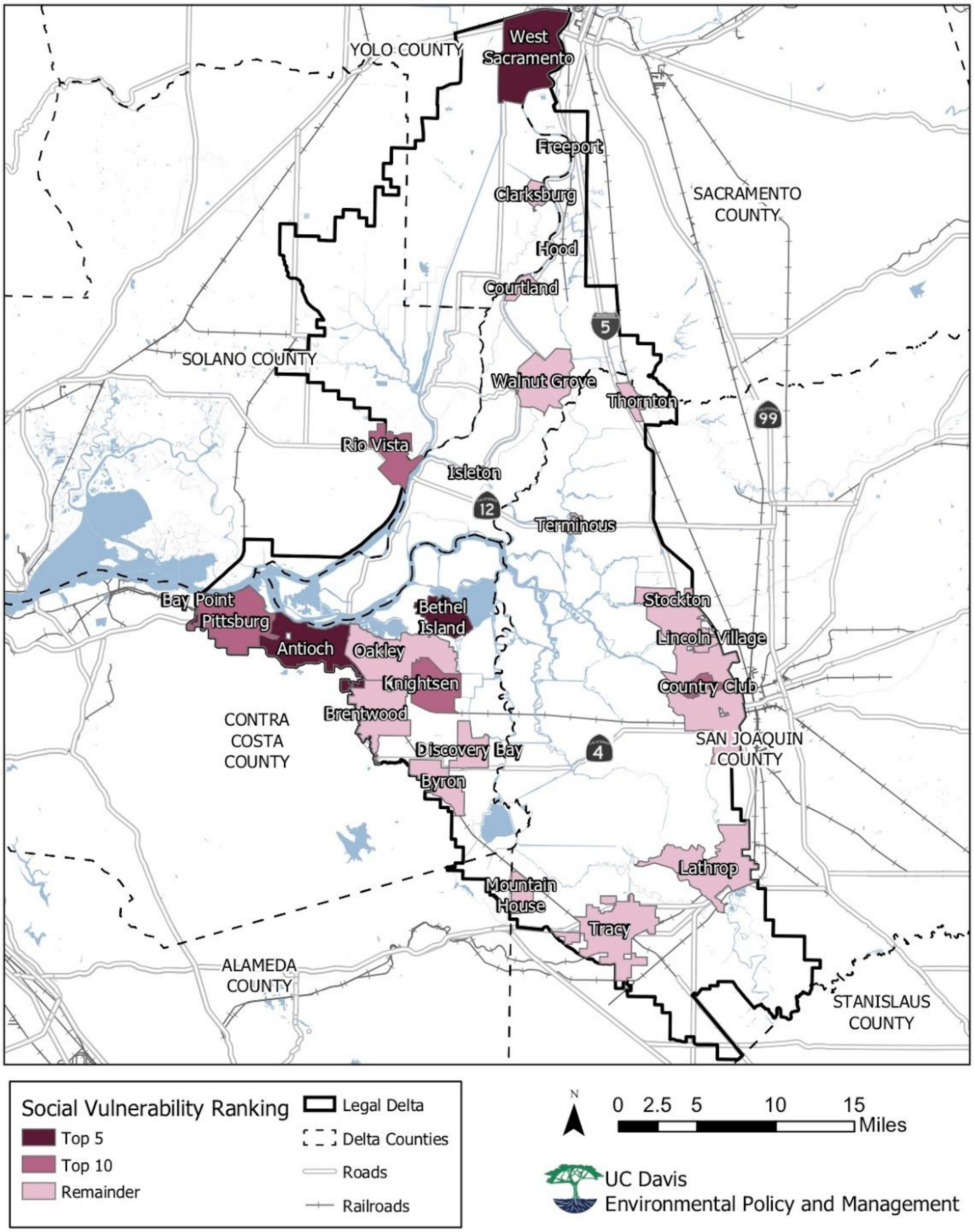
Appendix B

Maps

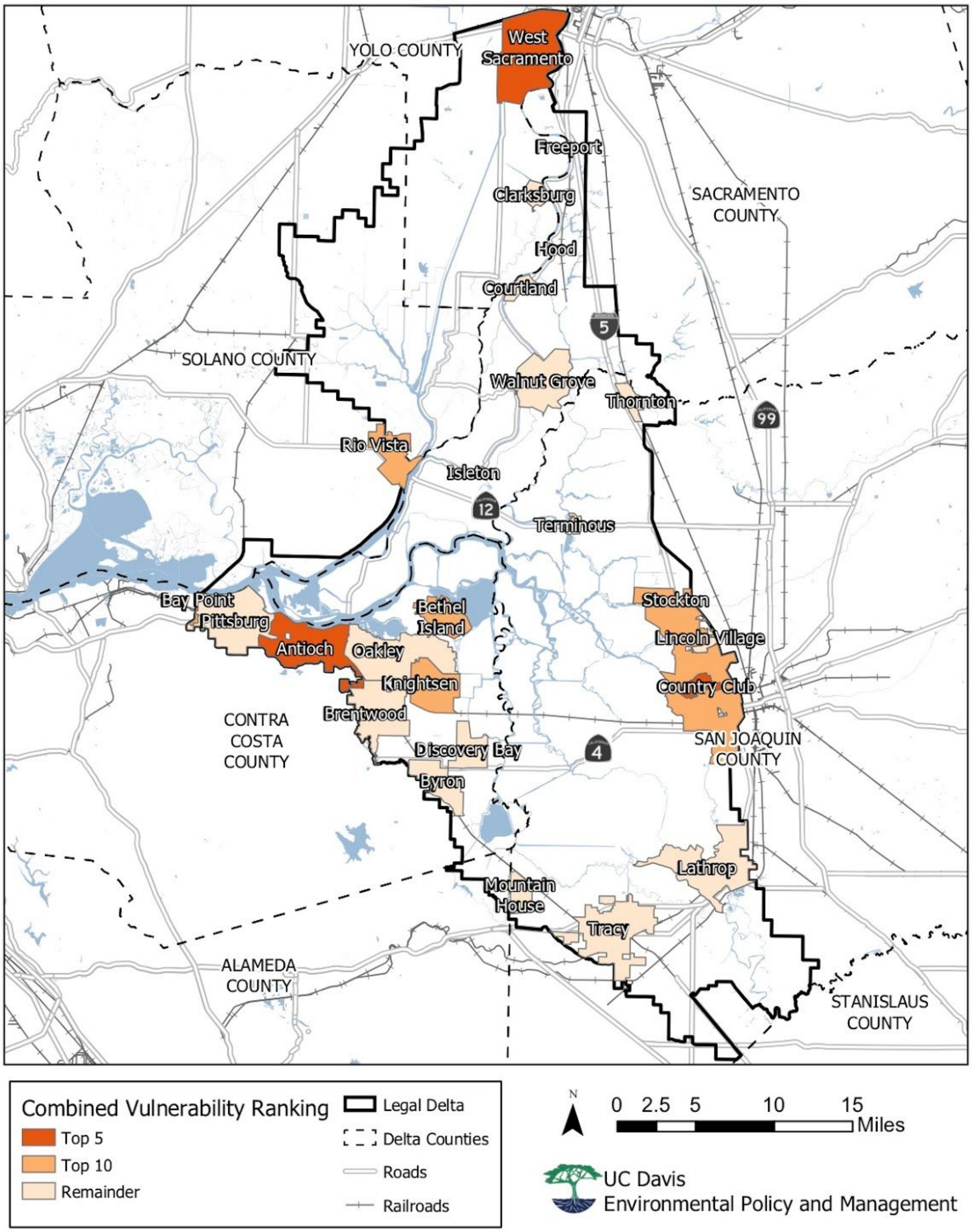
Physical Heat Vulnerability Rankings for Delta Communities



Social Heat Vulnerability Rankings for Delta Communities



Combined Heat Vulnerability Rankings for Delta Communities



Appendix C

Graphs

Social Factors:

Figure 1: Percentage of Population <5 yrs old in Bay Delta Vulnerable Communities

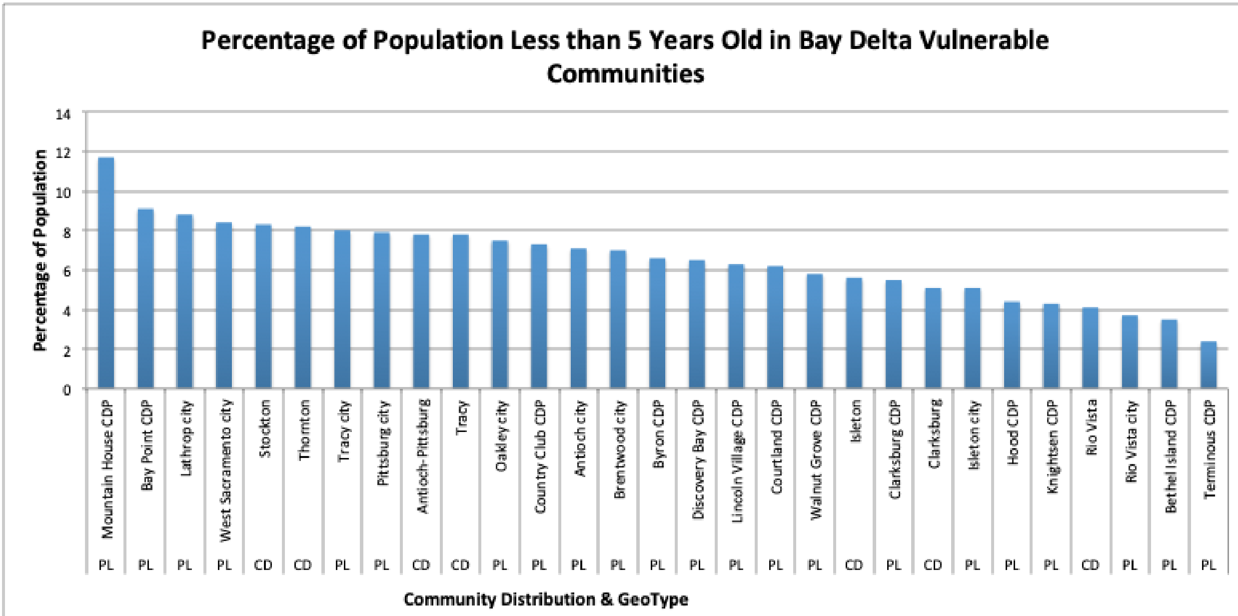


Figure 2: Percentage of Population >65 yrs old in Bay Delta Vulnerable Communities

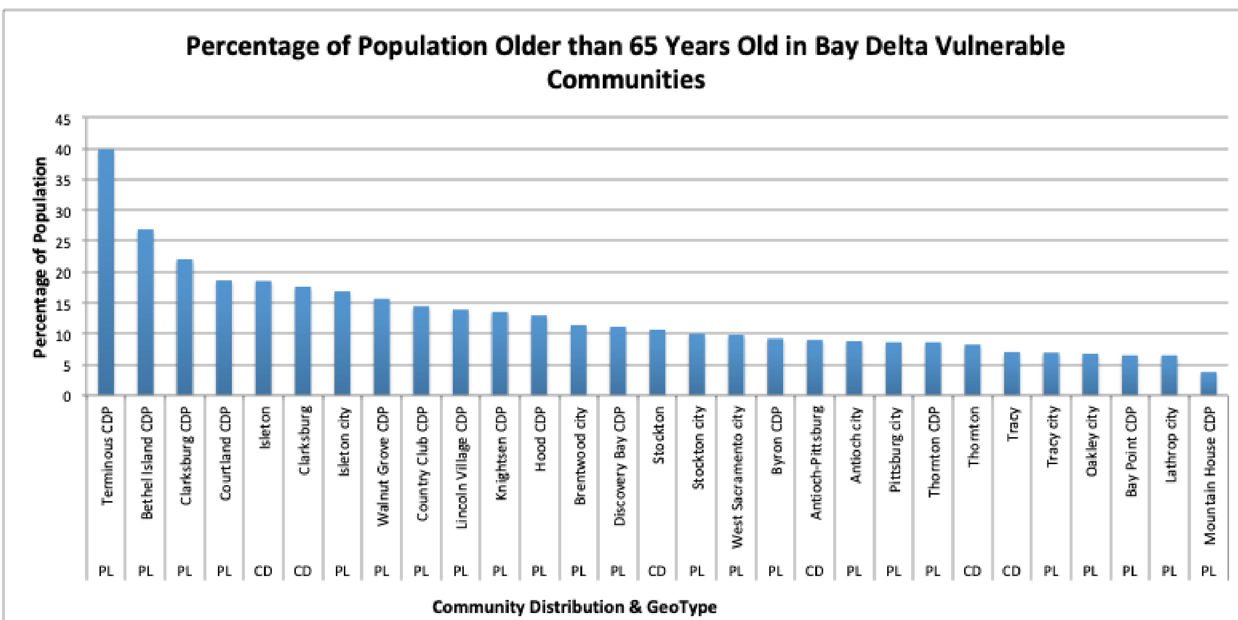


Figure 3: Percentage of Population w/ a High School Education >25yrs old in Bay Delta Vulnerable Communities

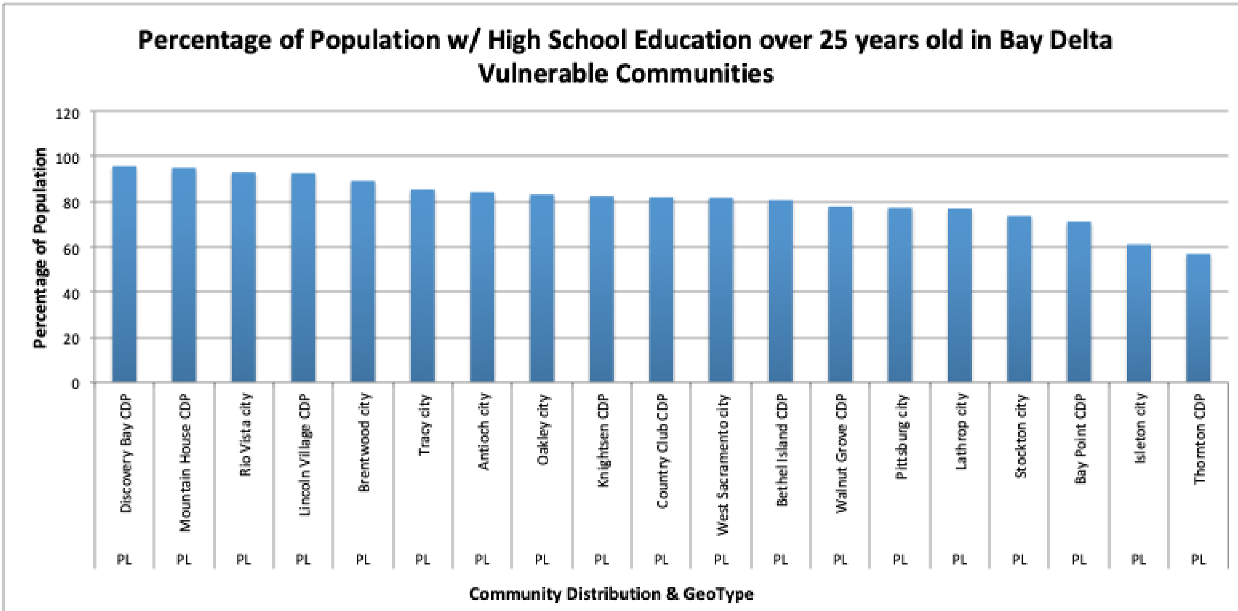


Figure 4: Percentage of Population Below Poverty Line in Bay Delta Vulnerable Communities

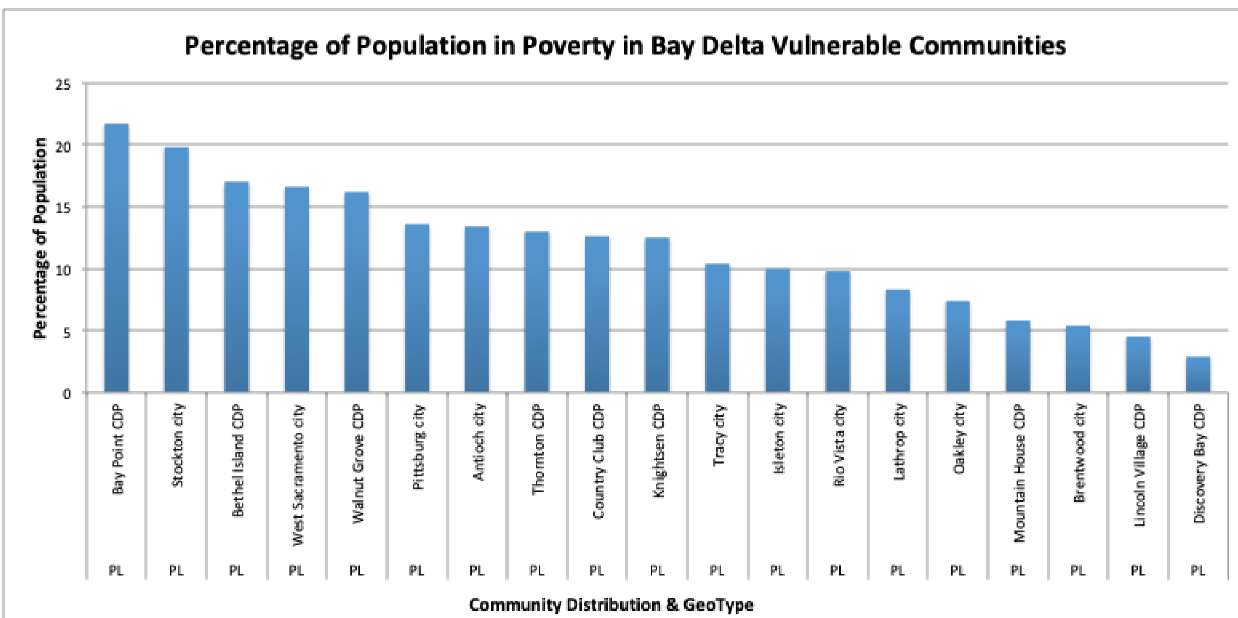


Figure 5: Percentage of Minority (Non-White) Populations in Bay Delta Vulnerable Communities

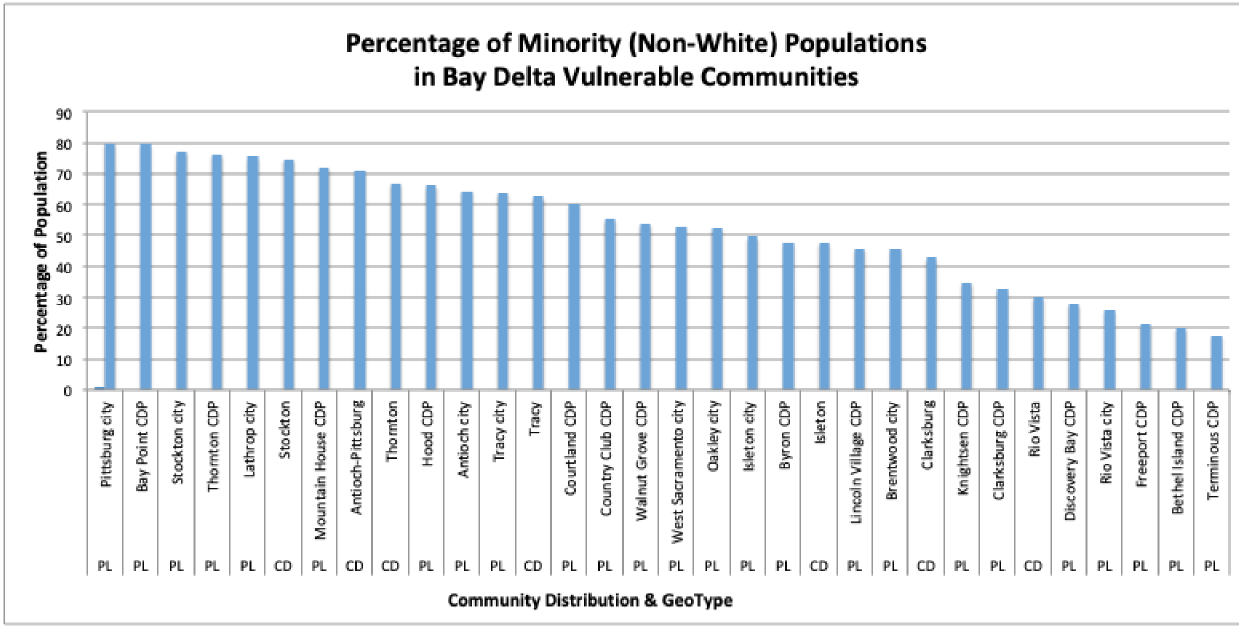
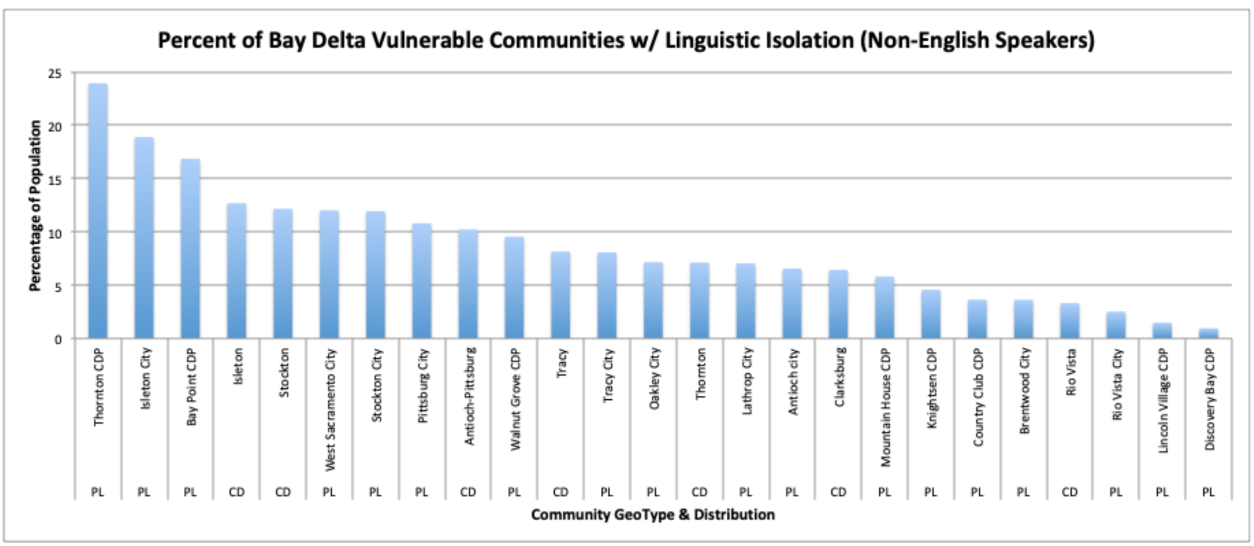


Figure 6: Percentage of Non-English Speakers (Linguistic Isolation) in Bay Delta Vulnerable Communities



Disabilities Data (Fig 7-10):

Figure 7: Percentage of Population w/ any Disability in Bay Delta Vulnerable Communities

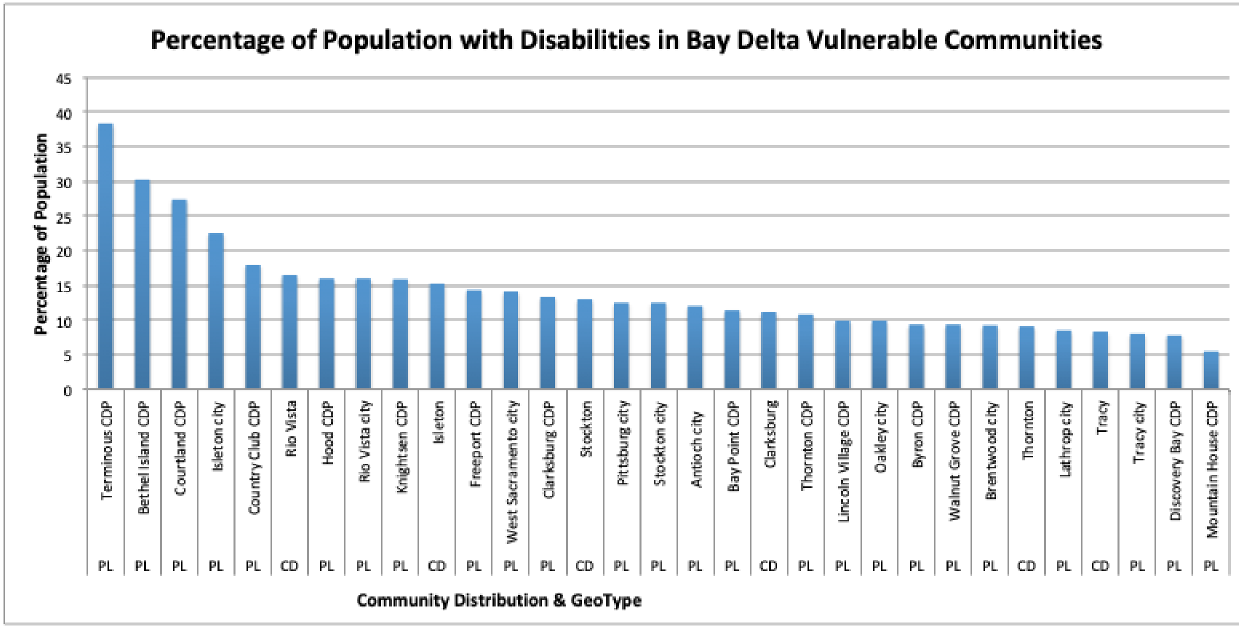


Figure 8: Small Population (<2000) Disabilities Breakdown

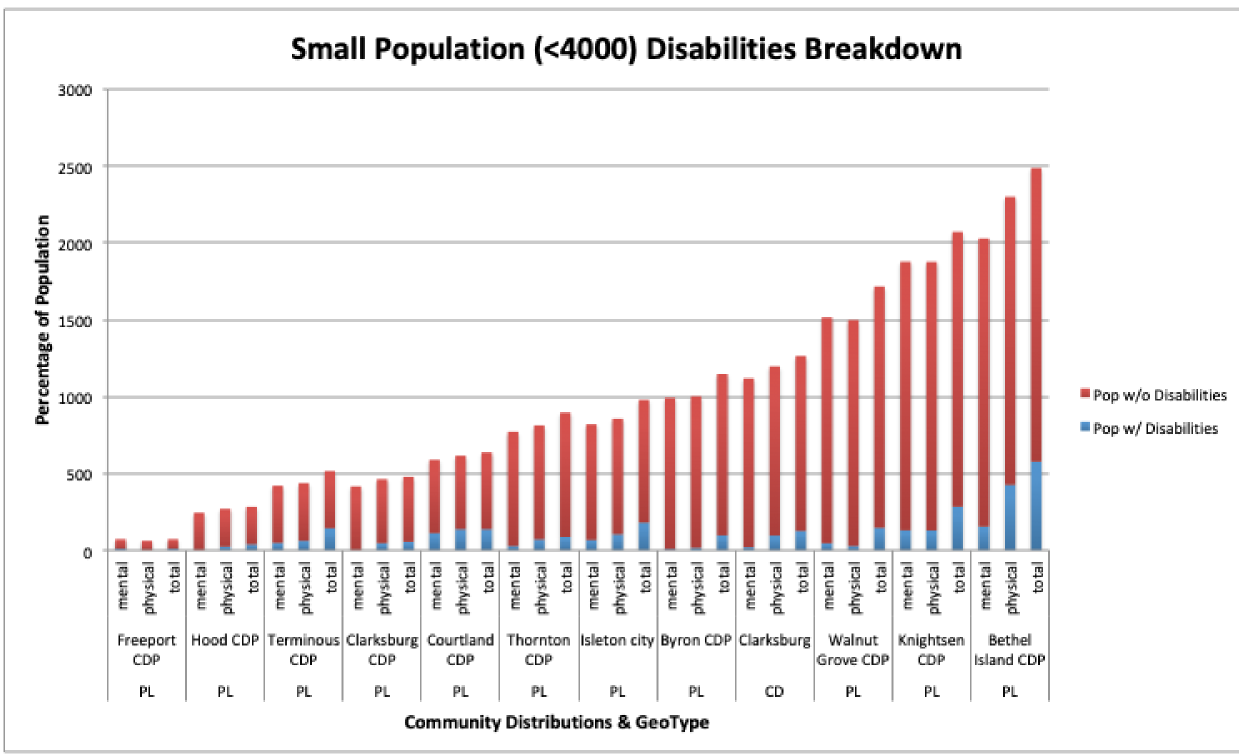


Figure 9: Mid-Size Population (4000 < x < 20,000) Disabilities Breakdown

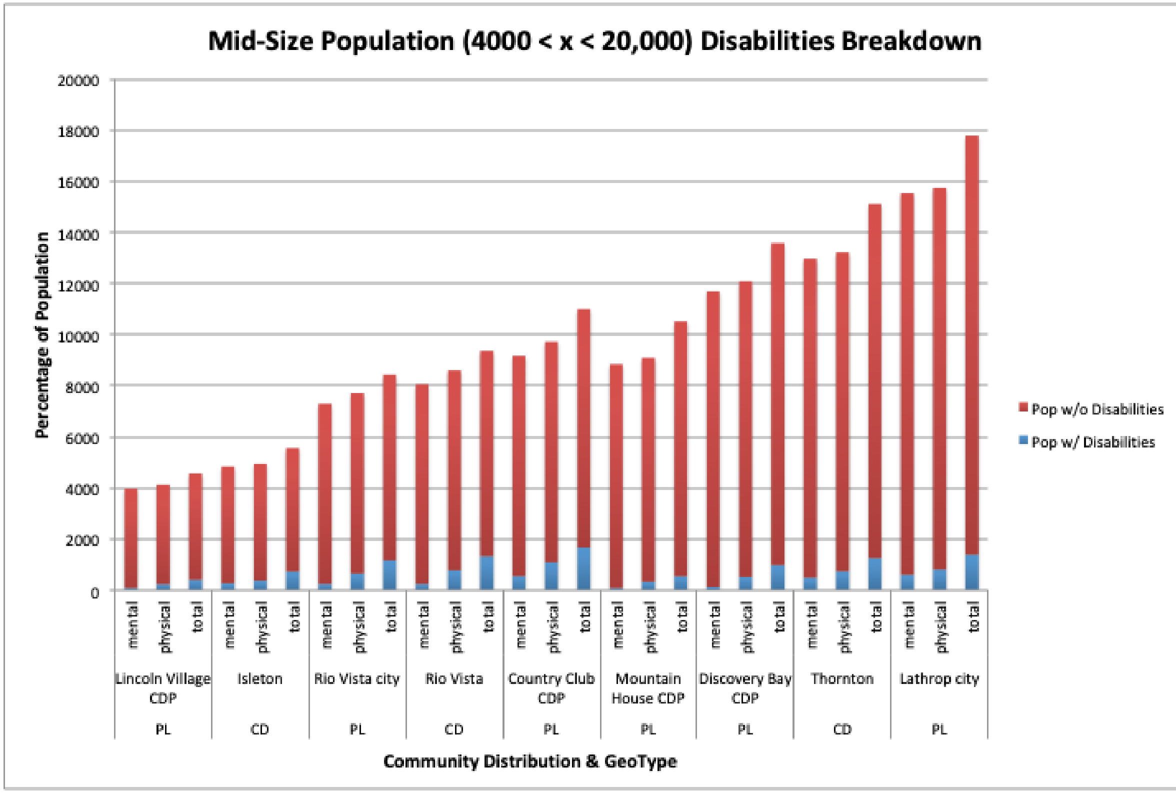
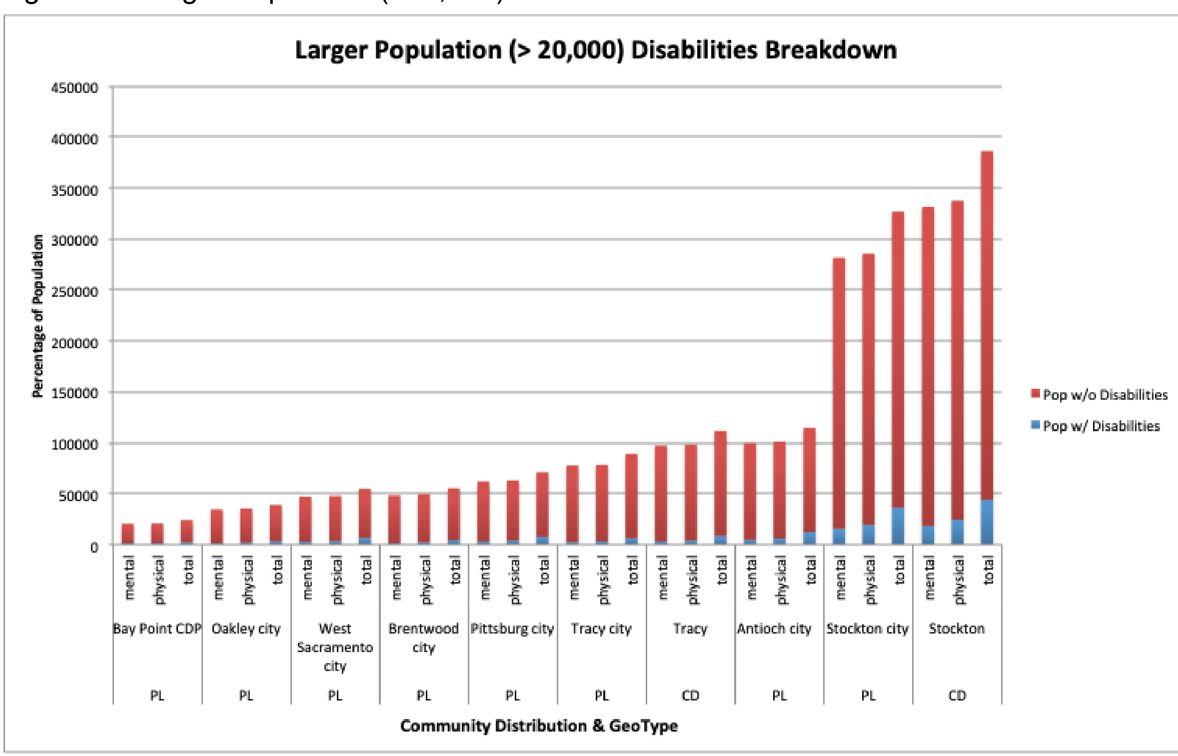


Figure 10: Larger Population (>20,000) Disabilities Breakdown



Health Insurance Data (Fig 11-14):

Figure 11: Percent of Populations Lacking Health Insurance in Bay Delta Vulnerable Communities

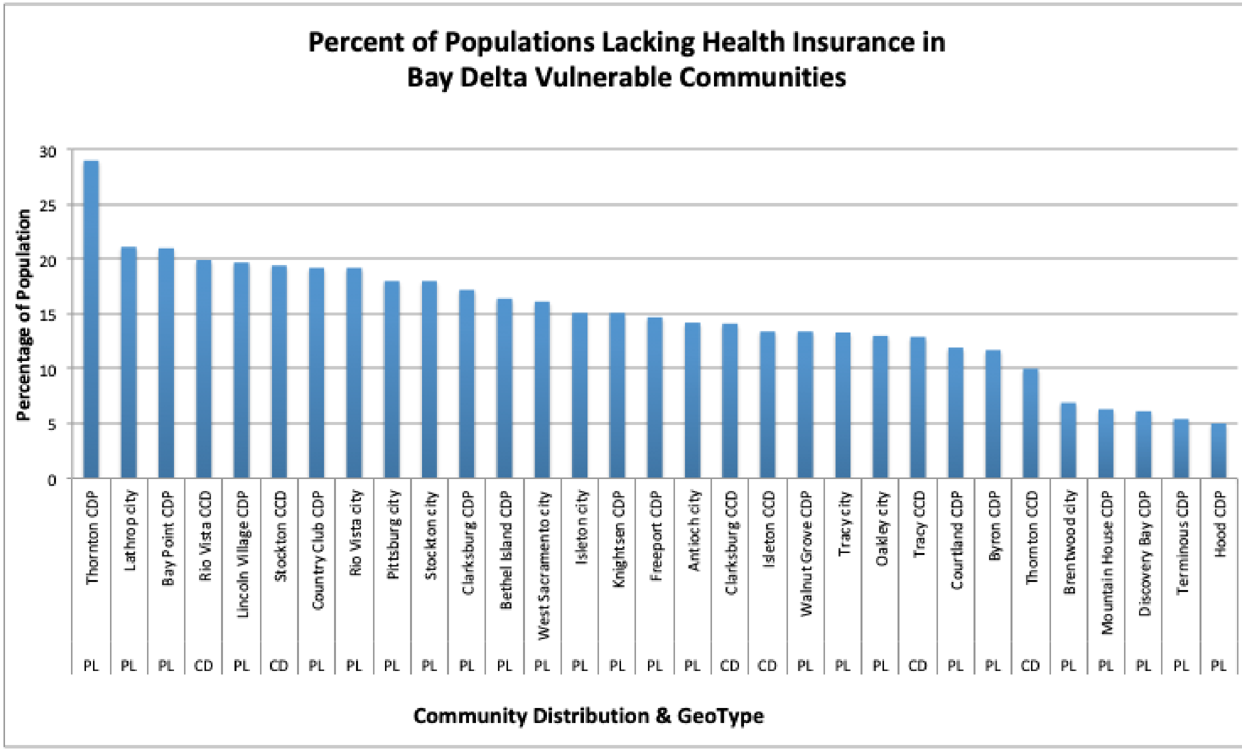


Figure 12: Small Population (<2000) Health Insurance Breakdown

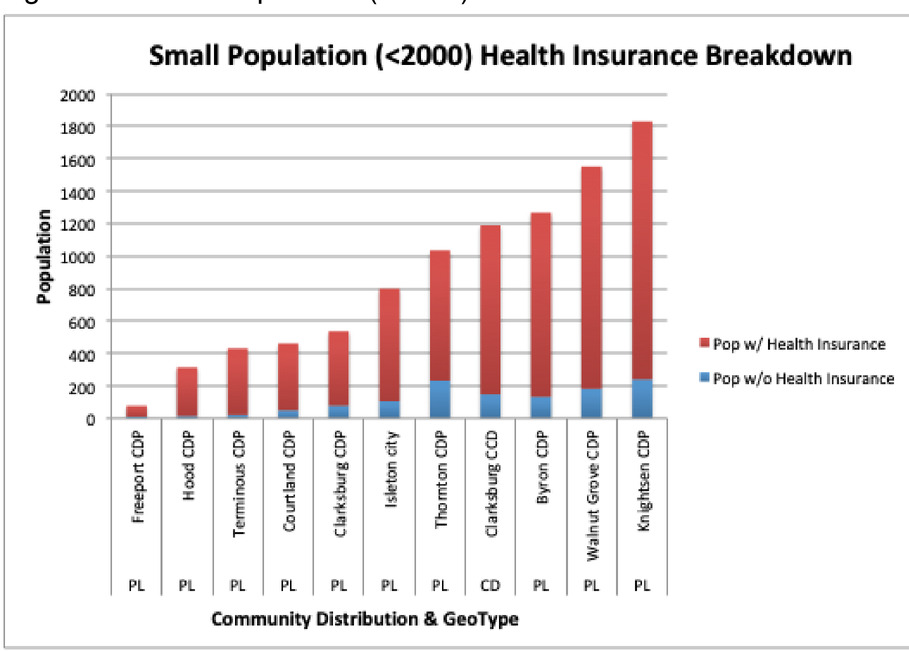


Figure 13: Mid-Size Population (2000 < x < 20,000) Health Insurance Breakdown

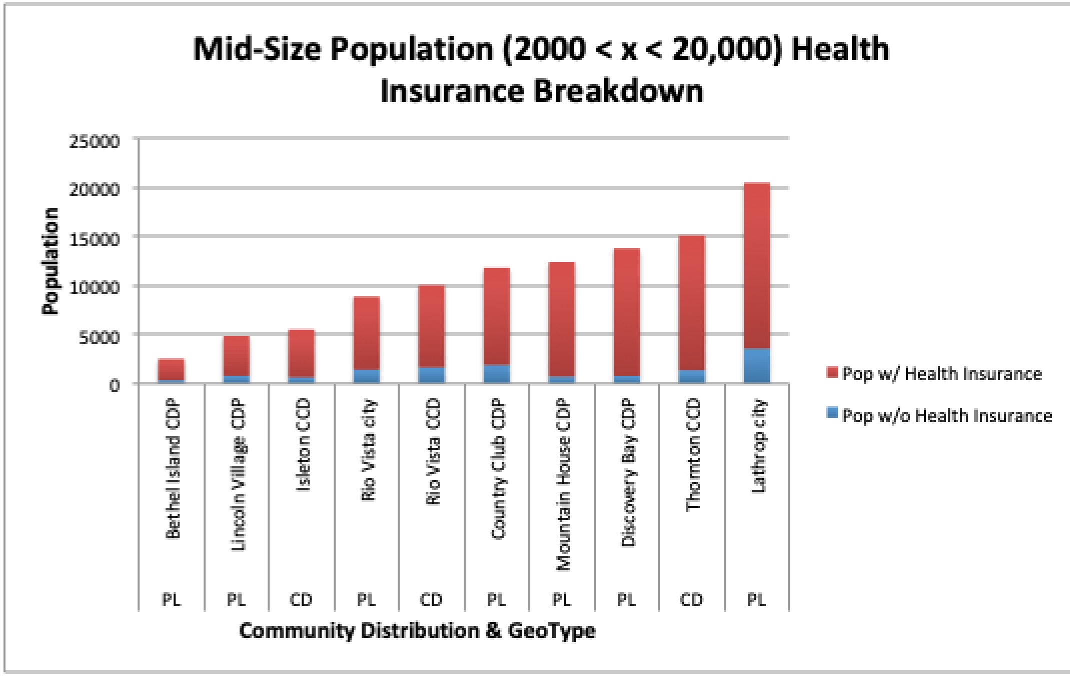


Figure 14: Larger Population (>20,000) Health Insurance Breakdown

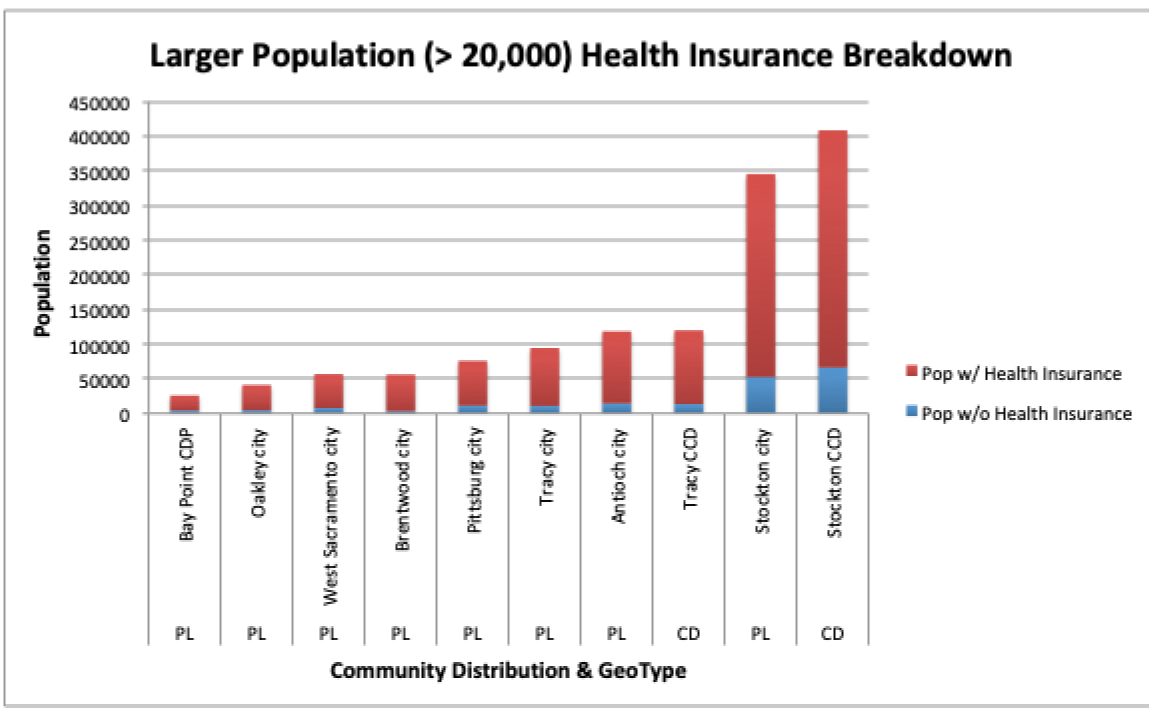


Figure 15: Percentage of Population w/out Vehicles in Bay Delta Vulnerable Communities

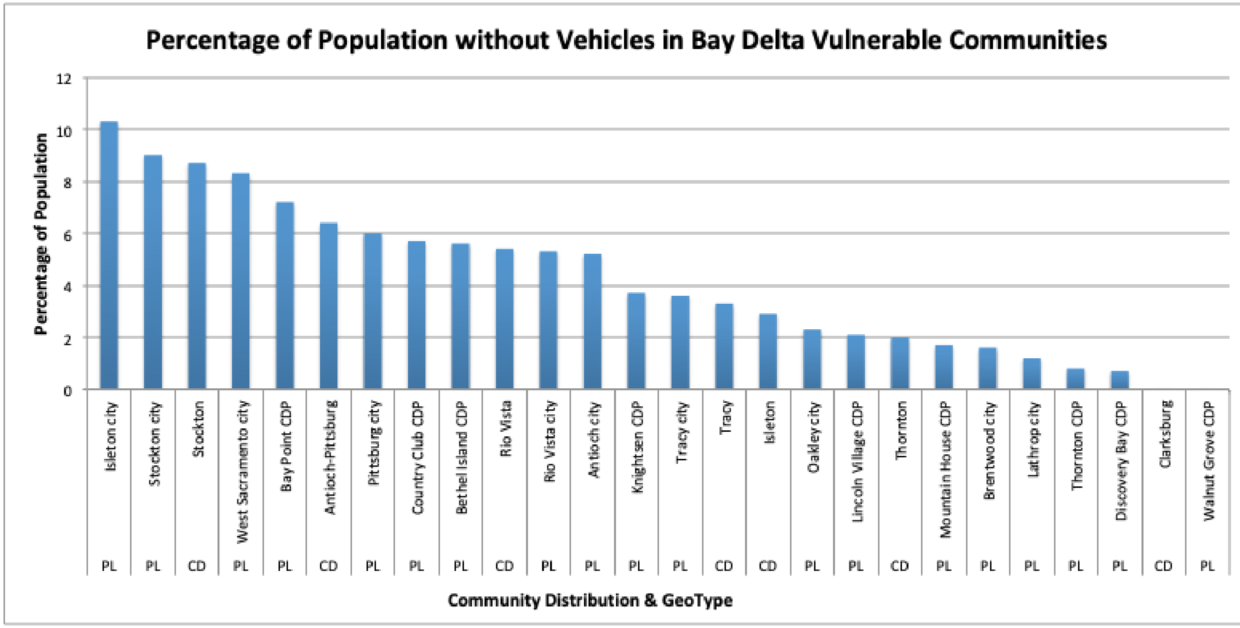
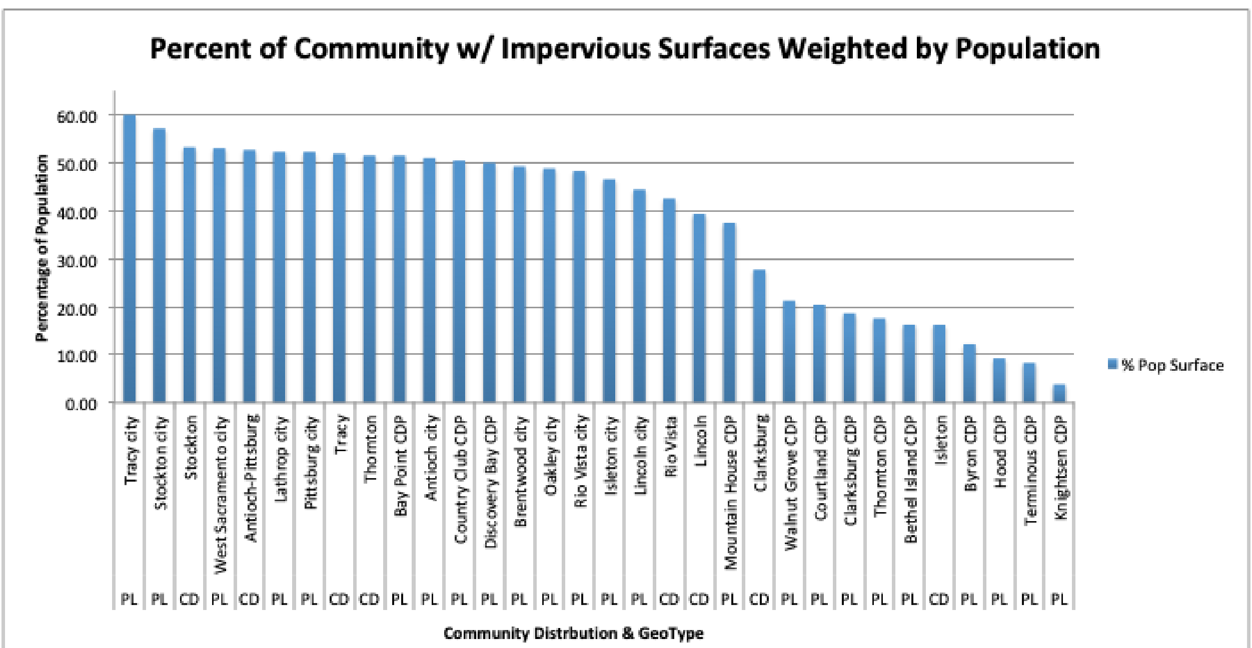


Figure 16: Percentage of Community w/ Impervious Surfaces Weighted by Population in Bay Delta Vulnerable Communities



Physical Factors:

Cal Adapt Data (Fig 17-20):

Figure 17: Historical/Projected Average Number of Extreme Heat Days in Vulnerable Communities from (1950-2100) in accordance with RCP 4.5 and RCP 8.5

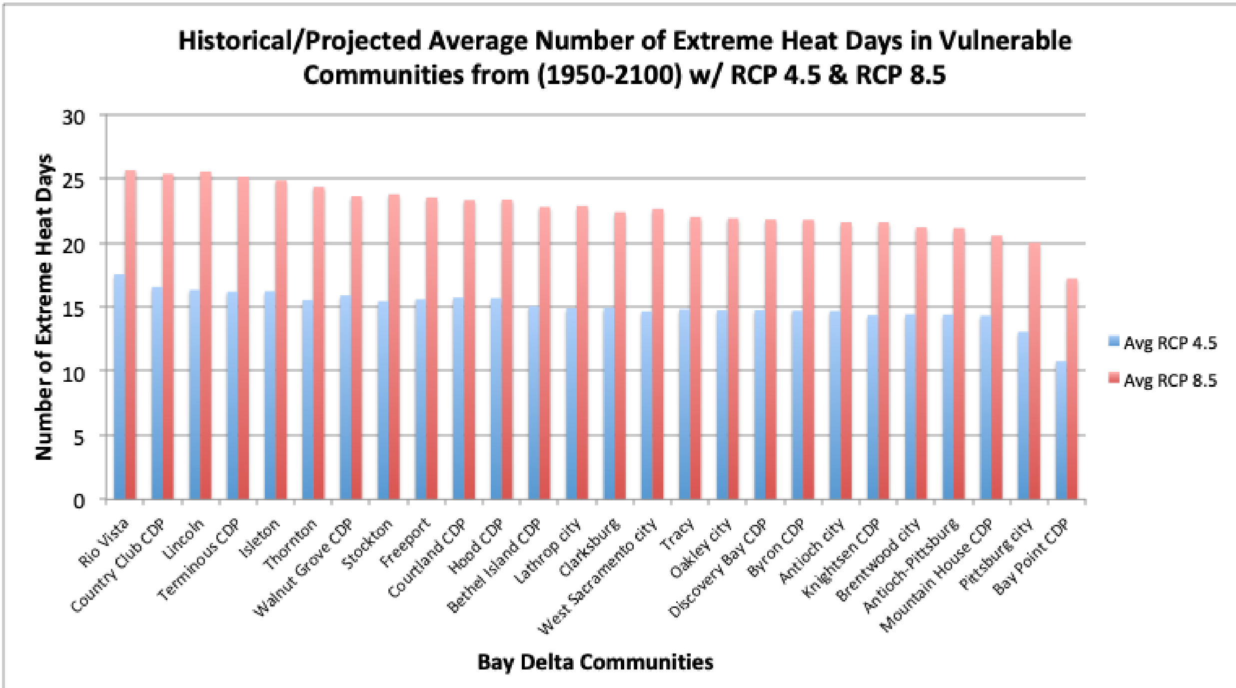


Figure 18: Average Number of Extreme Heat Days from RCP 4.5 and RCP 8.5 over the Historical and Projected Period from (1950-2100)

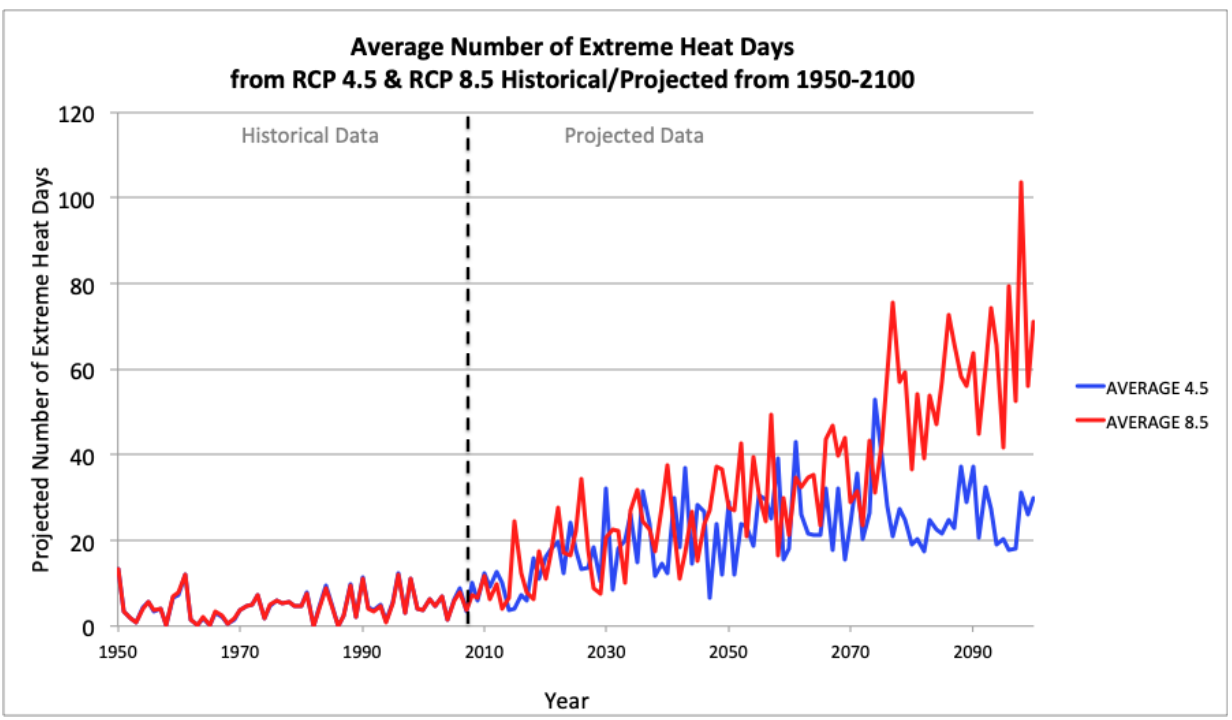


Figure 19: Full RCP 4.5 Spread

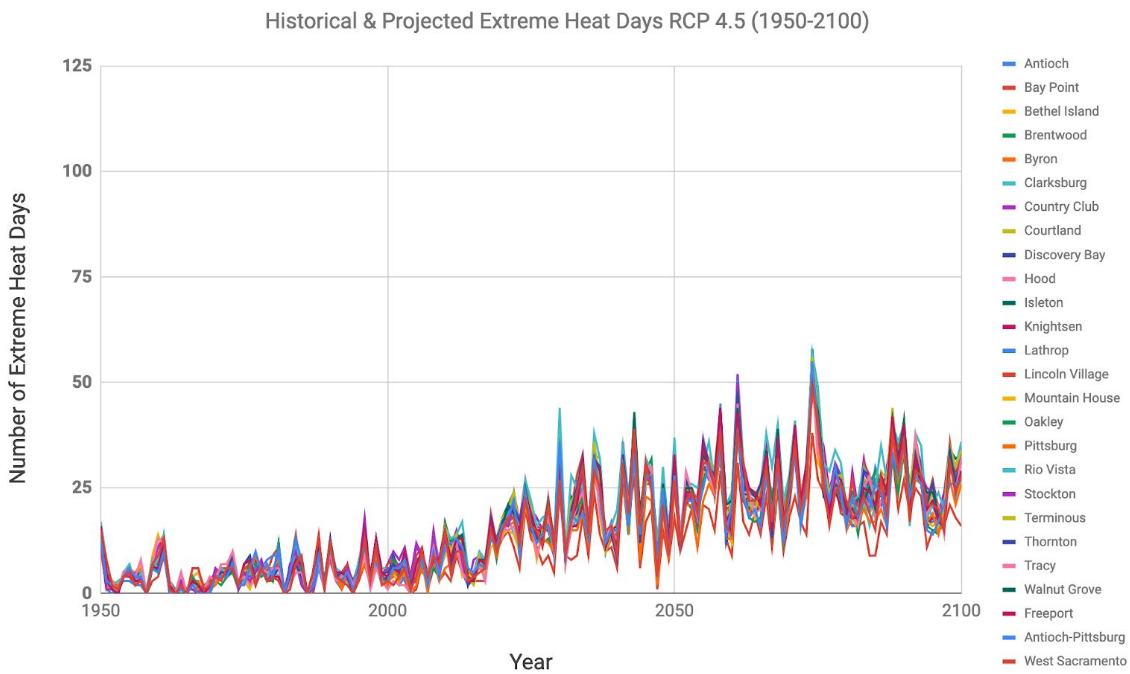


Figure 20: Full RCP 8.5 Spread

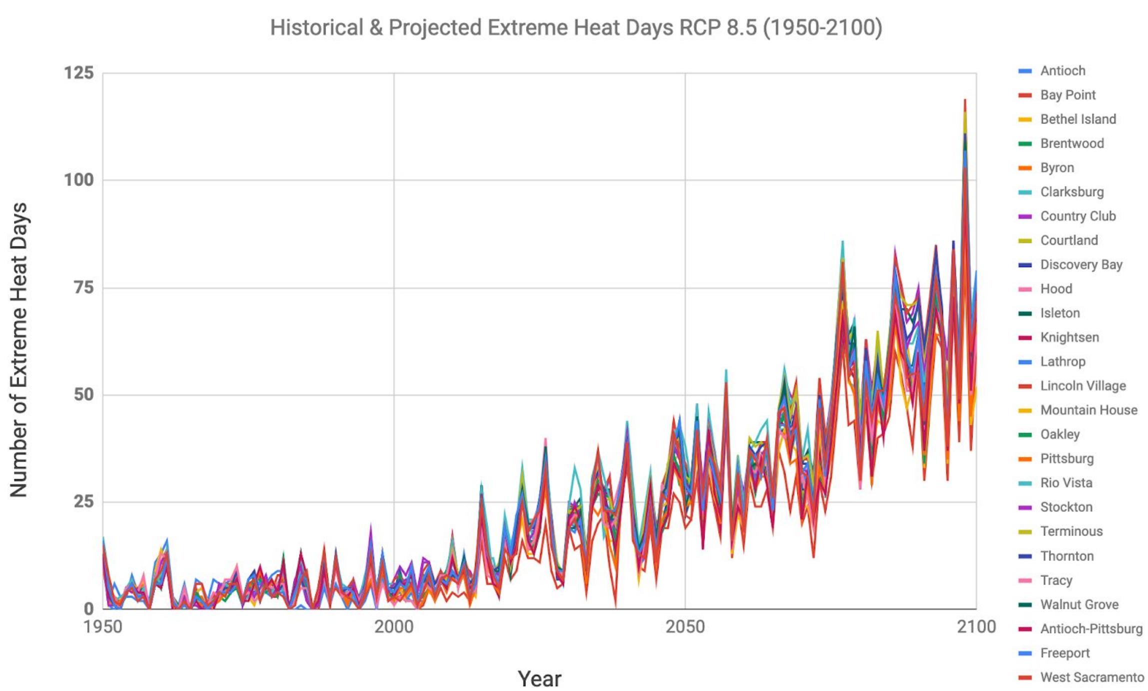


Figure 21: Percentage of Community w/ Impervious Surfaces Weighted by Area in Bay Delta Vulnerable Communities

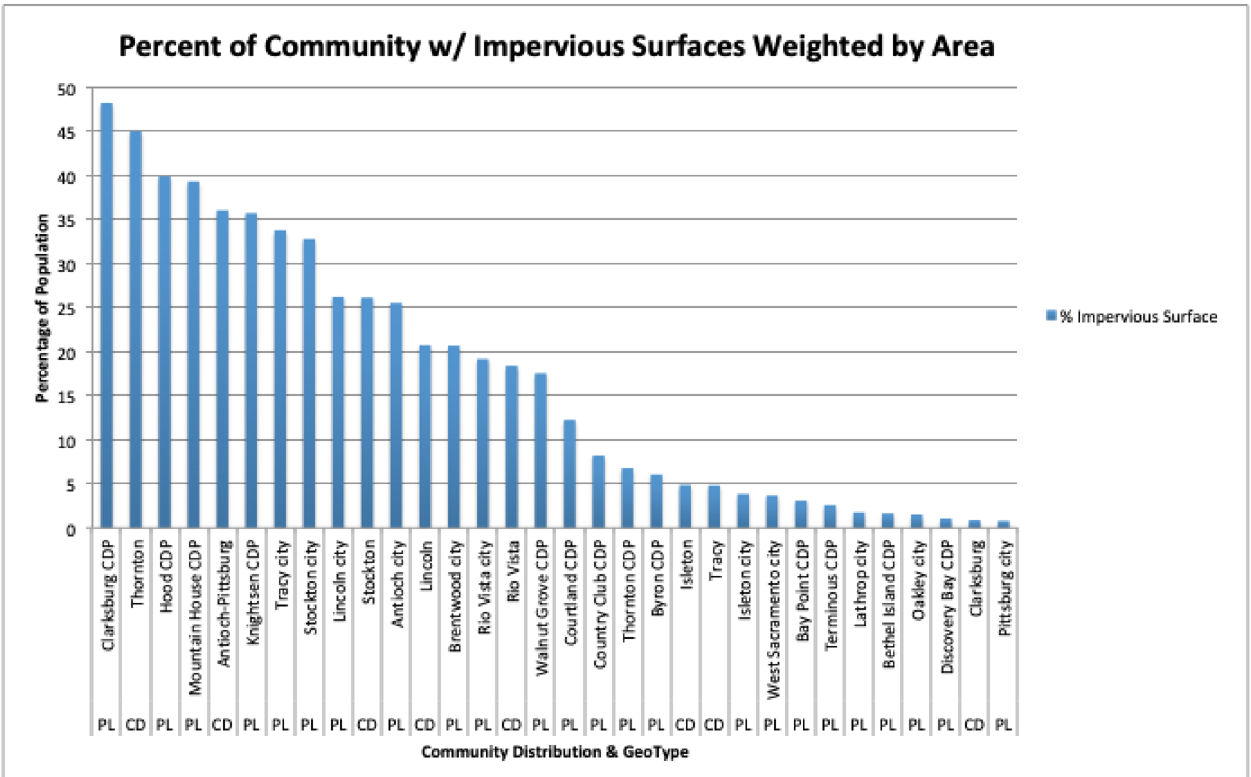
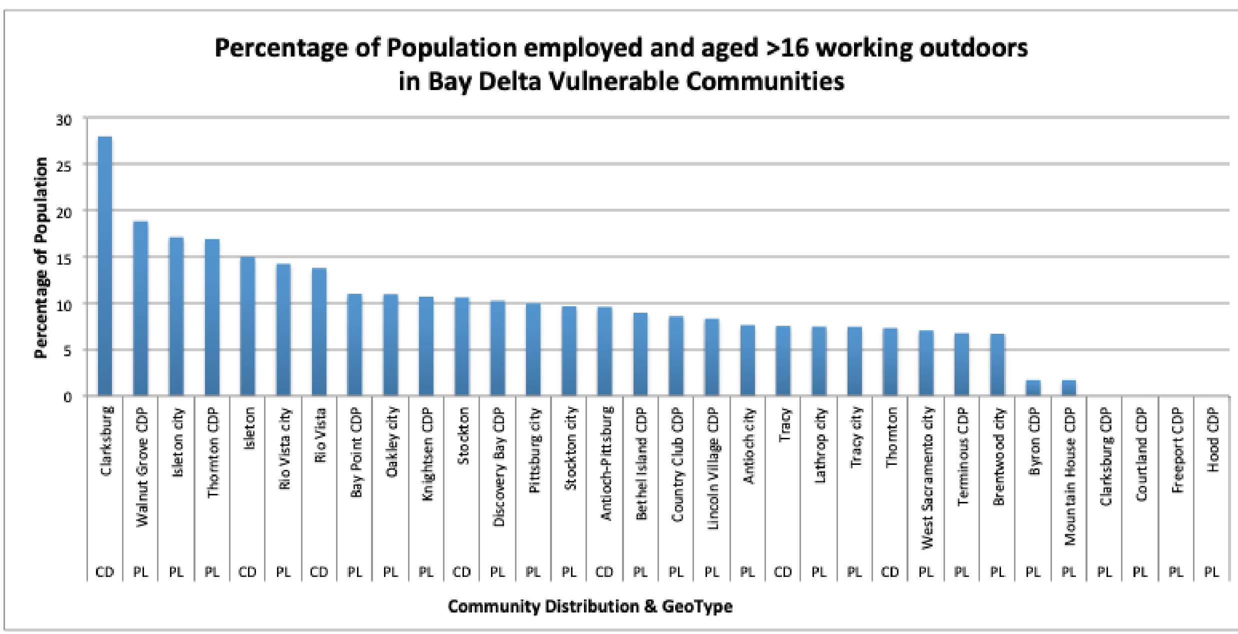


Figure 22: Percentage of Population >16 yrs Working Outdoors in Bay Delta Vulnerable Communities



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