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Spatial Triage: Data, Methods, and Opportunities to Advance Health Equity

By

Ellen Elisabeth Kersten

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Environmental Science, Policy, and Management

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Rachel Morello-Frosch, Chair

Professor Maggi Kelly

Professor Jason Corburn

Fall 2014

Spatial Triage: Data, Methods, and Opportunities to Advance Health Equity

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By

Ellen Elisabeth Kersten

Abstract

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by

Ellen Elisabeth Kersten

Doctor of Philosophy in Environmental Science, Policy, and Management

University of California, Berkeley

Professor Rachel Morello-Frosch, Chair

This dissertation examines whether spatial measures of health determinants and health outcomes are being used appropriately and effectively to improve the health of marginalized populations in the United States. I concentrate on three spatial measures that have received significant policy and regulatory attention in California and nationally: access to healthful foods, climate change, and housing quality. I find that measures of these health determinants have both significant limitations and unrealized potential for addressing health disparities and promoting health equity.

I define spatial triage as a process of using spatial data to screen or select place-based communities for targeted investments, policy action, and/or regulatory attention. Chapter 1 describes the historical context of spatial triage and how it relates to ongoing health equity research and policy. In Chapter 2, I evaluate spatial measures of community nutrition environments by comparing data from in-person store surveys against data from a commercial database. I find that stores in neighborhoods with higher population density or higher percentage of people of color have lower availability of healthful foods and that inaccuracies in commercial databases may produce biased measures of healthful food availability.

Chapter 3 focuses on spatial measures of climate change vulnerability. I find that currently used spatial measures of “disadvantaged communities” ignore many important factors, such as community assets, region-specific risks, and occupation-based hazards that contribute to place-based vulnerability. I draw from examples of successful actions by community-based environmental justice organizations and reframe “disadvantaged” communities as sites of solutions where innovative programs are being used to simultaneously address climate mitigation, adaptation, and equity goals.

In Chapter 4, I combine electronic health records, public housing locations, and census data to evaluate patterns of healthcare utilization and health outcomes for low-income children in San Francisco. I find that children who live in redeveloped public housing are less likely to have more than one acute care hospital visit within a year than children who live in older, traditional public housing. These results demonstrate how integrating patient-level data across hospitals and with data from other sectors can identify new types of place-based health disparities. Chapter 5 details recommendations for analytic, participatory, and cross-sector approaches to guide the development and implementation of more effective health equity research and policy.

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CHAPTER ONE

Introduction

“Unfortunately, *many Americans live on the outskirts of hope — some because of their poverty, and some because of their color, and all too many because of both.* Our task is to help replace their despair with opportunity. This administration today, here and now, declares unconditional war on poverty in America...Our aim is not only to relieve the symptom of poverty, but to cure it and, above all, to prevent it.”

President Lyndon Johnson, 1964

“...today’s economic challenges are different but they’ve still resulted in communities where in recent decades wrenching economic change has made opportunity harder and harder to come by. There are communities where for too many young people it feels like their future only extends to the next street corner or the outskirts of town...*A child’s course in life should be determined not by the zip code she’s born in, but by the strength of her work ethic and the scope of her dreams.*”

President Barack Obama, 2014

“Where you live affects your health” and other similar statements about how spatial, or “place-based,” factors influence health have become pervasive across sectors and fields of research over the past two decades. Even President Barack Obama, as quoted above, asserts that a child’s zip code shapes life chances. This sentiment is echoed by academics, such as the 2014 theme for the American Public Health Association conference, “Healthography,” and geographers pronouncing a “spatial turn in health research” (Richardson et al., 2013). Similarly, numerous foundations and public agencies direct resources toward projects that support “healthy places.” Community-based organizations have also embraced spatial approaches to environmental health and justice and healthy community development by advocating for designated “green zones” (Communities for a Better Environment, 2014) to transform areas overburdened by industrial pollution and by generating maps to measure a region’s “geography of opportunity” (Coalition for a Liveable Future, 2014).

In this dissertation, I examine if spatial measures of health determinants and health outcomes are being used appropriately and effectively to improve the health of disadvantaged populations in the United States. I find that spatial measures of health have both significant limitations and unrealized potential for addressing health disparities and promoting health equity. This introductory chapter provides an overview of key concepts and frameworks that inform my research approach, summarizes research questions and results from each chapter, and describes my work’s novel contributions to research and policy.

Health, health disparities, and spatial triage

Health is an inclusive concept, defined by the World Health Organization in 1948 as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”(World Health Organization, 1948). As such, spatial measures of health take many different forms, including metrics of health determinants, such as access to essential resources

and exposure to environmental harms, as well as measures of health outcomes, such as disease incidence and life expectancy. Spatial measures of health are those that are associated with a particular place (e.g. neighborhood, census tract, or county) and contrast with other types of health measures that only consider aspatial categories or characteristics such as race/ethnicity, class, or gender. Indeed, the quote above by former President Lyndon Johnson is an example of an aspatial description of health; he mentions poverty and skin color as factors that drive disparate life opportunities, which contrast with President Obama's spatial, place-based references to a street corner, town, and zip code.

Researchers, policymakers, and advocates increasingly use spatial data to not only measure place-based differences in health but also to highlight that many of these differences are *unjust* and to guide strategies to address health disparities. Health disparities are “health differences that adversely affect socially disadvantaged groups...disparities in health and its determinants are the metric for assessing health equity” (Braveman et al., 2011). Health equity is both a process and an outcome of “achieving the highest level of health for all people” (U.S. Department of Health and Human Services, 2014). Thus, spatial measures of health disparities identify place-based communities that are not able to achieve their highest level of health.

There are multiple drivers and manifestations of health disparities (Thomas et al., 2011), but much recent research has focused on neighborhood-level factors. Public health and epidemiology research show a consistent, cross-sectional relationship between neighborhood context and health outcomes and behaviors, even after controlling for individual characteristics (Kawachi and Berkman, 2003). For example, socio-economic neighborhood deprivation, such as the wealth, education, and employment of an area's population, is associated with incidence of cardiovascular disease (Diez Roux et al., 2001; Sundquist et al., 2004; Winkleby et al., 2007), body mass index (BMI) (Cubbin et al., 2006; Mujahid et al., 2005), smoking rates and levels of physical activity (Cubbin et al., 2006), individual diet (Morland et al., 2002), and adverse birth outcomes (Messer et al., 2006, 2008). Neighborhood built environment features, such as street-connectivity, land use, and green space have been found to be associated with BMI (Frank et al., 2006; Lachowycz and Jones, 2011) and walking behaviors (Owen et al., 2007). Limited availability of nutritious food in relation to fast food and convenience stores increases risk for obesity and diabetes (Babey et al., 2008). Psychosocial hazards, such as violent crime and abandoned buildings, are related to increased rates of cardiovascular disease (Augustin et al., 2008), and social capital measures correlate with self-rated health (Kawachi et al., 1999). Physical environmental exposures, such as air pollution from point and mobile sources, are associated with cardiovascular and respiratory diseases (Dominici et al., 2006) and preterm births (Wilhelm and Ritz, 2003).

Despite the broad evidence-base highlighting the multitude of neighborhood-level factors that affect health, conventional methods focus on the *distinction* between compositional (individual/local) and contextual (environmental/place) effects. However, there is an emerging shift in the health and place literature toward the implementation of a relational approach, which concentrates on the *processes* and *interactions* that occur between individuals, communities, and their environments over time (Cummins et al., 2007). Similarly, environmental justice advocates and public agencies are calling for improved characterizations and assessments of the *cumulative* impacts of the socio-economic, built, and physical environmental contexts as they relate to health disparities (U.S. Environmental Protection Agency Office of Environmental Justice, 2011). This

dissertation seeks to inform the implementation of a relational health assessment approach that can guide policy, planning, and community organizing efforts across multiple scales to promote health equity.

The title of this dissertation, “spatial triage,” refers to what I identify as one among many other possible approaches to addressing health disparities and promoting health equity. Triage draws from the French word *trier*, meaning “to separate out.” Triage is most commonly used as a process in healthcare and disaster response settings to categorize patients or victims based on the urgency of their condition with the goal of assigning scarce resources in ways that will maximize favorable health outcomes. Spatial triage, therefore, refers to the process of using spatial data to screen or select place-based communities for targeted investments, policy action, and/or regulatory attention.

Spatial triage is not a new process. Even before the growth of geographic information systems and other spatial technologies such as global positioning systems and remote sensing, spatial measures were used for research, public policy, and program implementation. However, spatial triage has historically created and exacerbated health disparities, and there is cause to critically evaluate the expanding focus on spatial measures that purport to measure, monitor, and promote health equity.

For example, zoning ordinances, which are supposedly designed to “protect the health and safety of the community,” have had discriminatory and marginalizing effects on particular communities (Wilson et al., 2008). Zoning applications from New York as early as 1956 show that residential neighborhoods that had a higher percentage of minority populations, lower than average incomes, and lower rates of home ownership were deemed “marginal” or “deteriorated” and were targeted for rezoning to industrial use (Maantay, 2001). Meanwhile, neighborhoods with a higher than average percentage white population, higher than average incomes, and higher rates of home ownership were classified as “maintained” and experienced reductions in proximate industrial land uses (Maantay, 2001). Federal regulators and financial institutions have also used spatial data for “redlining”, the practice of denying or offering less favorable terms for mortgages, home improvements, business loans, and property insurance to particular neighborhoods based on their racial/ethnic makeup or other discriminatory measures of subjective financial risk (Squires and Velez, 1987). Federally-funded urban renewal, or “slum clearance,” was supported by spatial surveys by public health professionals of blighted housing units and neighborhoods and resulted in the displacement of over 4 million people, of which the vast majority were African American (Lopez, 2009).

The above examples demonstrate how spatial triage has been used to legitimize a variety of policies that have contributed to health disparities through increased exposure to industrial pollution, denied financial resources, and forced displacement for targeted communities. Although the explicit racial discrimination that fueled these and other similar spatially-guided policies is now deemed illegal by the Fair Housing Act and other legislation from the civil rights movement in the 1960s, the spatially marginalizing and segregating effects of these policies persist. Indeed, spatially concentrated poverty and racial residential segregation has increased over the past decade (Lichter et al., 2012), and present-day spatial triage has the potential to further marginalize these same populations and places and exacerbate health disparities.

For instance, transit-oriented development, which provides incentives for housing development around major transit centers, is promoted as a way to create healthy, diverse, “smart growth” neighborhoods. Yet, most new housing near transit centers is unaffordable to the very populations who rely most on public transportation, low- and moderate-income households (Belzer and Poticha, 2009; Pollack et al., 2010), and can gentrify communities. At a recent California Strategic Growth Council (SGC) meeting to solicit public input on proposed criteria for selecting projects to receive funding from the state’s Affordable Housing and Sustainable Communities program, a community advocate from Richmond pointed out that the stipulation for projects to be near a “major transit stop” precluded most areas of his city from being eligible for funding. He noted that regional transit operators have reduced transit service in his neighborhood over the past decade. If the funding criteria remains as proposed, spatial measures of transit availability will essentially perpetuate the disadvantage of this man’s neighborhood.

Research approach

In light of these examples of the real and potentially marginalizing effects of spatial measures, there is a need to evaluate if and how spatial measures of health determinants and health outcomes can be used to promote health equity. I concentrate on three recent and ongoing examples of spatial triage that have received significant policy and regulatory attention in California and nationally: improving access to healthful foods in “food deserts,” mitigating and adapting to climate change in “disadvantaged neighborhoods,” and redeveloping “dilapidated” public housing. For each chapter, I ask:

- What data is being used to create spatial measures of these health determinants, and why?
- Who is creating and using spatial measures, and how?
- What are the limitations of spatial measures, and how can those be addressed?
- What are the policy and regulatory implications of spatial measures and the methods used to analyze them?

My approach to answering these questions is interdisciplinary. Figure 1.1 displays the major disciplines and specific and overlapping sub-fields that I integrate in this work. My unique combination of theoretical and applied fields of research is in line with Amartya Sen’s description of health equity as “a broad discipline, rather than as a narrow formulaic criterion, there is room for many distinct approaches within the basic idea of health equity” (Sen, 2002). Each field in Figure 1.1 has distinct theories and methods that contribute to my conceptualization and evaluation of health equity.

For instance, I use an environmental justice (EJ) framework, which emphasizes both procedural and distributive justice for historically marginalized populations, to evaluate factors relevant to spatial data analysis, such as scale, accuracy, precision, and representation. These overlapping concepts within EJ and spatial analysis relate to the field of Critical GIS, which evaluates the social implications of geospatial technologies. Critical GIS scholars recognize that geospatial data and methods can be both marginalizing and empowering depending on contextual and structural factors such as political economy, politics, and power relations (Harris and Weiner, 1998). I also draw from emerging work in the fields of community development and health impact assessment that use spatial health data and combined qualitative and quantitative methods to evaluate community needs and potential health equity impacts of new projects (Pastor and Morello-Frosch, 2014). Public policy literature on the policy process and issues of governance

and democratic decision-making (Bach et al., 2012; Jann and Wegrich, 2007) guide my development of specific policy recommendations that are included in each of the following chapters.

Chapter overview

As discussed above, each of the next three chapters of this dissertation evaluate how spatial data and methods are used to target communities for health equity policies related to different types of health determinants: healthful food availability, climate change, and housing quality. For each of these determinants, I consider various scopes, scales, and sources of spatial data as they relate to ongoing policy implementation processes.

In chapter two, I compare spatial measures of small food stores from a commercial database versus “ground-truthed” data from in-person store surveys. Commercial database measures classified all of the evaluated stores as “small grocery” stores. However, the survey data show that 15 percent of stores in the commercial database did not exist, and more than half of the remaining stores were convenience or specialty stores that did not sell a healthful selection of foods. Furthermore, variation in the healthful food availability did not vary randomly across the sampled stores; stores in neighborhoods with higher population density or higher percentage of people of color had lower availability of healthful foods. The spatial and categorical inaccuracies in commercial databases may therefore produce biased measures of community nutrition environments. Ongoing programs that seek to support equitable access to healthful foods, such as the Federal Healthy Food Financing Initiative and the California FreshWorks Fund, must incorporate in-store survey data to accurately measure and monitor healthful food availability across diverse neighborhood contexts.

In chapter three, I also compare different types of spatial data, but in relation to climate change impacts and policies in California. I compare place-based perceptions of climate change impacts, vulnerability, and solutions in communities that have been active in California’s environmental justice movement with quantitative measures of community disadvantage and investment strategies planned by state agencies. I use both qualitative and quantitative methods and demonstrate that currently used spatial measures of “disadvantaged communities” ignore many important factors, such as community assets, region-specific risks, and occupation-based hazards that contribute to place-based vulnerability. I propose a climate equity framework that integrates adaptation, mitigation, and equity policy objectives and identify common components of community-based work (specific equity targets, multi-level civic engagement, and local knowledge integration) that can inform more equitable implementation of climate change policies in California and elsewhere.

In chapter four, I combine multiple types of spatial data, including electronic health records, public housing locations, and neighborhood poverty, to evaluate patterns of healthcare utilization and health outcomes for low-income children in San Francisco. I find that children who lived in redeveloped public housing were less likely to have more than one acute care hospital visit within a year than children who lived in older, traditional public housing. Children who lived in any type of public housing seek acute health care for medical conditions that are distinct from those of other low-income children in the same neighborhood. These variations in healthcare utilization and health outcomes by children’s housing type would not have been distinguishable if the analysis only used common neighborhood-level spatial measures or data from a single

hospital. Integrating patient-level data across hospitals and with data from other sectors can identify new types of place-based health disparities. These findings are relevant for non-profit hospitals that are required by the Affordable Care Act to conduct community health needs assessments and create implementation plans to improve health outcomes for vulnerable populations in their service areas.

In chapter five, I detail recommendations for health equity research and policy, with a focus on necessary changes to data collection and management, intra- and inter-sector collaboration, and adaptive interventions. I highlight new critical questions for future research and propose approaches for addressing ongoing issues related to health disparities and health equity.

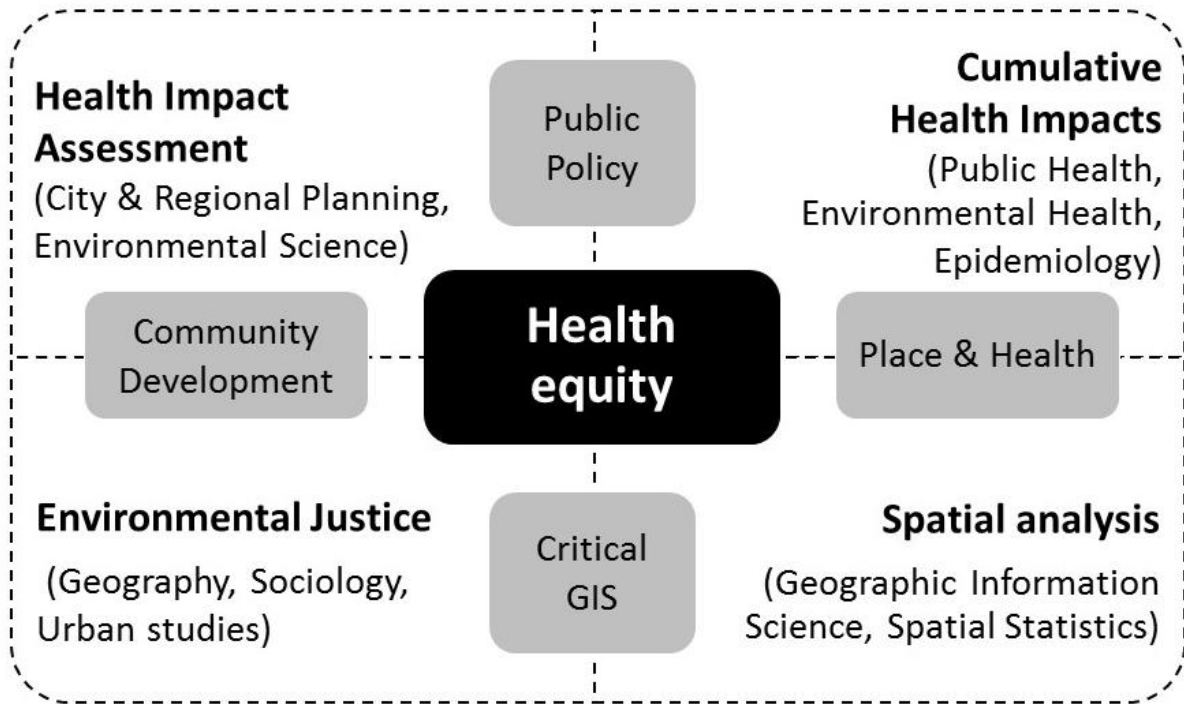
Novel contributions

Together, the two quotes by US Presidents at the beginning of this chapter raise three overarching issues to which this dissertation provides some important insights. First, disparities in opportunities for well-being are not just spatial; disparities also manifest across and within population groups by race/ethnicity and class as highlighted by President Johnson, as well as by immigration status, gender, sexual orientation, and a host of other categorizations. To be accurate and effective, spatial measures of health disparities must take into account historical and ongoing patterns of discrimination and marginalization that are inherently and intimately related to the place-based differences identified through spatial analysis. Each chapter demonstrates that relying on one source or type of spatial data alone can lead to misleading characterizations of spatial factors associated with health disparities. Prior research has found that it is not always necessary to wait to develop a flawless set of measures to move forward with health equity programs and policies (Corburn, 2005). Yet, this research demonstrates that it is necessary to consider and be transparent about potential bias, missing data, and alternative scales of impact that influence our spatial measures and understanding of health disparities.

Secondly, zip codes, race/ethnicity, poverty, and other classifications are not the *causes* of health disparities; they are socially constructed categorizations of places and people that are used to identify and communicate differences. The causes of health disparities are historical, systemic, and not yet sufficiently conveyed by spatial data and methods. Nancy Krieger points out that “determinants of health inequities necessarily include issues of power, governance, and social inequality,” and many images that purport to depict the drivers of health inequities actually only identify determinants of overall population health (Krieger, 2008). Krieger’s work critiqued various text-based descriptions and schematics of health and health disparities, but this dissertation focuses on *spatial* measures and representations of health determinants and how they influence our explanations of health disparities. Even with incomplete and limited data, commonly used spatial measures and visualizations of health have very effectively brought attention to the many forms of health disparities. However, I argue that the spatial measures and representations currently used by academics, policymakers, and advocates most often simply depict the *symptoms* of health disparities, not the causes. We need new measures and methods to better communicate and address the upstream drivers of health disparities, such as racism, classism, and other forms of discrimination as well as the inequitable distribution of power within our systems of governance. This dissertation highlights examples of analytic, participatory, and cross-sector approaches that are needed to guide the development and implementation of more effective health equity research and policy.

Lastly, disparities were a policy concern fifty years ago and remain so today. Despite, and in some cases because of, a variety of policy actions targeted to improve the “most disadvantaged” areas, many populations and places have disparate access to health promoting resources, excessive exposure to environmental harms, and limited capacity to engage in the decision-making processes that effect their lives and communities. How can we change our course? This dissertation is not just an academic critique of spatial measures; it also offers practical ways to improve our capacity to understand and address health disparities. Specific recommendations for policy and research are detailed in each chapter and synthesized in the conclusion.

Figure 1.1: Interdisciplinary approach to health equity used in this dissertation



CHAPTER TWO

Food for health: Comparing database and survey measures of community nutrition environments across neighborhood contexts*

Abstract

Small food stores are prevalent in urban neighborhoods, but the availability of nutritious food at such stores is not well known. The objective of this study was to determine whether data from three sources would yield a single, homogenous, healthful food store category that can be used to accurately characterize community nutrition environments for public health research. In-store surveys on store type and the availability of nutritious food were collected from a sample of non-chain food stores (n = 102) in six predominantly urban counties in Northern California (Alameda, Contra Costa, Marin, Sacramento, San Francisco, and Santa Clara). I compared survey results with commercial database information and neighborhood sociodemographic data by using independent sample *t* tests and classification and regression trees. Sampled small food stores yielded a heterogeneous group of stores in terms of store type and nutritious food options. Most stores were identified as convenience (54%) or specialty stores (22%); others were small grocery stores (19%) and large grocery stores (5%). Convenience and specialty stores were smaller and carried fewer nutritious and fresh food items. The availability of nutritious food and produce was better in stores in neighborhoods that had a higher percentage of white residents and a lower population density but did not differ significantly by neighborhood income. Commercial databases alone may not adequately categorize small food stores and the availability of nutritious foods. Alternative measures are needed to more accurately inform research and policies that seek to address disparities in diet-related health conditions.

* Portions of this chapter were published by *Preventing Chronic Disease* as Kersten E, Laraia B, Kelly M, Adler N, Yen I. Small Food Stores and Availability of Nutritious Foods: A Comparison of Database and In-Store Measures, Northern California, 2009. *Prev Chronic Dis*. 2012;9:120023. Available at <http://dx.doi.org/10.5888/pcd9.120023>.

Introduction

One aspect of neighborhood context that has received considerable attention from public health researchers and advocates in recent years is the availability of food outlets and nutritious food, commonly referred to as the community nutrition environment (Glanz, 2009). Given the strong relationship between diet and health, and the limited availability of sources of nutritious food in many low-income and racial/ethnic minority neighborhoods, community nutrition environments may contribute to disparities in diet-related health conditions, such as obesity, diabetes, and cardiovascular disease (Nicole et al., 2009; Walker et al., 2010).

To evaluate community nutrition environments, researchers frequently use food store location and classification data from secondary data sources, such as proprietary commercial databases or business listings from public agencies (Kelly et al., 2011). Supermarkets and large chain grocery stores tend to offer a variety of nutritious foods, and access to such stores is related to improved diet and reduced risk for obesity (Nicole et al., 2009; Walker et al., 2010). However, the classification of small, independently owned (non-chain) food stores remains a challenge. Small, independent food stores have been either ignored (Moore et al., 2008; Zenk et al., 2005) or distinguished from supermarkets and convenience stores according to the number of cash registers (Glanz et al., 2007), industry codes (Powell, Auld, et al., 2007), store name (Laraia et al., 2004; Morland et al., 2002), number of employees (Gibson, 2010; Moore and Diez-Roux, 2006), or annual sales volume (Wang et al., 2007). More recent approaches use combinations of characteristics included in commercial databases to categorize independent food stores as either “healthy” or “unhealthy” (Babey et al., 2008; Jones-Smith et al., 2013; Rundle et al., 2008; Truong et al., 2010).

Small, independent food stores comprise most food retail locations in urban neighborhoods, and proper categorization of such stores is important for studies on community nutrition environments. The primary objective of this study was to examine the categorization of small food stores and determine whether data from three sources would yield a single homogenous healthful food store category. I hypothesized that most small food stores (defined as generating less than \$1 million in annual sales) selected from a single industry category for grocery stores would represent a homogenous group of healthful food stores (i.e. offer nutritious and fresh food items). Secondary objectives were to examine the availability of nutritious foods in small food stores across neighborhood sociodemographic contexts and test for inaccuracies in commercial database variables that could bias or misrepresent measures of nutritious food availability.

Methods

Study design

I used stratified random sampling to select stores from a commercial database to survey. I used in-store surveys to assess store type and the availability of fresh and nutritious food items at selected stores and compared these measures with neighborhood-level sociodemographic characteristics and commercial database attributes. Institutional review board approval was not required for this study because no human participants were involved.

Study sample

I selected a six county study area in the Sacramento and San Francisco Bay Area (Alameda, Contra Costa, Marin, Sacramento, San Francisco, and Santa Clara counties) because two co-authors (B.L. and I.H.Y.) were working on two studies in this area. All six counties have predominantly urban populations; more than 90% of both food stores and households are located in urban areas in each county. I identified all small grocery stores in the study area by using 2008 data from InfoUSA (www.infousa.com), a provider of data on commercial establishments, through an Esri Business Analyst extension (Esri, Redlands, California). The InfoUSA database includes attributes for each business location, including industry code (as reported by each business using the North American Industry Classification System [NAICS]), annual sales volume, number of employees, franchise status, and size (categorical square footage).

Using the NAICS industry code for “supermarkets and other grocery (except convenience) stores” (445110), I identified 2,400 stores. I excluded stores that had a NAICS code for convenience stores (445120) because they comprise a much smaller portion of the retail food environment ($n = 522$) than grocery stores do in the study area, and more than half of the convenience stores are chains (e.g., 7-Eleven, Circle K) that tend to have a limited availability of nutritious food. Of the grocery stores identified, 1,604 (67%) had an annual sales volume of less than \$1 million, which I used to define “small.” I used this threshold because it is the lowest value used in previous studies to differentiate between “healthy” and “unhealthy” small food stores in California (Babey et al., 2008; Truong et al., 2010).

After also excluding stores designated as headquarters or franchises, there were 1,582 small, nonchain food stores in the sample. All of these stores were in the same size category (1–2,499 sq. ft.) and had fewer than five employees. To ensure sampling across the number of employees that has been used to differentiate stores in previous studies (Babey et al., 2008), I divided the sample into two groups: stores that had two or fewer employees ($n = 1,289$ [81%]) and stores with three or four employees ($n = 293$ [19%]). I stratified each of the two groups by county and by quartile of neighborhood deprivation (Messer et al., 2006) and randomly selected 5% of the stores from each stratum. Each 5% sample was rounded up to the next whole number, resulting in an initial sample of 102 stores, or 6% of small grocery stores in the study area.

Compared with the other small, independent stores in the study area, the stores in this sample had a higher mean annual sales volume (\$579,000 vs \$642,000) and more employees (mean employee count of 1.5 for all stores vs mean of 1.7 for stores in the sample). Of the 102 stores, I could not survey 15 (4 could not be found, 3 were out of business, and 8 were not food stores). No store managers declined to have their stores surveyed. My final sample included 87 stores.

In-store survey

I designed a two-page, 39-question survey to assess each store (Appendix A). The survey was adapted from the CX³ Food Availability and Marketing Survey created and validated by the California Department of Public Health (Ghirardelli et al., 2011). My research team and I conducted surveys from May through early September 2009. In each store, surveyors introduced themselves to store managers, described the survey, and provided a letter, including author contact information, about the study. The survey included questions in seven main categories: store name and location; exterior characteristics; estimated area in square feet; availability and

variety of fresh fruit, vegetables, and raw meat/seafood (coded from 1 to 4, with 4 being the most variety); quality of fresh fruit and vegetables (coded from 1 to 4, with 4 being the highest quality); and presence of 17 nutritious food items (e.g., canned and frozen fruits and vegetables, low-fat milk, high-fiber cereal) (coded 1 for presence or 0 for absence). I created 4 categories of store type as the dependent variable for analyses:

Large grocery: a large store that sells food and other items, including canned and frozen foods, fresh fruits and vegetables, and fresh (raw) and prepared meat, fish, and poultry.

Small grocery: usually an independent store that may sell food including canned and frozen foods, fresh fruits and vegetables, and fresh (raw) and prepared meat, fish, and poultry as well as convenience items and alcohol.

Convenience: a store that sells convenience items only, including bread, milk, soda, and snacks and may sell alcohol and gasoline. These stores do not sell fresh (raw) meat.

Specialty: liquor store, bakery, donut shop, meat or fish markets (predominantly selling fresh/raw meat), or other specialty stores.

The inventory of 17 food items was summed to create a “nutritious food score” (possible range of 0–17), and a “fresh score” was created by summing the coded values for the availability of fresh fruit, vegetables, and raw meat/seafood (possible range of 3–12, with 3 indicating no fresh food and 12 indicating a variety of fresh foods).

Neighborhood sociodemographic context

I used 2000 US Census data at the tract level (FactFinder, 2000) to characterize the neighborhood sociodemographic context for each store. A neighborhood deprivation index was created as a continuous variable according to previous methods (Messer et al., 2006) that used principal component analysis of eight derived census variables (percentage of people who have an income below poverty level, percentage of female-headed households that have dependents, percentage of households that have an annual income of less than \$30,000, percentage of households that have public assistance income, percentage of people aged 16 or older in the civilian labor force who are unemployed, percentage of men in management, percentage of all people aged 25 or older who did not graduate from high school, and percentage of households with more than one person per room). The resulting scores ranged from -3.3 to 14.8; the mean (standard deviation [SD]) score was 0 (2.2). The more positive the score, the more deprived the census tract. The index was divided into quartiles for sampling purposes.

I created continuous variables for race/ethnicity according to the percentage of white, Hispanic, black, and Asian populations. Each neighborhood was also characterized according to population density (total population divided by area in square miles), percentage of children (population aged younger than 18 divided by total population) and elderly (total population 65 or older divided by total population), and neighborhood stability (percentage of population that lived at the same location in 1995 and 2000).

Statistical analyses

Independent sample *t* tests were used to compare the mean differences for fresh food availability among store types and to evaluate the differences between neighborhood sociodemographic context and store type. I used Stata/SE 9.0 (StataCorp, College Station, Texas) for these analyses. I also conducted classification and regression tree (CART) analysis by using variables from the in-store surveys, the InfoUSA database, and census information to identify store attributes and neighborhood characteristics that most parsimoniously identified store type. CART analysis can handle multiple outcome groups and dichotomous, ordinal, categorical, and continuous explanatory variables, which makes it an ideal method in this analysis where various attributes are associated with each food store. CART builds a “tree” for classifying the data by finding “nodes,” or values of the explanatory variables that significantly differentiate one or more outcome groups (Breiman et al., 1984). For the CART analysis, large and small grocery stores were combined into one outcome group because these two store types represented the same outcome of interest, healthful food availability. Convenience and specialty stores remained separate groups because of their more varied and distinct survey results, for a total of three outcome groups. Trees were “pruned” based on a complexity parameter of 0.01, which means that each resulting branch increased the fit of the tree by at least a factor of 0.01. The CART analysis was conducted using the *rpart* library (Therneau and Atkinson, 2010) in the R Statistical Environment 10.1.1 (R Development Core Team, Vienna, Austria).

Results

Types of food stores

The 87 stores surveyed were categorized as four large grocery stores, 17 small grocery stores, 47 convenience stores, and 19 specialty stores (Figure 2.1). Of the 19 specialty stores, 12 were ethnic food stores, three were liquor stores that sold some microwavable food items, two sold only meat and produce, one was a delicatessen, and one was a wine and cheese store that sold some produce items.

Availability of nutritious food

Of the 87 surveyed stores, 53 (61%) sold at least a limited variety (1–3 types) of both fresh fruit and vegetables, and 20 stores (23%) sold no fruits or vegetables. Of the 60 (69%) stores that sold at least some fruit, more than half ($n = 35$) had high- or fair-quality fruit (all good or more good than poor quality). Of the 59 (68%) stores that sold at least some vegetables, more than two-thirds ($n = 40$) had high- or fair-quality vegetables. Fifty stores (57%) carried more than half of the surveyed items (nutritious food score >8), and 35 (40%) had more than 3 types of fresh fruits, vegetables, and raw meat/seafood (fresh score >6). Twenty-eight stores (32%) had fewer than half of the surveyed nutritious food items (nutritious food score >8) and sold no or a limited variety of fresh foods (fresh score >6).

Nutritious and fresh food availability varied by store type (Table 2.1). All four large grocery stores had a variety of nutritious food items and good-quality produce and meat products. The small grocery stores had a greater number of nutritious food items and fresh fruit and vegetables than convenience or specialty stores. Of the stores that carried some fruits or vegetables, larger grocery stores had better-quality vegetables than small grocery stores and better-quality fruits

and vegetables than convenience stores. Specialty stores that had some fruit had better-quality fruit than convenience stores.

Other store attributes

According to in-store surveys, large grocery stores had the greatest estimated square footage, and small grocery stores were larger than convenience and specialty stores. According to InfoUSA, the mean number of employees did not differ significantly by store type; large grocery stores had a significantly larger sales volume than convenience stores (Table 2.1).

Neighborhood sociodemographic differences by store type

Neighborhood deprivation did not differ by store type (Table 2.2). However, neighborhoods that had small grocery stores were on average 63% white; neighborhoods that had convenience stores were on average 49% white ($t = 2.32, P = .02$). Neighborhoods that had small grocery stores were less densely populated than neighborhoods that had convenience stores ($t = -2.92, P = .005$). Neighborhoods that had specialty stores had a larger average percentage of Asians (36%) than neighborhoods that had small grocery (7% Asian; $t = -3.80, P < .001$) or convenience stores (22% Asian; $t = -2.32, P = .02$). No other sociodemographic measure differed by store type.

Classification of stores by data source

When I used in-store survey information for the CART analysis, 86% of the stores were classified correctly (Figure 2.2a). The most distinguishing variables were variety of vegetables, estimated store square footage, and nutritious food score. When only census information was used, 72% of the stores were classified correctly; neighborhood population density, percentage Asian population, percentage white population, and percentage black population were the most distinguishing variables (Figure 2.2b). A CART analysis of the InfoUSA values for the number of employees and annual sales volume could not be completed because none of the database variables adequately distinguished store type.

Discussion

A stratified random selection of small, independent food stores drawn from a single industry category in a single commercial database did not yield a homogenous group of small food stores. Instead, the sample yielded a heterogeneous group of stores in terms of nutritious food options: some stores provided many nutritious food options and fresh fruits and vegetables, but most provided a limited variety of nutritious food items and produce. Store attributes (number of employees and sales volume) listed in the commercial database did not distinguish store type as well as the in-store survey and census data did. These findings reinforce those of previous studies that found significant discrepancies between store categorizations from secondary food retail databases and field observations (Cummins and Macintyre, 2009; Liese et al., 2010; Paquet et al., 2008; Powell et al., 2011) and suggest that database imprecision may introduce error or bias or both into public health and epidemiological research.

Commercial databases may not identify food stores in more deprived neighborhoods as accurately as they do in less deprived neighborhoods (Cummins and Macintyre, 2009). This was not the case in this study. However, convenience stores (limited availability of nutritious foods)

tended to be in more densely populated census tracts, and grocery stores (better availability of nutritious food) tended to be in tracts that had a higher percentage of whites. Convenience and specialty stores were found in tracts that had a higher average percentage of Asians. Powell et al. also found differences in agreement on census tract race/ethnicity between field observations and proprietary database information for grocery stores in Chicago (Powell et al., 2011), corroborating evidence that discrepancies in measures of community nutrition environments do not vary randomly among all neighborhoods. Store visits may be necessary to obtain a more accurate understanding of the availability of nutritious food.

My results show discrepancies between a commercial database and surveyed characterizations of store types across neighborhoods, thereby complicating efforts to quantify the availability of nutritious food in large areas by using commercial databases. Improving the availability of nutritious food items and fresh foods at small grocery, convenience, and specialty food stores is a promising approach for improving community nutrition environments in underserved communities (Ghirardelli et al., 2010). The national Healthy Food Financing Initiative (HFFI) funds local, state, and regional collaborations that expand access to nutritious foods (U.S. Department of Health and Human Services, 2011), and the 2014 farm bill passed by Congress authorizes up to \$125 million for the HFFI (PolicyLink, 2014). Now that funding is available to support community nutrition environment projects, it is essential to accurately identify high-need areas that should be prioritized for intervention.

Limitations and strengths

This study had several limitations. The survey assessed the availability of nutritious food in each store but did not evaluate price or accessibility, such as proximity to public transportation, which could affect the ability of some people to access nutritious foods. I did not compare the availability of nutritious foods with energy-dense and snack foods, which are associated with higher body mass index (Donald et al., 2009) and fruit and vegetable intake (Timperio et al., 2008), nor did I examine the proximity of each store to other food stores. This study used data that are not temporally consistent. Socioeconomic and demographic data were from the 2000 US Census, commercial data were from 2008, and surveys were conducted in 2009. The 1-year lag between the collection of data obtained from the database and the administration of the surveys may have contributed to my inability to locate 15% of the stores selected from the database, but other field validation studies of food stores have found similar rates of database overcounts (Liese et al., 2010; Paquet et al., 2008). These study results may not be generalizable to other areas. Each county in this study has a higher median household income than that of California and the US.

This study had several strengths. It is the first to compare data from in-store surveys of nutritious food availability at small food stores with data from a commercial database and data on socioeconomic and demographic characteristics. It demonstrates the use of a multidimensional approach to evaluate variability in community nutrition environments (Rose et al., 2010) by considering both the location and context of food stores and the food products offered.

Conclusion

The variables in a commonly used commercial database do not accurately correspond to the variables public health and epidemiology researchers are interested in, namely indicators of the

availability of nutritious and fresh food. There is considerable variability within the industry data classification schema for small food stores. Sampled stores in neighborhoods with a higher percent white population or lower population density were more likely to carry nutritious food options and fresh produce. Even though in-store surveys require more time and resources than using database classifications, they may be a necessary component for accurate food environment assessments that will capture where improved access to nutritious food is most needed.

Figure 2.1: Spatial distribution of food stores surveyed, by store type and county, San Francisco Bay Area and Sacramento, California, 2009.

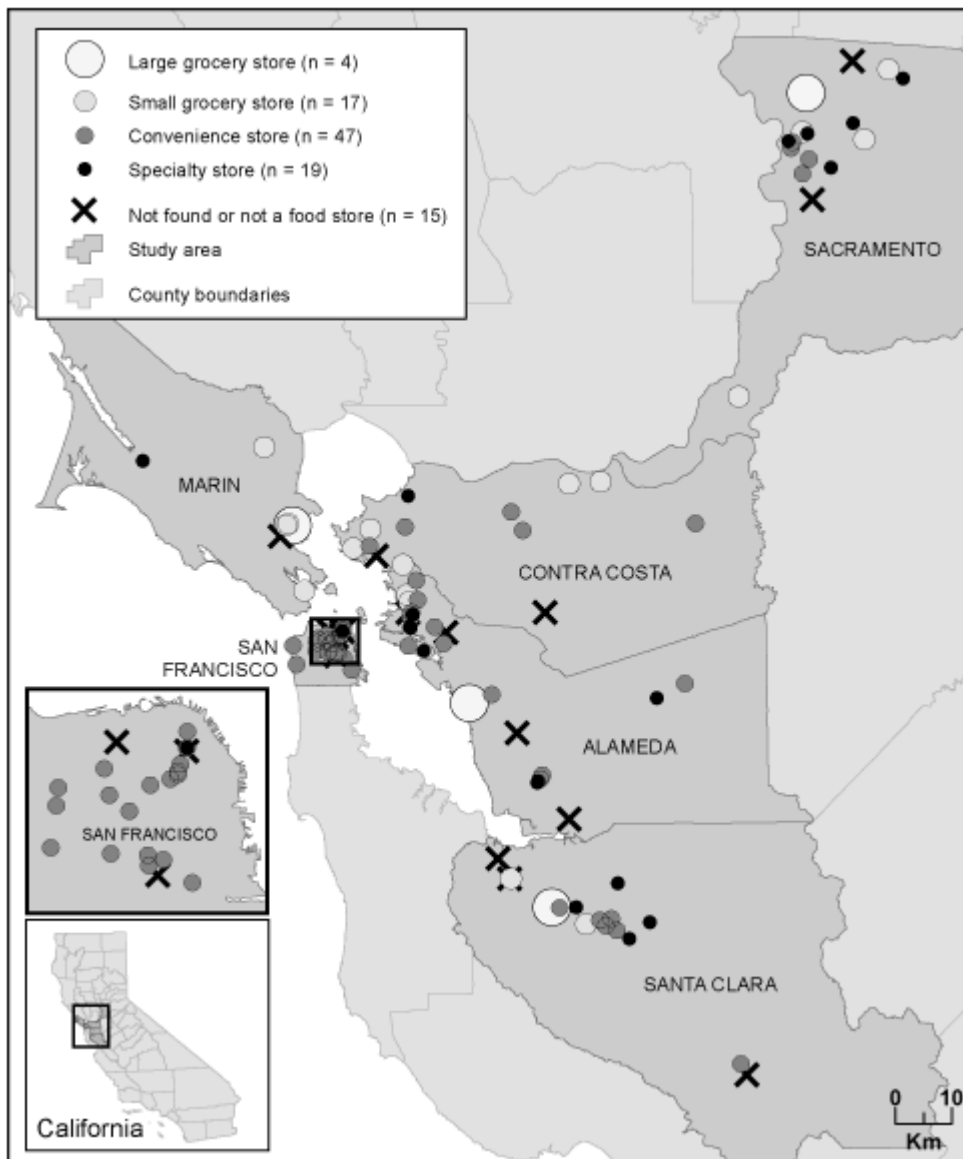
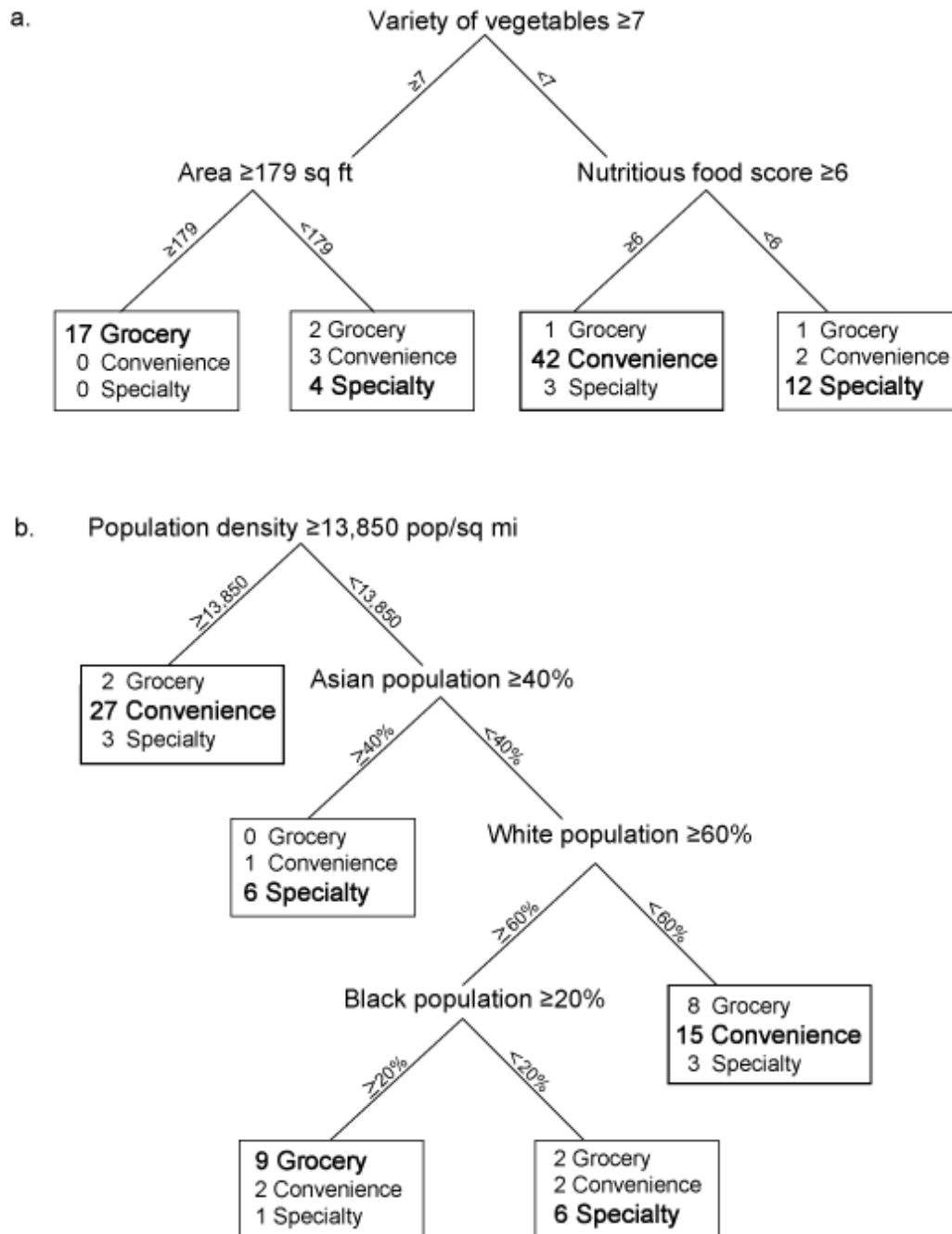


Figure 2.2: Classification and regression tree results based on a) in-store survey and b) sociodemographic variables.



Classification and regression tree results based on a) in-store survey (75/87 [86%] stores correctly classified) and b) sociodemographic variables (63/87 [72%] stores correctly classified). The variables included in each tree are those that most significantly differentiate store types. Reading the tree from top to bottom, the stores that meet the criteria at each node are moved down the tree to the left, and stores that do not meet the node criteria move to the right. The counts in boxes are the number of stores that follow the same pattern; bolded text indicates the best fit store type for the criteria of the nodes above it.

Table 2.1: Store Characteristics by Store (N = 87) Type, San Francisco Bay Area and Sacramento, California, 2009

Characteristic	Mean (SD) [Range]				
	Large Grocery (n = 4)	Small Grocery (n = 17)	Convenience (n = 47)	Other (n = 19)	Total (N = 87)
Nutritious food score (scored from 0–17)	14.8 ^{a,b} (2.2) [12–17]	11.5 ^{a,b} (3.1) [4–17]	9.2 ^b (2.7) [4–14]	4.4 (3.6) [0–14]	8.9 (4.0) [0–17]
Fresh food score (scored from 3–12)	12.0 ^{a,b} (0.0) [12]	9.6 ^{a,b} (2.2) [5–12]	5.0 (1.9) [3–10]	6.1 (3.0) [3–12]	6.4 (3.1) [3–12]
Fresh fruit variety score (scored from 1–4)	4.0 ^{a,b} (0.0) [4]	3.2 ^{a,b} (0.9) [2–4]	2.0 (1.0) [1–4]	1.9 (1.2) [1–4]	2.3 (1.2) [1–4]
Fresh vegetable variety score (scored from 1–4)	4.0 ^{a,b} (0.0) [4]	3.8 ^{a,b} (0.7) [2–4]	1.9 (0.9) [1–4]	2.0 (1.2) [1–4]	2.4 (1.2) [1–4]
Meat/seafood variety score (scored from 1–4)	4.0 ^{a,b,c} (0) [4]	2.6 ^b (1.1) [1–4]	1.1 (0.3) [1–3]	2.1 ^a (1.2) [1–4]	1.7 (1.1) [1–4]
Fresh fruit quality score ^d (scored from 1–4)	3.3 ^a (0.5) [3–4]	2.8 (0.7) [2–4]	2.4 (0.6) [1–4]	3.0 ^a (0.8) [2–4]	2.7 (0.7) [1–4]
Fresh vegetable quality score ^d (scored from 1–4)	3.5 ^{a,c} (0.6) [3–4]	2.9 (0.5) [2–4]	2.6 (0.6) [2–4]	2.4 (1.0) [2–3]	2.7 (0.6) [2–4]
Store area, sq ft	2,745 ^{a,b,c} (1,819) [1,134–5,248]	381 ^{a,b} (180) [112–792]	164 (211) [33–1,430]	155 (174) [30–693]	276 (627) [30–5,248]
No. of employees ^e	1.0 (2.0) [0–4]	1.6 (1.2) [0–3]	1.9 (1.1) [0–4]	1.8 (1.4) [0–4]	1.8 (1.2) [0–4]
Annual sales volume, ^e \$100,000	865 ^a (247) [494–988]	688 (243) [247–988]	578 (248) [247–988]	663 (297) [247–988]	627 (263) [247–988]

^a Value significantly higher than value for convenience stores ($P < .05$).

^b Value significantly higher than value for other stores ($P < .05$).

^c Value significantly higher than value for small grocery stores ($P < .05$).

^d Only stores that sold at least 1 type of fruit/vegetable were included in these comparisons.

^e Values reported from InfoUSA database. Values in all other rows are from in-store surveys.

Table 2.2: Census Tract Characteristics by Store Type, San Francisco Bay Area and Sacramento, California, 2000

	Mean [SD]			
	Large Grocery (n = 4)	Small Grocery (n = 17)	Convenience (n = 47)	Other (n = 19)
Neighborhood deprivation index^a	0.73 (2.4)	0.21 (2.1)	0.77 (2.4)	0.67 (2.3)
Population density, no. of people per square mile	7,631 (1,249)	7,107 (5,217)	26,340 ^b (26,896)	14,323 (22,799)
Median annual household income, \$	53,835 (18,432)	51,100 (17,839)	46,812 (18,380)	48,810 (26,167)
Race/ethnicity, %				
White	50 (8.6)	63 ^c (23.2)	49 (21.0)	45 (30.7)
Black	7 (9.3)	12 (18.0)	12 (18.3)	7 (11.1)
Hispanic	31 (26.3)	24 (21.1)	21 (19.3)	15 (10.1)
Asian	20 (10.5)	7 (5.0)	22 ^b (18.3)	36 ^{b,c} (30.8)
Age group, %				
Children	27 (7.0)	21 (8.3)	19 (10.0)	21 (7.4)
Elderly	11 (7.4)	12 (7.4)	11 (5.5)	16 (11.6)
Neighborhood stability				
People who lived in same tract in 1995 and 2000, %	92 (2.1)	94 (2.5)	95 (2.8)	94 (1.9)

^a The more positive the score, the more deprived the census tract. The values are created from principal component analysis of 8 derived census variables: percentage of people who have an income below poverty level, percentage of female-headed households that have dependents, percentage of households that have an annual income of less than \$30,000, percentage of households that have public assistance income, percentage of people aged 16 or older in the civilian labor force who are unemployed, percentage of men in management, percentage of all people aged 25 or older who did not graduate from high school, and percentage of households with more than 1 person per room (Messer et al., 2006). Scores for census tracts in study area ranged from -3.3 to 14.8.

^b Value higher than value for small grocery stores ($P < .05$).

^c Value higher than value for convenience stores ($P < .05$).

CHAPTER THREE

Facing the climate gap: An equity-based approach to climate change planning and policy¹

Abstract

The climate gap, defined as the disproportionate effects of climate change on low income populations and communities of color, has been documented across numerous scales from local to global. Less understood, however, are the policies and programs that can most effectively narrow or close the climate gap while also promoting climate change mitigation and adaptation goals. This chapter identifies four climate equity principles and presents a climate equity framework to guide climate policy development and analysis. I use semi-structured interviews, reviews of original documents, participant observation, and spatial analysis to evaluate the actions of community-based organizations as they relate to California's climate change policies, programs, and regulations. I find that currently used spatial measures of "disadvantaged communities" ignore many important factors, such as community assets, region-specific risks, and occupation-based hazards that contribute to place-based vulnerability. The actions of many community-based organizations demonstrate innovative strategies that can inform and catalyze more effective and equitable implementation of climate policies. In particular, I highlight three elements that contribute to "sites of solutions:" specific equity targets, multi-level civic engagement, and local knowledge integration and discuss how these elements can be incorporated into climate research and policy in California and other contexts, including local, regional, state, national, and international scales.

* Portions of this chapter were co-authored with Rachel Morello-Frosch, Manuel Pastor, and Marlene Ramos.

“*By effectively implementing environmental laws, we can improve quality of life and expand economic opportunity in overburdened communities. And recognizing these same communities may suffer disproportionately due to climate change, we must cut carbon emissions, develop more homegrown clean energy, and prepare for the impacts of a changing climate that we are already feeling across our country.*”

President Barack Obama (2014) [emphasis added]

“The impact of climate change and California’s policy approach to address it reaches beyond environmental protection and economic opportunity. *If done appropriately*, addressing climate change provides tremendous opportunity to improve the health and well-being of all of California’s citizens and to help unravel many of the patterns of environmental, health, and social inequalities within our communities.”

California Air Resources Board (2014, page 35) [emphasis added]

Introduction

As the anthropogenic causes and consequences of global climate change become increasingly evident (IPCC, 2013), so too does the urgency to enact effective mitigation and adaptation strategies. Most academics and many policymakers no longer question the need to reduce greenhouse gas emissions and prepare for the effects of climate change; the big questions we face now are how to most effectively, efficiently, and equitably adjust to ongoing impacts, prevent more extreme impacts, and plan for future impacts. The disparate, adverse, and unjust effects of climate change and climate policies, collectively referred to as the “climate gap” (Shonkoff et al., 2009, 2011), have not been adequately addressed in national-level climate policies in the US (Harden et al., 2013; Kaswan, 2008). Yet, the issue of equity with regard to climate change planning and policy is especially salient for both practical and ethical reasons.

Mounting evidence demonstrates that social inequities are both an upstream driver and downstream effect of climate change. Social inequities inhibit the development of effective agreements to protect the climate (Parks and Roberts, 2008) and are associated with weak environmental policies, poor environmental quality, and adverse health outcomes (Agyeman et al., 2002; Boyce et al., 1999). Linking social equity and climate change policy can mobilize broader constituencies to address the multiple socioeconomic, political, and environmental challenges associated with climate change. A recent Los Angeles Times / USC poll found that Latinos and Asian Americans in California were significantly more concerned about global warming, air pollution, and water/soil contamination than non-Hispanic white respondents (Pastor, 2010). Similarly, a poll by the Public Policy Institute of California revealed that people of color in the state are more favorable to government action to reduce greenhouse gas emissions by improving land use planning and reformulating fuels (Baldassare et al., 2013). These polling data were also consistent with national trends (Sierra Club and National Council of La Raza, 2012). Finally, ethics-based motivations to address the inequitable effects of climate change are guided by evidence that the direct and indirect effects of climate change disproportionately harm the poor and other marginalized populations, thereby exacerbating existing inequities and placing undue burden on the populations that are least responsible for greenhouse gas emissions (Grineski et al., 2012; IPCC, 2007; Mohai et al., 2009; Patz et al., 2005; Shonkoff et al., 2009, 2011).

To empirically evaluate if and how an equity-based approach to climate planning and policy can lead to more effective climate strategies, I turn to California because of the state's leadership in climate change research and policy and the environmental justice movement. California's climate legislation and regulatory actions are hailed as the most ambitious and comprehensive efforts to control greenhouse gas (GHG) emissions in the United States (Hanemann, 2008). Likewise, in a review of the nation's state-level efforts to advance environmental justice, California is a "pre-eminent example" of the "comprehensive approach" to environmental justice, which includes partnership and coordination with affected communities in all programs, policies, or activities (Bonorris, 2007). The state's strong environmental justice policies are credited in large part to the active political organizing by environmental justice organizations that are based in California's low-income communities of color and also coordinate their advocacy at regional and state levels (Sze, Gambirazzio, et al., 2009). Furthermore, California is a bellwether of demographic change for the nation; a majority of the state's 37 million residents are people of color, and the rest of the nation is projected to mirror this demographic shift by 2042 (PolicyLink, 2012). The challenges and successes of California's climate strategies, particularly if and how they yield protections and benefits for the state's diverse communities, can pave the way for regional, state, federal, and international climate equity action.

California has developed a suite of strategies initiated by legislation and executive orders that set ambitious goals to reduce greenhouse gas emissions (Núñez, 2006), monitor and prepare for climate change impacts (Schwarzenegger, 2008), and ensure that disadvantaged communities benefit from and are not disproportionately burdened by the environmental and economic changes associated with climate change (De León, 2012; Núñez, 2006). These landmark climate mitigation, adaptation, and equity policies are promising, but the difficult task of translating goals and plans into actions remains. The implementation process has already been marked by profound conflict, most notably between state regulators and community-based environmental justice (EJ) organizations (London et al., 2013). Despite extensive collaboration while drafting key legislation, public agencies and many EJ organizations remain at odds over which programmatic and regulatory actions should be used to realize shared equity goals. The future success of California's climate policies hinges upon aligning equity goals in the law with effective impacts on the ground.

In this chapter, I document and evaluate the work of community-based organizations in California as they relate to the state's triple aim approach to climate change (mitigation, adaptation, and equity). My objectives are to: 1) identify examples of actions that successfully achieve climate change adaptation, mitigation, and equity objectives; 2) understand factors that affect the success of particular climate equity actions; and 3) develop guidance for policy and research that will support more effective and equitable implementation of climate policies in California and elsewhere. My focus on the work of community-based organizations draws from prior research that underscores the crucial role that these stakeholder groups played in the drafting and passage of California's leading climate change law, known as the Global Warming Solutions Act of 2006 (Assembly Bill 32 or AB 32), including the bill's equity elements (Sze, Gambirazzio, et al., 2009). Now that AB 32 and other state climate policies have entered the implementation stage, community-based organizations are actively holding policymakers and regulators accountable to reaching climate equity goals (London et al., 2013). My analysis here contributes practical guidance for policymakers, scholars, and advocates on how to face the

climate gap and move forward with policy implementation in ways that also achieve equity goals.

I begin by defining climate equity and presenting a climate equity framework. Drawing from broader academic and policy discussions related to environmental justice, public health, urban development, and environmental governance, I detail how the concept of equity can inform plans and policies that address the unique environmental, economic, social, and political challenges of climate change. The background section also provides additional details about California's climate and environmental justice laws and policies. I then outline my mixed methods approach, which uses case studies and qualitative and quantitative analysis to identify and evaluate the actions of community-based organizations as they relate to the implementation of state climate policies. My results describe common characteristics found across the work of community-based organizations that advance climate change adaptation, mitigation, and equity goals. I highlight three elements that contribute to these "sites of solutions:" specific equity targets, multi-level civic engagement, and local knowledge integration. The discussion section details how these elements can be better integrated into climate policy development, implementation, and evaluation. I conclude by considering the implications of these California case studies for climate research and policy in other contexts, including local, regional, state, national, and international scales.

Background

Defining climate equity

I draw from theoretical and applied literature from the fields of urban development, environmental justice, and public health to identify four climate equity principles: 1) climate equity considers procedural, geographic, and social factors to identify disadvantaged populations, 2) climate equity seeks to ensure that less advantaged individuals and communities do not become more disadvantaged, 3) climate equity advances both inter- and intra-generational equity, and 4) climate equity is both a process and a desired outcome.

Robert Bullard (1994) describes "three basic types of equity: procedural, geographic, and social." Procedural equity is nondiscriminatory and inclusionary treatment in decision-making; it requires consideration of the diverse needs of individuals and communities (e.g. childcare needs, work schedule flexibility, transportation availability) to meaningfully involve all in democratic processes (Bullard, 1994, page 12). Geographic equity considers the spatial location of individuals and communities in relation to environmental harms (Bullard, 1994, page 13); more recent literature also looks at the spatial distribution and relative accessibility of environmental "goods" and resources such as water and greenspace (Walker and Bulkeley, 2006). Social equity includes the role of sociological factors, such as race/ethnicity, class, and culture, in environmental decision-making (Bullard, 1994, page 14); public health literature further defines social factors that may contribute to disadvantage to include religion, nationality, gender, sexual orientation, age, disability, illness, political or other affiliation, or other characteristics associated with discrimination or marginalization (Braveman et al., 2011). These three basic types of equity inform the first climate equity principle that can be applied across multiple scales and regions; climate equity planning and policies should consider procedural, geographic, and social factors to identify disadvantaged populations. Climate change is a multi-scaled and multi-sector problem which poses challenges for to the effective coordination of policy planning, implementation, and

evaluation (Levin et al., 2012). Fragmented leadership across geographic and political contexts means that no “one-size-fits-all” definition of disadvantage or advantage will be relevant in all settings. Yet, definitions of equity articulated in environmental justice literature highlight factors that can and should be considered to identify disadvantaged groups.

A second principle of climate equity is that those who are worse off to begin with do not become more disadvantaged. Equity scholarship in the field of urban development explains, “Pro-equity regimes would require that the distributional outcomes of programs be measured in terms of (a) who benefits from them, and (b) to what extent?...That is, it should be redistributive, not simply economically but also, as appropriate, politically, socially, and spatially” (Fainstein, 2010, page 36). A changing climate produces both direct environmental, economic, and socio-political effects as well as indirect impacts from policy and regulatory responses. Policies and programs to address climate change must therefore ensure that disadvantaged populations receive an appropriate distribution of benefits as well as protection from additional harms. This principle contrasts with other common policy ideals, such as equality, which seeks to treat each individual or community exactly the same, and the utilitarian ideal of creating overall maximum benefits and minimum harms.

Third, climate equity advances both inter- and intra-generational equity. Climate science suggests that fossil fuel emissions must be reduced or else “climate deterioration and gross intergenerational justice will be practically guaranteed” (Hansen et al., 2013). An equity-based approach to climate policy considers disparate effects of climate change and climate policy on future generations as well as those that affect the current population. Scholarship that brings together concepts from environmental justice and sustainability movements explains that policy and planning should not choose between addressing either current or future inequities. Rather, there is a “need to ensure better quality of life for all, now, and into the future, in a just and equitable manner, while living within the limits of supporting ecosystems” (Agyeman and Evans, 2003).

A fourth principle is that climate equity is both a process and desired outcome. It is informed by public health literature that defines health equity as “the value underlying a commitment to reduce and ultimately eliminate health disparities” as well as a desired result of “social justice in health” (Braveman et al., 2011). This principle addresses the urgency of the climate change problem; indeed, climate mitigation and adaptation cannot wait for a silver bullet solution, a perfect policy window, or more research. An equity-based approach to climate policy must move forward even with incomplete information yet guided by a commitment to consider and address disparate effects.

These four climate equity principles present an interdisciplinary approach to understanding and addressing the many challenges posed by climate change. They synthesize guiding principles that have been articulated in a variety of academic disciplines and social movements. Research and advocacy on environmental and climate justice (Burkett, 2008; Shepard and Corbin-Mark, 2009), sustainable development (Haughton, 1999), and health inequities (Walpole et al., 2009), have brought the distributional and procedural effects of climate change and climate policy to the forefront of local, state, national, and global policy agendas. I build off of this important historical and ongoing work to present an equity-based approach to climate planning and policy that integrates climate mitigation, adaptation, and equity priorities.

Climate equity framework

The above principles provide a framework for climate change planning and policy goals, strategies, and outcomes (Figure 3.1). A climate equity framework expands current climate planning and policy discourses in three important ways. First, a climate equity framework demonstrates how the causes and consequences of climate change are shaped by geographic, procedural, and social inequities. For example, sprawl, a pattern of low-density development associated with concentrated poverty, racial residential segregation, and fragmented planning across multiple municipalities (Squires and Kubrin, 2005) is causally related to vehicle miles driven (Handy et al., 2005). Nationally, vehicle miles traveled in passenger cars and light trucks are the largest source of transportation-related greenhouse gas emissions, and urban sprawl has contributed to the 35 percent increase in travel miles since 1990 (U.S. Environmental Protection Agency, 2014). It is therefore necessary to reduce inequitable development patterns such as sprawl to most effectively reduce anthropogenic GHG emissions that cause climate change.

Relatedly, geographic, procedural, and social inequities interact with the effects of climate change. For instance, extreme weather events, such as heat waves, magnify existing inequities in land cover. Racially segregated communities of color in the US have fewer trees and more impervious surfaces than white communities, thereby creating inequitable patterns of heat-related mortality risk (Jesdale et al., 2013). Climate change also interacts with income inequality by increasing costs for basic necessities such as food (Lobell et al., 2011) and water (Hanak and Lund, 2012), thereby disproportionately affecting low-income households that already spend the highest percentage of their incomes on such essential goods (Shonkoff et al., 2011).

Secondly, a climate equity framework recognizes that policy interventions that fail to consider or address equity concerns will likely exacerbate inequities and hence climate change. For instance, California's cap-and-trade carbon trading system seeks to reduce statewide greenhouse gas emissions but does not specify which facilities, such as those that release the most emissions near vulnerable populations, must reduce emissions. The policy misses an opportunity to reduce geographic and social inequities caused by harmful co-pollutants that are released with greenhouse gases from the state's largest polluters and disproportionately affect low-income populations and communities of color (Pastor et al., 2013). In addition to raising equity concerns, the cap and trade policy fails to capitalize on the potential health and environmental co-benefits that could be gained from limiting co-pollutant emissions and improving air quality in overburdened communities (Boyce and Pastor, 2013).

Lastly, a climate equity framework highlights opportunities for integrated climate mitigation, adaptation, and equity policies. Mitigation (reducing and sequestering GHG emissions) and adaptation (preparing for and coping with climate change impacts) have frequently been treated as separate objectives by science and policy because of the issues' different spatial and temporal scales (e.g. global and long-term benefits from mitigation vs. local and short-term benefits from adaptation), main sectors involved (e.g. energy, transport, and industry sectors for mitigation policy vs. urban planning, water, agriculture, and health for adaptation policy), and need for incentives (e.g. mitigation usually requires incentives because benefits are more broadly dispersed vs. no incentives usually needed for adaptation policies because benefits accrue more directly to implementers) (Swart and Raes, 2007). However, mitigation and adaptation also have similarities in that they both aim to reduce climate change risks, can generate substantial economic and health co-benefits, and are dependent upon technological advances and

institutional and societal capacity to change (Swart and Raes, 2007). As such, recent science and policy has evaluated how to take advantage of these linkages to create synergistic policies that meet both adaptation and mitigation goals, such as increasing energy and water efficiency measures to reduce consumption and dependency, reducing point and mobile sources of pollution to reduce GHG emissions and improve public health, and expanding and protecting green spaces to sequester/store carbon and provide protection from extreme weather events (Swart and Raes, 2007). A climate equity framework expands upon “win-win” mitigation-adaptation policies to include “triple win” outcomes that reduce GHG concentrations, vulnerability, and inequities.

Background on California’s Climate Change and Environmental Justice Laws and Policies

Climate change was first raised as a policy issue in California in 1988 and ascended the political agenda due to a combination of factors, including the state’s national leadership in regulating automobile emissions and promoting energy efficiency, strong political leadership on environmental issues within both political parties, and its support of climate science research (Franco et al., 2008; Hanemann, 2007, 2008). California is also a national leader in environmental justice action. It has many low-income communities of color that have advocated for better environmental quality and inclusion in environmental decision-making, and its state- and regional-level legislation, agency programs, permitting procedures, research, and public participation strategies provide models of best practices for addressing environmental justice concerns (National Academy of Public Administration, 2002). State agencies in California have been working for over a decade to promote “the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations and policies (Government Code Section 65040.12)” (California Environmental Protection Agency, 2014a). However, these efforts have been found to have “uneven success” (London et al., 2008) at best and more often ignore input from disadvantaged communities and/or exacerbate socioeconomic, political, and environmental inequities (Cole, 1998; London et al., 2008; Sze, London, et al., 2009). As California moves forward with climate policy implementation, there is an ongoing need to recognize, respect, and learn from the experiences of disadvantaged communities to ensure equity goals become reality.

California’s most comprehensive climate change policy is the Global Warming Solutions Act of 2006 (Assembly Bill 32 or AB 32), which establishes a binding reduction of the state’s greenhouse gas emissions to 1990 levels by 2020 and to 80 percent of 1990 levels by 2050 (Núñez, 2006). Environmental justice organizations successfully ensured that AB 32 included language mandating consideration of procedural, geographic, and social equity in the law’s implementation (Sze, Gambirazzio, et al., 2009). Nevertheless, many environmental justice advocates are critical of how the state has been implementing AB 32, especially the California Air Resources Board (CARB)’s choice to enact a market-based cap and trade program (London et al., 2013). The cap and trade program sets a firm limit on 85 percent of California’s GHG emissions, and CARB considers the regulation to be a “vital component in achieving both California’s near and long-term GHG emission targets” (California Air Resources Board, 2014). A group of environmental justice organizations filed a lawsuit against CARB in 2010 that temporarily delayed but did not significantly alter the implementation of the cap and trade program. Environmental justice advocates have since been holding the state accountable to climate equity goals through other means, such as the Environmental Justice Advisory

Committee (Board, 2014), providing public comments on updated state climate research and policy reports, working with local and regional governments on climate policy implementation (Public Advocates, 2013), and lobbying for new climate equity legislation.

One particularly notable set of recent laws is Assembly Bill 1532 and Senate Bill 535, which work together to stipulate how the state must distribute revenue generated by the state's cap and trade program. Assembly Bill 1532 requires the development of a three-year investment plan that allocates funds to programs based on specific criteria, such as those that "facilitate the achievement of reductions of greenhouse gas emissions" (mitigation), "direct investment toward the most disadvantaged communities and households in the state" (equity), and "lessen the impacts and effects of climate change on the state's communities, economy, and environment" (adaptation) (Pérez, 2012). Senate Bill 535 further specifies that at least 25 percent of monies from the greenhouse gas reduction fund shall support projects that provide benefits to disadvantaged communities, with a minimum of 10 percent going toward projects that are located within disadvantaged communities (De León, 2012). The legislation details that the California Environmental Protection Agency (CalEPA) shall use "geographic, socioeconomic, public health, and environmental hazard criteria" to identify disadvantaged communities for investment opportunities. These bills reflect California's triple aim approach to climate change (mitigation, adaptation, and equity) and create a revenue stream to turn the goals into actions.

Methods

I used a multi-method case study approach (Yin, 2003) to identify and evaluate equity-based strategies for climate change policy and planning. I first sought to ground my work in the local knowledge of individuals living and working in California urban and rural communities identified as most vulnerable to the impacts of climate change. Expanding my scope and scale of analysis, I then connected these lived experiences to state-level climate laws, policies, and programs. I utilized qualitative and quantitative methods including content analysis, semi-structured interviews, participant observation, and spatial analysis.

To select case study focus areas and locations, I began with a literature review to identify climate change planning and policy priorities in California. I identified four main types of climate planning and policy priorities: physical environment changes, built environment changes, economic shifts, and local policy responses. I considered all issues that are within the purview of state climate change law and policy, focusing on those that have the strongest evidence base for impacting the health and livelihoods of disadvantaged populations, including people of color and the poor (Mazur et al., 2010; Shonkoff et al., 2011).

Climate planning and policy priorities in the physical environment category include direct environmental effects of climate change on temperature, water, and food supplies. The specific climate equity concerns include urban heat islands (California Natural Resources Agency, 2009), extreme heat (Cooley et al., 2012) and infectious disease (Cooney, 2011) in rural areas, drinking water quality and quantity (Connell-Buck et al.; Hanak and Lund, 2012), and food security (California Natural Resources Agency, 2009; Mazur et al., 2010). Built environment changes refer to more indirect effects that result from the interaction of climate change with our existing infrastructure, such as housing, industry, and transportation (Ewing et al., 2007). The related climate equity concerns include air quality issues related to incompatible land use (close

proximity of residential and industrial land uses) (California Air Resources Board, 2005), cumulative impacts (concentration of multiple sources of pollution) (Huang and London, 2012; Su et al., 2009), and co-pollutants (harmful emissions that are released with greenhouse gases) (Shonkoff et al., 2009). Economic shifts comprise changes in production and employment, which are connected to the climate equity concerns of just transitions (fair and sustainable shift away from fossil-fuel dependence) (Foster, 2010) and employment opportunities (Patterson, 2013). And, lastly, local policy responses are integrated reactions to multiple climate change adaptation and mitigation needs for a particular city or community, such as climate action plans and adaptive management strategies. These responses raise climate equity concerns related to public participation (California Emergency Management Agency, 2013) and respect for traditional indigenous ecological knowledge (Salick and Ross, 2009).

I recognize that these included issues are not exhaustive and do not cover all climate change or climate equity concerns in California (Kadir et al., 2013) or elsewhere (IPCC, 2007; Karl et al., 2009); particular regions, neighborhoods, or groups will experience different effects and have different priorities depending on their local environmental, social, economic, and political contexts. Nonetheless, I use these broad categories and particular planning and policy priorities to highlight the many dimensions of climate equity.

For each climate equity concern, I used key word web searches and professional networks to collect information about community-based organizations that are working on related issues or campaigns in California. I identified 62 distinct community-based organizations and used organizational web sites, reports, and email and phone conversations with leaders to compile details about each organization's work related to climate change and if/how they engage community members in their work. I also employed a snowball sampling method by asking each organization if they knew of other groups or community leaders working on campaigns or projects related to climate change in California.

To select organizations for the case studies, I narrowed the list to those that met three criteria: 1) strong community-engagement component to their work, such as through rank-and-file membership, skills trainings, and/or outreach events, 2) an explicit emphasis on working with marginalized populations including communities of color and the poor, and 3) availability and willingness to be interviewed. The resulting case study compilation was shared with leaders from two statewide coalitions of environmental justice and environmental health organizations to further refine the list and select a geographically diverse set of representative case studies. The final case study selection included 18 community-based organizations, grouped into 12 issue- and place-based case studies from 7 regions across California (Table 3.1).

My colleague Marlene Ramos and I conducted individual and group interviews with 30 leaders and members from the 18 community-based organizations using a semi-structured format. We followed a set of 16 open-ended questions that covered topics including organizational history and context, project details and impact, and broader goals and reflections related to climate change and environmental justice. Interviews were conducted in person or over the phone between July 2011 and June 2012. All interviews were recorded and transcribed for qualitative analysis. I used news articles, grey and peer-reviewed literature, and U.S. Census data to corroborate and supplement information from the interviews. Case study write-ups were completed in June 2012 and shared with interviewees to confirm accuracy.

To connect the content from the case studies to state-level climate change policies, programs, and regulatory actions, I reviewed state agency reports, analyzed publicly-released data, and attended public meetings as participant observers from January 2010 through April 2014. In line with the focus of the case studies, I concentrated my review on materials and meetings related to climate change, equity, and/or environmental justice.

Results

A complete review of all 12 of the case studies is beyond the scope of this paper and is available elsewhere (Kersten et al., 2012). Here, I present illustrative examples of common factors from the case studies that contributed to community-based organizations' success in achieving adaptation, mitigation, and equity aims. Examples from these "sites of solutions" demonstrate how climate equity principles can be translated into effective actions and provide guidance for how to operationalize a climate equity framework.

Specific equity targets

All of the interviewed organizations are working at the intersection of climate mitigation, adaptation, and equity (Table 3.1). Yet, many organizational leaders reflected that their programs' connections to climate change are secondary and/or more recent. Even though their work addresses particular climate change drivers and impacts, their ultimate motivation and specific objectives are prioritized and communicated in terms of equity targets related to places (where they work), people (who they work with), and processes (how they meet their community's diverse needs). Whether or not they call it "climate change work," community-based organizations' strategic focus on addressing inequities creates local environmental, socioeconomic, and political changes that support climate change mitigation and adaptation objectives.

Urban forestry projects, for instance, contribute to climate mitigation and adaptation by sequestering carbon, improving air quality, reducing energy consumption (Nowak, 1993; Nowak et al., 2013), and reducing extreme urban temperatures (Harlan et al., 2006). Urban Releaf, has been working for over 13 years to plant trees in low-income neighborhoods in Oakland and Richmond that have little to no shade coverage. Urban Releaf primarily works in North, West, and East Oakland, neighborhoods with exceptionally poor environmental conditions due to the confluence of freeways, industrial land uses, and ports. The rate of asthma-related emergency department visits for children who live in these neighborhoods is two to three times the rate for the rest of Alameda County (Alameda County Department of Public Health, 2008). Since 1999, Urban Releaf has planted over 15,000 trees and worked with over 4,000 youth through their Urban Forestry Education and Stewardship Training Program (Urban Releaf, 2014).

Despite these clear connections between Urban Releaf's work and climate change, Urban Releaf's Founder and Executive Director reflects that her motivations for starting the organization were to create jobs and environmental education opportunities for at-risk and hard-to-hire youth and adults:

"The conditions that you see here on the Oakland streets are a lot of young people hanging out on corners, idle, with no jobs, underemployed and a terrible education. The kids aren't getting a good education...but then at the end of the day they are blamed. So,

with that I wanted to do something to give people jobs as well as make them stewards of their own environment.”

Urban Releaf is still based out of the North Oakland neighborhood where it began and has an extensive understanding of the interconnected health, environmental, and social issues that affect nearby residents. The Executive Director describes the challenging circumstances that residents in her community face:

“The health issues don’t just involve air quality. The health issues also involve issues of poverty, issues of food, issues of education, issues of unemployment. Being an organization of color, we are besieged with those social ills because a lot of the young people that we deal with, they have arrest records, they may have issues around housing, drugs, or jobs.”

Urban Releaf’s Director of Urban Forest Education adds that working with the most at-risk or disadvantaged residents is essential to their program’s long-term impact.

“When a community group is supposedly focused on West Oakland or East Oakland is planting trees, then there is a certain percentage of the people from that community that need to be hired to do that work. We have to think about it in that way. We have to think about it more economically, and more about economic sustainability for that community.”

There are over 50 other non-profit tree planting organizations in California, but less than a dozen of them focus on working in or with disadvantaged communities (California Releaf, 2014). Urban Releaf, however, works to not only plant trees but to also address social, procedural, and geographic inequities. The organization has specific targets to improve the education and employment opportunities for disadvantaged youth in Oakland’s environmentally burdened neighborhoods, which makes their climate adaption and mitigation work uniquely important and effective. Creating local employment and education opportunities supports neighborhood social networks and abilities to collectively organize and solve problems (Wilson, 1997), which in turn improve local-level resilience to extreme events, such as heat waves (Lochner et al., 2003). Urban Releaf’s Urban Forestry Education and Stewardship Training Program has contributed to research that evaluates the shade and climate effects of various tree species that can be used to ensure future tree planting programs provide maximum carbon sequestration and vegetation coverage benefits (Urban Releaf, 2012).

The synergy between equity targets and climate mitigation and adaption outcomes is not unique to Urban Releaf. All of the actions listed in Table 3.1 have specific geographic, social, and procedural equity targets (i.e. place-, people-, and process-based goals) that are central to the organizations’ effectiveness in improving equity as well as achieving climate mitigation and adaptation outcomes.

Multi-level civic engagement: bonds, bridges, links, and ladders

To meet their specific equity targets, community-based organizations use a variety of tactics to engage their diverse communities. Many of the organizations have their roots in environmental and social justice movements and therefore engage their communities across multiple levels of decision-making by building internal community bonds and bridges, external links to decision-makers, and cross-scale ladders to positions of leadership and influence.

Community bonds and bridges refer to types of social capital that are formed from traditional organizing tools such as door knocking, surveys, trainings, and community meetings. Bonding social capital is connections within a homogenous group, and bridging social capital is connections across heterogeneous groups (Gittel and Vidal, 1998; Putnam, 2000). Community-based organizations most often work with diverse constituencies (race/ethnicity, language, culture, age, religion, etc.), and they work to cultivate both bonds and bridges to collect meaningful and representative input from community members and engage them in their campaigns. Although these two forms of social capital are necessary to support community cohesion and adaptive capacity, a third type, linking social capital, is especially important to address the challenges of climate change (Ebi and Semenza, 2008).

Linking social capital is a particular type of bridging social capital that refers to relationships and networks among actors that have unequal levels of power (Szreter, 2002). Ebi and Semenza (2008) emphasize that linking social capital, such as connections between community members and government officials, improves community-level resilience to climate change by connecting a wide range of expertise to understand, monitor, and prepare for climate change risks. For instance, the Asian Pacific Environmental Network (APEN) works in Richmond, CA to facilitate relationships between the Laotian community and county officials who manage an emergency warning system and other public health and emergency preparedness resources. APEN's former Executive Director describes the extensive process of cultivating these relationships:

“When the community came up with the demand for the multilingual warning system, we had to explain that you take that demand to the County Board of Supervisors who are the ones that control the warning system. Some folks were like, “Do we bring guns when we go to talk with the county officials?,” because to challenge the state was to literally put your life on the line from where they were from. It has been a process of understanding our system, our government, our democracy, how we all have a right to make demands and how you build power to be able to have those demands met.”

APEN's long-term organizing work with Richmond's Laotian community and collaboration with county officials spurred the creation of a multi-lingual emergency call system that will help all Contra Costa residents, including those with limited English proficiency, better cope with extreme weather events related to climate change as well as other hazards such as explosions at nearby oil refineries. APEN also helped mobilize residents in the City of Richmond to contribute to the City's General Plan update, which now includes innovative elements, such as Energy and Climate Change and Community Health and Wellness. The Energy and Climate Change Element establishes city-wide climate mitigation and adaptation goals as well as policies and implementing actions that prioritize the mobility, transit, affordable housing, and employment needs of vulnerable populations, such as low-income, youth, elderly, and formerly incarcerated individuals (City of Richmond, 2012c). The Community Health and Wellness Element includes a broad range of goals and actions to address the socioeconomic conditions, environmental quality, and built environment factors that drive health disparities, with particular attention to the disproportionate health risks faced by low-income residents of color (City of Richmond, 2012b). These climate and health equity policies, many of which have never before been included in a general plan, are the result of an extensive, five-year community visioning and planning process

that engaged over 2,000 community members and organizational representatives (City of Richmond, 2012a).

In addition to improving communication between diverse community members and policymakers, many of the case studies highlight another way for policies and programs to better address community needs: local community members can become the policymakers. Many of the organizations interviewed mentioned that their jurisdictions do not have leaders who are representative of their diverse constituency, and they work to create leadership ladders that help underrepresented populations win elected office and other leadership positions. For instance, governing body leadership of special districts that manage water in the Central Valley are 21 percent women and 19 percent Latino, yet the districts' population is 50 percent women and 57 percent Latino (Community Water Center, 2012). The Community Water Center (CWC) helped organize support for the appointment of the first low-income woman of color to the Central Valley Regional Water Quality Control Board, an agency that the CWC reports has been dominated by the interests of the agricultural industry instead of the drinking water needs of the region's 4 million residents. Agricultural activity consumes 80 percent of California's developed water resources and is responsible for seven percent of California's GHG emissions (California Air Resources Board, 2014). The Community Water Center advocates for policies and regulations that reduce agricultural GHG emissions and limit run-off, such as fertilizers, pesticides, and manure, from contaminating scarce groundwater supplies.

Climate change will impact California's water systems in multiple ways, including decreased water supply from mountain snowpack, increased agricultural and residential water demands, and increased flood flows and flood frequencies (Hanak and Lund, 2012). Effective adaptation to these changes requires equitable water management strategies guided by leaders who represent the water needs of disadvantaged populations. "Not only is it important for community residents to understand their rights.., but also to be able to feel empowered to join the decision making body that will affect them ultimately," says Community Water Center's Executive Director. By training and encouraging local residents to become regional decision-makers, the Community Water Center and other community-based organizations give many disadvantaged communities a more direct influence on the institutions that make and implement environmental plans, policies, and regulations that affect their individual and community health as well as the drivers and effects of climate change.

Local knowledge integration

As discussed in the background section, community-based organizations in California have worked closely with state agencies and legislators to influence many climate policies, but the policy implementation processes have been met with conflict. Prior research suggests that incorporating local knowledge in environmental decision-making processes can lead to less contentious and more effective policies and programs (Corburn, 2005). Here, I present how local knowledge can inform the implementation of one particular state climate policy, Senate Bill 535 (SB 535). SB 535 requires the CalEPA to identify disadvantaged communities to receive targeted funding from the Greenhouse Gas Reduction Fund, a multi-billion dollar revenue stream generated from the state's cap and trade program. The CalEPA proposes using the CalEnviroScreen tool to identify disadvantaged communities. The CalEnviroScreen tool is a collection of 19 environmental and socioeconomic variables and is the "largest public screening tool effort in the nation—both in geographic scope and level of detail" (California

Environmental Protection Agency, 2014b, page iv). It was developed with input from regulators, scientists, and community advocates and is lauded for combining both scientific rigor and transparency to diverse audiences (Sadd et al., 2011).

The CalEnviroScreen tool uses a “cumulative impacts” approach, which considers the interactions across multiple environmental, health, and socioeconomic influences on health as opposed to just isolated measures of singular pollutants or poverty. By incorporating both intrinsic factors of biological susceptibility (e.g. age), and extrinsic factors, such as environmental exposures and psychosocial stressors (e.g. poverty rate), cumulative impacts approaches to regulatory science and decision making are more holistic than other risk assessment practices, and their use may help reduce existing environmental health disparities between socioeconomic and racial or ethnic groups (Morello-Frosch et al., 2011).

Although the CalEnviroScreen tool expands traditional risk assessment methodologies in promising ways, it is not without limitations. For instance, the tool relies on a limited selection of statewide government data sources that may not capture many important aspects of environmental and public health, such as pollution exposures from unregulated or unmonitored sources and incidence of cancer and chronic diseases other than asthma. (Meehan August et al., 2012). In addition, the tool does not include specific measures of climate change vulnerability even though it is supposed to direct investments from a fund created for climate mitigation, adaptation, and equity programs. Public health research suggests that it is essential to incorporate measures of climate change exposures (e.g. projected temperature changes and flood risk), population sensitivity to climate change (e.g. elderly living alone) and adaptive capacity to climate change impacts (e.g. tree canopy coverage and air conditioner ownership) to inform and evaluate climate adaptation strategies that protect vulnerable populations (English et al., 2009, 2013; Reid et al., 2009). While it is not possible to measure and monitor *all* factors that contribute to community-level disadvantage, it is possible, and in fact necessary, to use local knowledge to consider the unique strengths and vulnerabilities of particular regions and communities. By comparing local knowledge about climate change vulnerability from the case studies to the CalEnviroScreen’s measures of disadvantage, I find three important ways that local knowledge can contribute to more effective and equitable climate policy implementation.

First, local knowledge from community-based organizations can help avoid type I errors, or false positives. In the context of identifying disadvantaged communities to target for climate equity policies, this would mean that a community is identified as more disadvantaged than another community when in fact it actually has more assets or resources. The CalEnviroScreen tool only incorporates measures of environmental hazards and social disadvantage, whereas many community leaders emphasize the importance of also tracking community assets. Ubuntu Green, for instance, has helped create over 150 home, school, and community gardens in low-income communities of color in Sacramento. They map the location of each of these gardens to track their success toward reaching a goal of 350 gardens (Ubuntu Green, 2013), a number symbolically chosen in reference to a global grassroots movement that aims to solve the climate crisis, 350.org. The number 350 refers to what many climate scientists consider to be a “safe” level of atmospheric carbon dioxide in parts per million (ppm) (Rockström et al., 2009); the current concentration of carbon dioxide in the atmosphere is just over 400 ppm (NASA, 2014). Ubuntu Green’s Edible Garden Campaign promotes overlapping goals decreasing GHG emissions from industrial agriculture production and transportation while also improving food security, public health, and civic engagement. Ubuntu Green incorporates measures of financial

need and environmental quality in their site selection, but they also collect and share measures of progress to track the success of the gardens, engage additional stakeholders, and identify underserved areas for future garden development as the program expands.

Other indicators of community assets identified through the climate equity case studies include solar panel installations, urban trees, retrofitted “green” homes and businesses, environmental education and mentorship programs, local “green” jobs, and transit services. Measures of both risks and assets are needed to more fully understand the distribution of advantage and disadvantage across communities, and local knowledge from community-based organizations about both their successful and struggling programs can ensure that scarce resources are directed toward the most underserved areas.

Local knowledge can also help correct type II errors, or false negatives, which occur when disadvantaged communities are undetected. For example, Figures 3.2 and 3.3 show that the Karuk tribe in Northern California is not identified as a disadvantaged community by the CalEnviroScreen tool; all of the tracts in Siskiyou and Humboldt counties where the Karuk tribe is based are well below the 50th percentile threshold. However, local knowledge from the Karuk tribe shows that they face significant climate vulnerability risks that fall outside of the scope of the CalEnviroScreen tool, such as food security concerns related to depleting fish populations and wildfire threats. The Tribe drafted an Eco-Cultural Resources Management Plan that outlines the social and environmental issues that are of greatest concern to their health, well-being, and sovereignty.

The Plan is described as “An integrated approach to adaptive problem solving, in the interest of managing the restoration of balanced ecological processes utilizing Traditional Ecological Knowledge supported by Western Science” (Karuk Tribe of California, 2010) [capitalization in original]. Unlike the CalEnviroScreen tool which relies solely on quantitative measures, the Karuk’s Plan brings together qualitative and quantitative data sources. Quantitative data include environmental management indicators of forestry and fishery resources, and qualitative data is communicated through oral histories, descriptions of cultural practices and spiritual significance, and historical and personal narratives. A member of the Karuk tribe reflects that California environmental and climate policies do not value indigenous ecological knowledge, “A lot of people don’t realize that tribes even exist in California, but we are stakeholders too, with the rights of indigenous peoples.” Diverse forms of local knowledge, both qualitative and quantitative, must be incorporated into measures of community disadvantage or else vulnerable communities will remain under the radar of state climate plans, policies, and programs.

The climate equity case studies also highlight how local knowledge can address type III errors, which public health scholars describe as “a right answer for the wrong question” (Schwartz and Carpenter, 1999). A type III error in the context of climate equity planning and policy means correctly designating a community as disadvantaged but using criteria that does not accurately measure the full extent or causes of the area’s vulnerability. Figures 3.2 and 3.3 show that Líderes Campesinas, a collective of farmworker women based in the Central Valley region, has members who live in a census tract with a CalEnviroScreen score above the 85th percentile, which likely qualifies it as a “community of concern” that is eligible for targeted investments. The CalEnviroScreen tool incorporates many pollution and population characteristics that Líderes Campesinas members mentioned as issues of concern, such as high pesticide use and

asthma rates. But, it does not include measures of occupational risks that exacerbate these conditions.

A Líderes Campesinas member in Madera describes how her employer does not comply with many regulations that are supposed to be enforced by the state Occupational and Safety Health Standards Board, making her and other farmworkers especially vulnerable to the effects of extreme heat and pesticides:

“I regularly work picking tomatoes and working conditions are unbearable. Why? Because employers’ need for more profits forces us to work during peak hours of the afternoon when the sun is the strongest. They also create dangerous conditions for us...sometimes we don’t have enough water, or the water is not fresh enough to drink; sometimes they spray pesticides nearby and the employers don’t order us to stop working. These are very strong chemicals, but they do not share that information with us.”

Additionally, Líderes Campesinas members expressed concerns about the safety and availability of public transportation for getting to work, the grocery store, and cooling centers as well as increasing rates of valley fever, a fungal disease commonly caused by breathing in contaminated dirt spores. None of these vulnerabilities related to occupational hazards, limited public services, and infectious disease are included in CalEnviroScreen, thereby limiting the tool’s capacity to accurately identify the full scale and sources of disadvantage that many communities experience.

These case examples from Ubuntu Green, the Karuk Tribe, and Líderes Campesinas lift up the numerous assets, unquantified risks, and complex community contexts that influence community-level disadvantage. Quantitative and qualitative local knowledge about community assets and vulnerabilities can help avoid type I, II, and III errors when classifying disadvantaged communities.

Discussion

Despite, and because of, the overlapping environmental and social challenges in many communities, these areas are sites of solutions and resilience, not just disadvantage. Community-based organizations have been working for decades to reduce environmental risks and cultivate community assets in disadvantaged neighborhoods, and their strategies provide essential guidance for climate mitigation, adaptation, and equity policy and research. Specific equity targets, multi-level civic engagement, and local knowledge integration are methods that exemplify climate equity principles and confirm that it is possible to simultaneously reduce harmful greenhouse gases, help communities prepare for and respond to a changing climate, and dismantle systemic inequities.

The community-based organizations I interviewed use one or more of a variety of frames to classify their work, such as green economic development, sustainable communities, community empowerment, environmental health, human rights, and/or justice of many types (e.g. environmental, economic, social, racial, climate, transit, food). I find that all of these frames can guide actions that meet climate mitigation, adaptation, and equity aims and therefore fit within a climate equity framework. A climate equity framework can be a useful tool to unify the diverse perspectives and priorities of advocates, policymakers, planners, and academics who seek to understand and address the complex challenges of climate change.

The quotes from President Obama and the California Air Resources Board at the beginning of this article suggest that policymakers recognize that “effective” and “appropriate” implementation of climate policies require new approaches that unravel rather than reinforce the inequities that persist today as a result of past policy failures. Climate planning and policy is at a proverbial crossroads; it can either stay on the same business-as-usual track of the other environmental and social policies that have created geographic, procedural, and social inequities, or it can embrace new methods and actions that set us on a course for a more equitable and sustainable future. An equity-based approach to climate change planning and policy can guide us toward the latter option, and this collection of climate equity case studies suggest particular lessons that policy and research can learn from the community-based organizations that are leading the way.

Policy implications

The CalEnviroScreen tool is a promising new method to identify and direct resources to disadvantaged areas, but the climate equity case studies demonstrate a need, and offer guidance, for improving the CalEPA’s approach to identifying disadvantaged communities. Local knowledge from communities should be integrated into future versions of the screening methodology so that community assets, qualitative measures, and additional factors that capture local and regional issues of concern are included. These forms of local knowledge contribute to more accurate measures of the places and populations that are vulnerable to the adverse effects of climate change and highlight successful processes and programs that can be used to address these vulnerabilities.

Collecting and monitoring qualitative data and measures of assets in addition to risks will help avoid type I, II, and III errors while also bringing state-level climate policy implementation in better alignment with research from the fields of community development and environmental health. The “Communities of Opportunity” model of community development considers both high and low opportunity indicators to emphasize the linkages between advantaged and disadvantaged people and places. Opportunity mapping can be used as a diagnostic tool to inform policies and investments that connect marginalized populations to housing, employment, and other resources that affect advantage and disadvantage at neighborhood and regional scales (Morgan and Ziglio, 2007; Powell, Reece, et al., 2007). In the field of environmental health, assets are framed in terms of “adaptation” and are one of three components that contribute to a “geography of risk” (Jerrett et al., 2009). The CalEnviroScreen model includes the other two risk components, exposure and susceptibility, but not yet adaptation. Adaptation measures could include local level measures from community-based programs (e.g. new tree plantings and solar panel installations), qualitative information about cultural practices and oral histories, as well as statewide measures of healthcare coverage, transit access, and other assets that help individuals and communities cope with and recover from environmental challenges.

Local knowledge can not only be used to identify where to invest public resources in climate equity programs but also how and for whom resources should be used. For example, to address urban energy use and heat island risks, mitigation and adaptation policies that focus on urban greening should extend beyond goals to just plant a certain number of trees in a city and should also include equity objectives that specify which neighborhoods, with whom, and how particular communities will be engaged. This requires paying particular attention to issues such as: where the trees are planted in relation to neighborhood income, racial/ethnic composition, and rented

versus owned properties; who is hired to plant the trees; who is responsible for the long-term monitoring and maintenance of the trees; how local residents will be involved in the planning, implementation, and evaluation processes; and how the trees may affect other concerns of the community (e.g. gentrification, crime). These types of holistic measures should be used to select and monitor the success of climate equity programs.

To collect local knowledge and guide climate equity policy implementation, policymakers and public agencies can learn from the multi-level civic engagement strategies of community-based organizations. For example, it is necessary to move beyond traditional public participation strategies, such as large public meetings and/or token advisory boards, which fail to give communities power throughout all stages of the policy process. Public agencies should fund and designate community liaisons to work with and support the work of community-based organizations, thereby cultivating collaborative relationships and a more direct link between climate policy and community input. In addition, programs that use multiple forms of civic engagement to cultivate social and community capital co-benefits in disadvantaged communities should be prioritized during funding decisions. For instance, education and mentorship pipeline programs should be expanded to diversify the leadership of local, regional, state, and national decision-making bodies and elected officials. The Community Water Center's AGUA Coalition (la Asociación de Gente Unida por el Agua, or the Association of People United for Water) and the Environmental Health Coalition's SALTA training (Salud Ambiental, Líderes Tomando Acción, or Environmental Health, Leaders Taking Action) have successfully supported many low-income people of color to become local and regional community leaders. These programs exemplify the types of leadership development programs that are needed to ensure that environmental and climate policy leaders are representative of California's diverse population.

Research implications

These climate equity case studies provide an informative but limited collection of community-based actions that can support equitable climate change policies. More research is needed to further understand and monitor how climate change, inequities, and policy responses interact across scales and over time. In light of equity and environmental health concerns related to cap and trade as a climate policy tool in California (Pastor et al., 2013; Shonkoff et al., 2009), it is especially important to attentively monitor if and how the state is able to create tangible benefits for its diverse population and many disadvantaged communities. Furthermore, 30 plus other jurisdictions within and outside the US have recently adopted or considered adopting a cap and trade program to reduce greenhouse gas emissions (Betsill and Hoffmann, 2011). Ongoing research is needed to evaluate the equity implications of climate policy implementation in other contexts.

In addition to evaluating current climate change policies, researchers should work with communities to conduct research that informs new climate change plans and policies. Many of the organizations I spoke with expressed a variety of research needs that extend beyond their current capacities, such as testing for soil contamination at community garden sites, monitoring air quality near schools, and evaluating measures of neighborhood gentrification in relation to transit-oriented development and other neighborhood improvement projects. Such research could be supported through collaborative research partnerships between public agencies, universities, and community-based organizations. Community-based participatory research (CBPR) is an especially apt approach to guide such research because it prioritizes equitable engagement of

multiple stakeholders to link place-based research and practice with broader policy change (Minkler, 2010). It has been successfully used to address health disparities in disadvantaged communities (Minkler, 2010) and would likely be an effective strategy to promote climate equity because it incorporates equity targets, civic engagement, and local knowledge.

Community-level climate change actions will remain relevant to broader-scaled climate change causes and consequences, but there is a need to more fully understand the unique characteristics and appropriate scales of particular climate policies. For instance, previous research on climate strategies in developing countries suggests that policies that try to meet all three climate mitigation, adaptation, and equity objectives may be more difficult to implement, more expensive, and less effective than policies that simply try to meet one or two of these objectives (Klein et al., 2005). Rather than creating new, synergistic policies or programs to address climate change challenges in developing countries, it can be more effective to “mainstream” or work within existing sectoral and development policies (Klein et al., 2005). Continuing research is needed to identify the specific institutional other contextual factors that contribute to successful or failed climate change strategies.

Limitations and strengths

This research highlights climate equity work by a select group of community-based organizations and does not present a comprehensive review of how all non-profits or organizations in other sectors such as philanthropy, private businesses, and public agencies are working to address climate equity. Future research can use the climate equity principles and framework to identify additional programs and actions that support climate equity goals. I did my best to select a representative sample of urban and rural community-based organizations from across California’ main regions. I did not, however, identify any community-based organizations who work primarily in suburban areas. Recent research highlights that suburban areas have much higher carbon footprints than urban and rural areas (Jones and Kammen, 2014), and low-income suburban areas may be ideal areas to consider for future evaluations of climate equity programs. Even with these limitations, this work has considerable strengths. I integrate qualitative and quantitative methods to show how local-level actions can improve statewide climate policy implementation. I present both theoretical and applied evidence that demonstrates the central role that equity considerations can and should take in ongoing climate planning and policy discussions. The many examples of climate strategies that I collected from community-based organizations across California show the potential to successfully integrate equity, adaptation, and mitigation goals in areas that have diverse populations and varied environments. The case studies can inform similar community-based actions in other areas of the state, nation, and globe and affirm that local-level impacts and responses must not be ignored as we work to address the global-level problem of climate change.

Conclusion

I have presented a climate equity framework that places equity as a central component of climate mitigation and adaption planning and policy. With examples from community-based organizations in California, I reframe disadvantaged communities as sites of solutions where innovative programs are being used to simultaneously address climate mitigation, adaptation, and equity goals. Specific equity targets, multi-level civic engagement, and local knowledge integration are commonly used by community-based organizations and highlight effective

methods that community advocates, policymakers, and researchers can use to achieve climate equity.

The most recent update to California's Climate Change Scoping Plan indisputably warns that unabated climate change will create an even more inequitable future:

“The impacts of climate change will not affect everyone the same way. Climate change is expected to more seriously affect the health and well-being of the communities in our society that are the least able to prepare for, cope with, and recover from the impacts of climate change...If this “climate gap” is not addressed, climate change will exacerbate many of the health and social disparities among California residents.” (55)

The disparate effects of climate change do not stop at California's borders and also manifest at national and global scales. For the sake of current and future generations, we have an opportunity and obligation to figure out how to face, and close, the climate gap. An equity-based approach to climate policy and planning sets us on course to not only survive the current and impending challenges of climate change but also thrive in a more equitable future.

Figure 3.1: Climate equity framework for climate change planning and policy

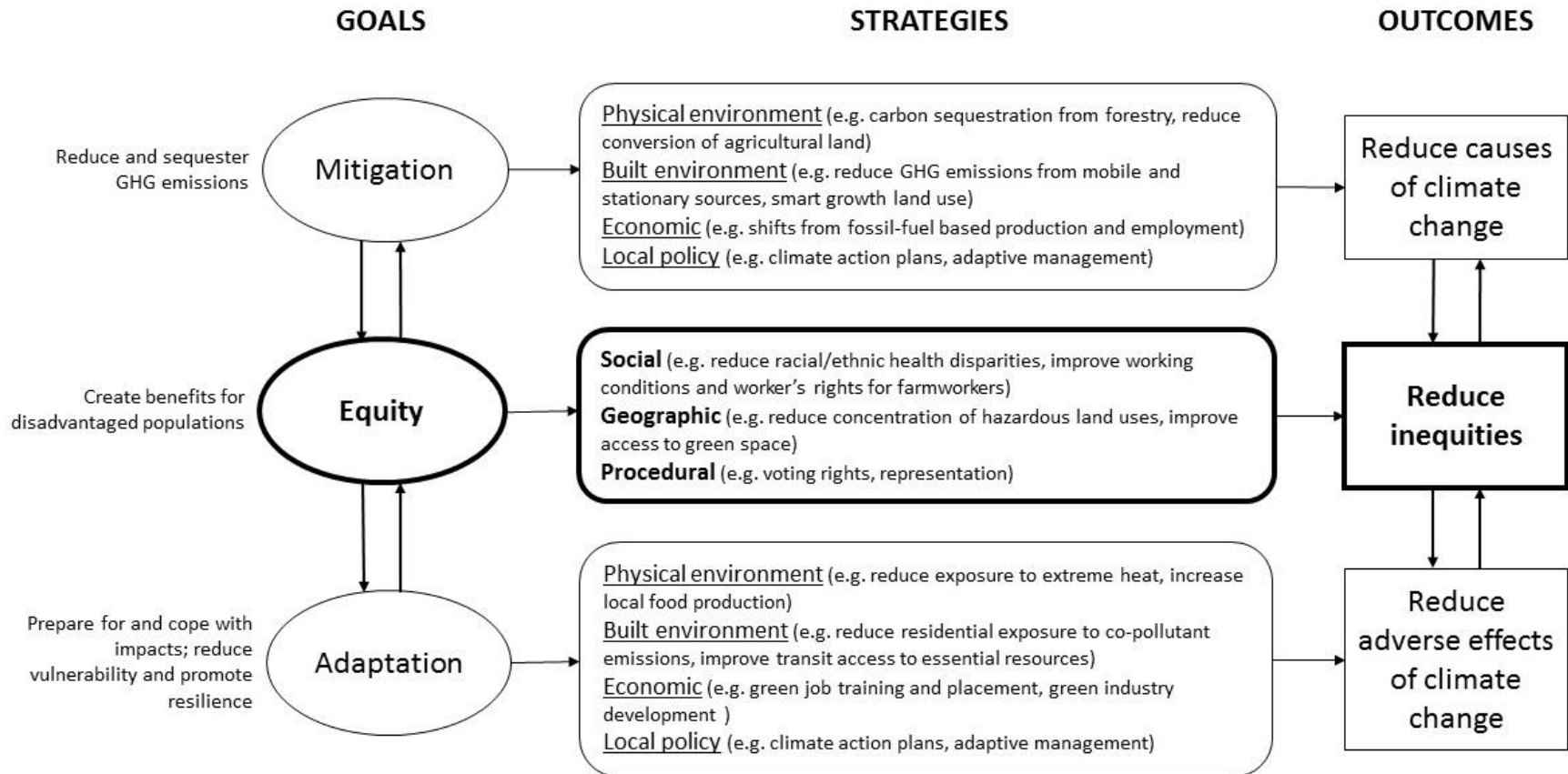
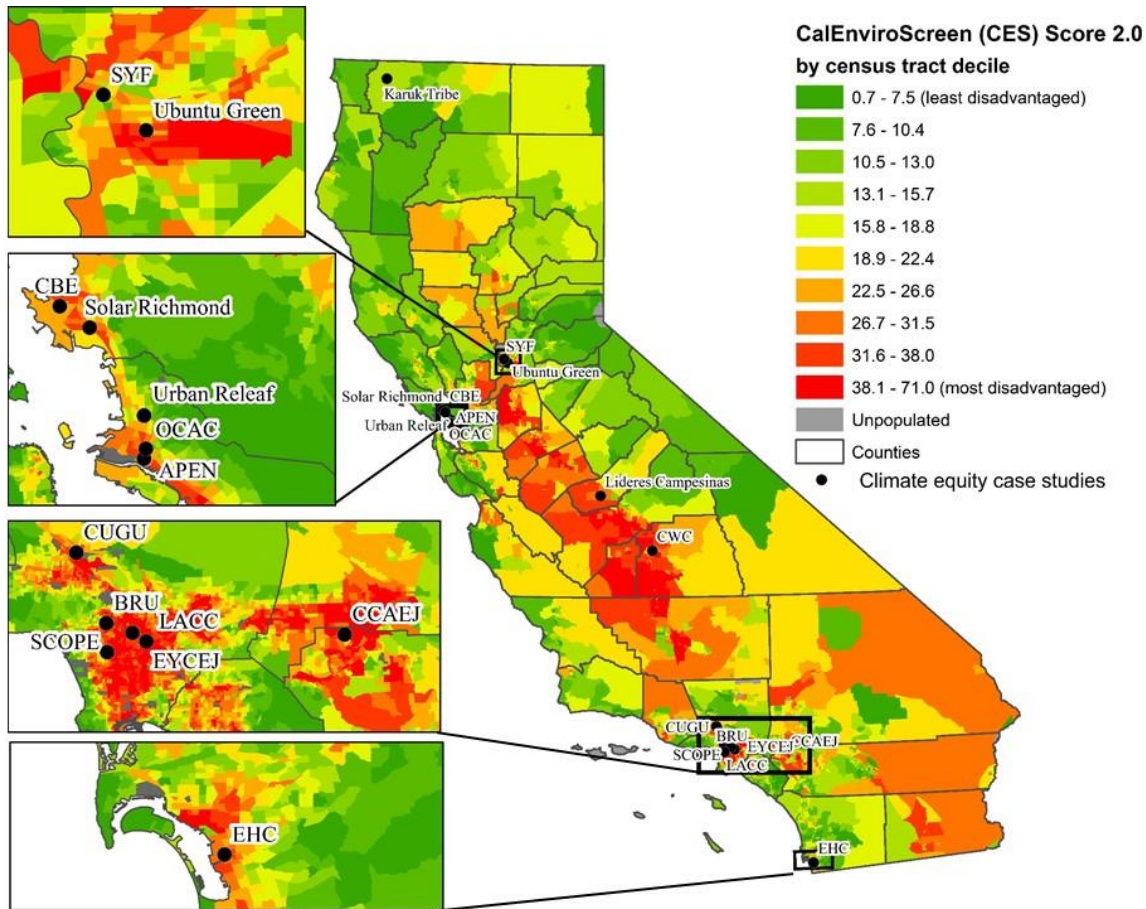


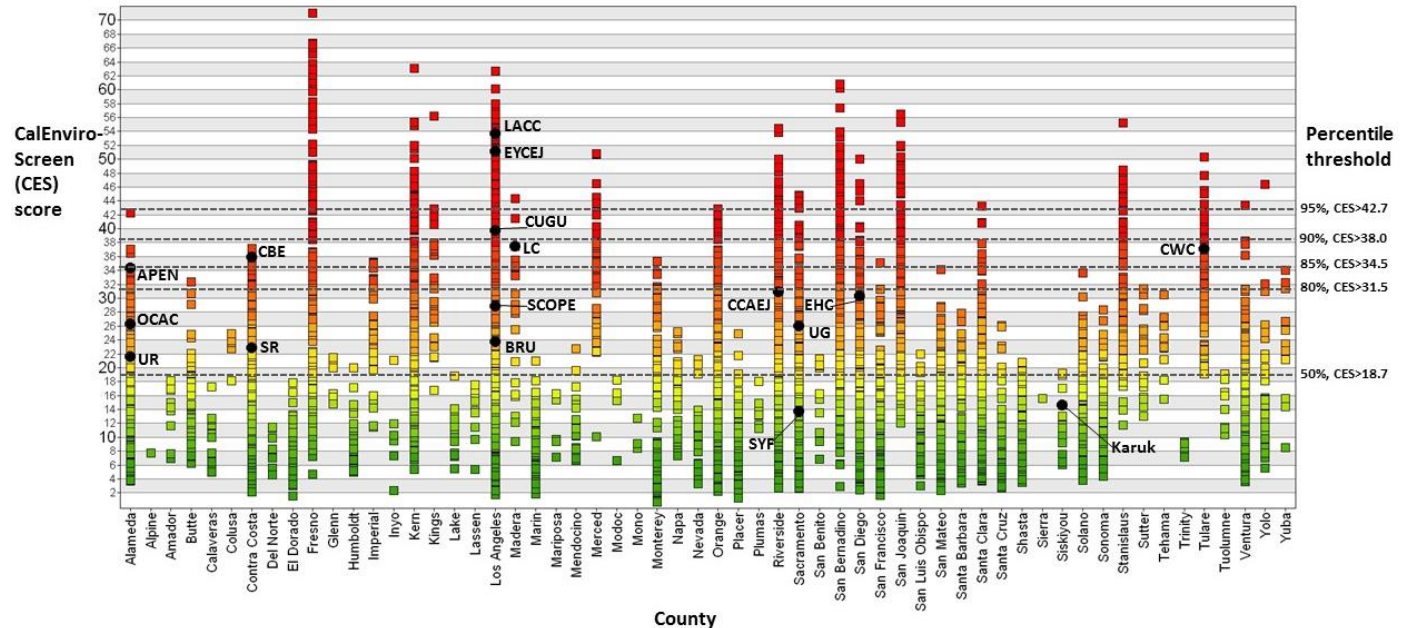
Figure 3.2: Spatial distribution of case study organizations and CalEnviroScreen scores



Acronyms: APEN = Asian Pacific Environmental Network; BRU = Bus Riders Union; CBE = Communities for a Better Environment; CCAEJ = Center for Community Action and Environmental Justice; CUGU = Clean Up Green Up; CWC = Community Water Center; EHC = Environmental Health Coalition; EYCEJ = East Yard Communities for Environmental Justice; LACC = Los Angeles Conservation Corps; OCAC = Oakland Climate Action Coalition; SCOPE = Strategic Concepts in Organizing and Policy Education; SYF = Sacramento Yard Farmer

Note: The CalEnviroScreen (CES) Score 2.0 combines measures of pollution burden and population characteristics to create a cumulative measure of relative disadvantage that accounts for multiple pollution sources in a community and the community’s vulnerability to the adverse effects of pollution. The pollution burden measure includes 7 environmental effects variables (ozone concentrations, PM 2.5 concentrations, diesel PM emissions, drinking water quality, pesticide use, toxic releases from facilities, and traffic density) and 5 exposure variables (cleanup sites, groundwater threats, hazardous waste, impaired water bodies, and solid waste sites and facilities). The population characteristics measures includes 3 sensitive population variables (children and elderly, low birth-weight births, asthma emergency department visits) and 4 socioeconomic variables (educational attainment, linguistic isolation, poverty, and unemployment). Each census tract’s CES score is relative to other census tracts in California. The maximum possible score is 100 and would represent a tract that is in the 100th percentile for all 19 variables. The CES scores are compiled by the California Environmental Protection Agency and the

Figure 3.3: Quantitative distribution of case study organizations, CalEnviroScreen scores, and percentile thresholds



Acronyms: APEN = Asian Pacific Environmental Network; BRU = Bus Riders Union; CBE = Communities for a Better Environment; CCAEJ = Center for Community Action and Environmental Justice; CUGU = Clean Up Green Up; CWC = Community Water Center; EHC = Environmental Health Coalition; EYCEJ = East Yard Communities for Environmental Justice; LACC = Los Angeles Conservation Corps; LC = Lideres Campesinas; OCAC = Oakland Climate Action Coalition; SCOPE = Strategic Concepts in Organizing and Policy Education; SYF = Sacramento Yard Farmer; SR = Solar Richmond; UR = Urban Releaf

Note: See note for Figure 2 for a description of the CalEnviroScreen (CES) Score. Census tracts with CES scores above the 80th percentile threshold will likely be targeted for investment opportunities from California’s Greenhouse Gas Reduction Fund.

Table 3.1: Climate equity case studies and actions

Case study organization(s) and places of focus	Climate equity strategies	Mitigation outcome	Adaptation outcome	Equity outcome
Urban Releaf <i>Oakland, CA (San Francisco Bay Area)</i>	<ul style="list-style-type: none"> - Tree planting in residential areas with poor canopy coverage - Urban forestry education and research with at-risk and hard-to-employ youth and adults 	<ul style="list-style-type: none"> - Sequester GHG emissions - Reduce emissions from energy use 	<ul style="list-style-type: none"> - Reduce extreme heat exposure - Increase social cohesion - Improve environmental health - Reduce stormwater runoff and flooding risk 	<ul style="list-style-type: none"> - Education and employment for at-risk and hard-to-employ youth and adults - Improve environmental health for overburdened populations
Lideres Campesinas <i>San Joaquin Valley, Coachella Valley, and other rural and agriculture-based regions in CA</i>	<ul style="list-style-type: none"> - Heat preparedness trainings with farmworkers - Transit and pesticide policy advocacy - Community organizing and leadership training with farmworkers, rural, low-income, Spanish-speaking, and/or immigrant populations, especially females 	Reduce emissions from vehicles and agriculture	<ul style="list-style-type: none"> - Preparedness for extreme heat events - Improve environmental health - Improve transit access to essential resources - Increase social cohesion - Increase awareness about infectious disease risk and prevention 	<ul style="list-style-type: none"> - Improve extreme heat coping strategies for immigrant and farmworker communities - Improve access to essential resources for rural communities - Civic engagement with underrepresented populations
Ubuntu Green; Sacramento Yard Farmer <i>Sacramento, CA (Central Valley)</i>	Plant household and community gardens in low-income neighborhoods	Reduce emissions from agriculture and food transport	<ul style="list-style-type: none"> - Improve food security - Increase social cohesion 	<ul style="list-style-type: none"> - Improve access to healthy and affordable food for disadvantaged populations - Civic engagement with underrepresented populations

Case study organization(s) and places of focus	Climate equity strategies	Mitigation outcome	Adaptation outcome	Equity outcome
Community Water Center (CWC) <i>San Joaquin Valley, CA (Central Valley)</i>	<ul style="list-style-type: none"> - Policy advocacy for clean drinking water - Community organizing and leadership training with rural, low-income, Spanish-speaking, and/or immigrant populations 	Reduce emissions from agriculture and dairy industry	<ul style="list-style-type: none"> - Improve environmental health - Increase access to clean drinking water - Increase social cohesion 	<ul style="list-style-type: none"> - Improve environmental health for overburdened populations - Civic engagement with underrepresented populations - Increase representativeness of elected officials
Environmental Health Coalition (EHC) <i>San Diego county, CA</i>	<ul style="list-style-type: none"> - Policy development and advocacy for amortization ordinance to replace polluting businesses that are near residential areas - Community-based participatory research with low-income and Spanish-speaking communities 	Reduce emissions from industry	<ul style="list-style-type: none"> - Improve environmental health - Increase social cohesion 	<ul style="list-style-type: none"> - Improve environmental health for overburdened populations - Civic engagement with underrepresented populations
Clean Up, Green Up Coalition <i>Los Angeles, CA</i>	<ul style="list-style-type: none"> - Develop and advocate for “green zones” land use planning - Community organizing and leadership training with low-income communities 	Reduce emissions from industry	<ul style="list-style-type: none"> - Improve environmental health - Increase social cohesion - Coalition building 	<ul style="list-style-type: none"> - Improve environmental health for overburdened populations - Civic engagement with underrepresented populations

Case study organization(s) and places of focus	Climate equity strategies	Mitigation outcome	Adaptation outcome	Equity outcome
Bus Riders Union (BRU) <i>Los Angeles, CA</i>	- Advocacy for improved bus service and Clean Fuel Bus Fleet	Reduce emissions from transportation	- Improve environmental health - Increase social cohesion - Improve access to essential resources	- Improve environmental health for overburdened populations - Civic engagement with underrepresented populations - Improve access to essential resources for low-income communities
East Yard Communities for Environmental Justice (EYCEJ); Center for Community Action And Environmental Justice (CCA EJ) <i>Los Angeles, Riverside, and San Bernardino Counties (Southern CA)</i>	- Advocacy for regulatory reform of rail industry and diesel particulates - Advocacy for air filters in schools, vegetative barriers around pollution sources, anti-idling zones	Reduce emissions from the goods movement	- Improve environmental health - Increase social cohesion	- Improve environmental health for overburdened populations - Civic engagement with underrepresented populations

Case study organization(s) and places of focus	Climate equity strategies	Mitigation outcome	Adaptation outcome	Equity outcome
Communities for a Better Environment (CBE); Asian Pacific Environmental Network (APEN); Solar Richmond <i>Richmond, CA (San Francisco Bay Area)</i>	<ul style="list-style-type: none"> - Enforcement of environmental impact review standards for industrial expansion - Solar panel installation, targeting low-income homes and local businesses - Coalition building - Education and green job training and placement for at-risk and hard-to-employ youth and adults 	Reduce emissions from industry and energy use	<ul style="list-style-type: none"> - Improve environmental health - Increase social cohesion - Coalition building - Increase financial resources for low-income populations 	<ul style="list-style-type: none"> - Improve environmental health for overburdened populations - Civic engagement with underrepresented populations - Education and job opportunities for hard-to-employ at at-risk youth and adults
L.A. Conservation Corps (LACC); Strategic Concepts in Organizing and Policy Education (SCOPE) <i>Los Angeles, CA</i>	<ul style="list-style-type: none"> - Building retrofits to save energy and water - Education and green job training and placement for at-risk and hard-to-employ youth and adults - Coalition building 	Reduce emissions from energy use	<ul style="list-style-type: none"> - Increase financial resources for low-income populations - Increase social cohesion 	<ul style="list-style-type: none"> - Education and job opportunities for hard-to-employ at at-risk youth and adults - Civic engagement with underrepresented populations

Case study organization(s) and places of focus	Climate equity strategies	Mitigation outcome	Adaptation outcome	Equity outcome
<p>Ella Baker Center; Oakland Climate Action Coalition</p> <p><i>Oakland, CA (San Francisco Bay Area)</i></p>	<ul style="list-style-type: none"> - Development and advocacy for an Energy and Climate Action Plan that creates benefits for low-income communities of color - Advocacy for green job programs in areas with high unemployment rates - Coalition building 	<p>Reduce emissions from energy use</p>	<ul style="list-style-type: none"> - Increase financial resources for low-income populations - Increase social cohesion - Coalition building 	<ul style="list-style-type: none"> - Improve environmental health for overburdened populations - Civic engagement with underrepresented populations - Education and job opportunities for hard-to-employ at at-risk youth and adults
<p>Karuk Tribe</p> <p><i>Humboldt and Siskiyou Counties (Northwest CA)</i></p>	<p>Development of and advocacy for adaptive management plan by tribal members</p>	<ul style="list-style-type: none"> - Store and sequester GHG emissions in forests - Reduce emissions from wildfires 	<ul style="list-style-type: none"> - Improve food security - Improve environmental health - Reduce wildfire risk 	<ul style="list-style-type: none"> - Improve environmental health for tribal members - Civic engagement with underrepresented populations

CHAPTER FOUR

From home to hospital: An integrated evaluation of public housing and child health in San Francisco, CA[†]

Abstract

I examined associations between public housing type and recurrent pediatric emergency and urgent care hospital visits. Children ages 0 to 18 with public insurance who sought emergency care from any of three large medical systems in San Francisco were categorized by whether they lived in public housing redeveloped through the Federal HOPE VI Program (n=368), other non-redeveloped public housing (n=2,077), or non-public housing in the same census tract as public housing (n=3,266). After adjusting for potential confounding characteristics, I found that children living in non-redeveloped public housing were 39 and 37 percent more likely to have one or more repeat visits for acute health care services unrelated to the initial visit within one year compared to children who lived in redeveloped HOPE VI housing or non-public housing, respectively. I observed no differences in repeat visits between HOPE VI and non-public housing residents. However, the populations in both types of public housing had higher rates of chronic disease, injury, trauma, and skin diseases than children who did not live in public housing. These findings support the continued redevelopment of dilapidated public housing and targeted health systems investments for families in public housing as a means of improving the health of high-risk children from low-income neighborhoods and reducing healthcare costs.

[†]Portions of this chapter are copyrighted and published by Project HOPE/*Health Affairs* as Kersten E, LeWinn K, Gottlieb L, Jutte D, Adler N. San Francisco Children Living In Redeveloped Public Housing Used Acute Services Less Than Children In Older Public Housing. *Health Aff (Millwood)*. 2014;33(12). The published article is archived and available online at www.healthaffairs.org/.

Introduction

Living conditions during childhood affect health outcomes at the time and across the life-course, contributing to socioeconomic and racial/ethnic health disparities for children and adults (Braveman and Barclay, 2009). Policies that focus on improving “upstream” environmental and economic factors such as housing may therefore improve population health while also reducing medical costs and health disparities (Woolf and Braveman, 2011).

Understanding the links between housing and health is increasingly important. Poor housing quality is a predictor of poor health (Leventhal and Newman, 2010) and developmental problems in low-income children (Coley et al., 2013), yet research on the health effects of housing policies is limited (Lindberg et al., 2010). Meanwhile, more children are visiting emergency rooms for potentially preventable reasons (LeDuc et al., 2006; Lu and Kuo, 2012). This utilization is costly; the average emergency room visit costs two to five times more than an office visit (New England Healthcare Institute, 2010). Emergency room visits are associated with a number of individual- and neighborhood-level factors, such as community household income (Beck et al., 2012; Colvin et al., 2013; Fieldston et al., 2013) and insurance status (Billings et al., 1993; Kellermann and Weinick, 2012), and there is a need to better understand the full range of social, economic, and environmental factors that can lead to higher emergency room visit rates for vulnerable populations.

Housing is a major challenge for low-income families, and various programs seek to address these needs. Approximately 7 million households, including more than 4 million children, live in housing that is made affordable through Federal rental assistance programs or the Low Income Housing Tax Credit program (Center on Budget and Policy Priorities, 2013b; Ellen and Horn, 2012). One of the nation’s main rental assistance programs is public housing, which includes 1.12 million public housing units administered by 3,100 local housing authorities (Center on Budget and Policy Priorities, 2013a). Forty percent of households that live in public housing have children under 18 years old (Center on Budget and Policy Priorities, 2013a).

Over the past two decades, 56,800 public housing units were redeveloped through the Federal HOPE VI program (U.S. Department of Housing and Urban Development, 2010). Initiated by Congress in 1992, HOPE VI was one of the most ambitious urban redevelopment strategies in US history (Popkin et al., 2004; U.S. Department of Housing and Urban Development, 2011). More than \$6.1 billion in Federal funds were invested with the aim of rebuilding the most severely distressed and dilapidated urban public housing (Popkin et al., 2004; U.S. Department of Housing and Urban Development, 2011). The program transformed notorious “housing projects” across the country into lower density, town home-style communities designed to also attract higher-income families and create mixed-income neighborhoods. HOPE VI differed from prior housing policies because it did not just focus on improving the physical conditions of particular housing developments; it also explicitly included goals to support individual- and neighborhood- level changes, such as improved resident well-being and self-sufficiency and community institutions and infrastructure (Popkin et al., 2004). Funded sites were required to use a portion of their resources to provide “community supportive services,” which in most cases focused on employment- and education-related programs (Popkin et al., 2004).

Much past research examining the impact of public housing—most prominently the Gautreaux Assisted Housing Program (Popkin et al., 2000) and the Moving to Opportunity for Fair Housing (MTO) demonstration program (Goering et al., 2003; Ludwig et al., 2008)—has focused on the

use of housing vouchers to allow families and individuals to move away from poor quality public housing. While health was not a primary outcome for either program, the MTO program did demonstrate some positive impacts for adult physical health and subjective well-being (Ludwig et al., 2011, 2012; Sanbonmatsu et al., 2011). Evidence of impact among youth has been limited to mental health with unexpectedly mixed outcomes by gender: lower rates of depression and conduct disorders among adolescent girls but higher rates of depression, posttraumatic stress disorder, and conduct disorders among boys (Gennetian et al., 2012; Kessler et al., 2014). Meanwhile, studies following former residents of HOPE VI sites relocated as part of the redevelopment process have generally noted worsening of their already very poor health, even in cases where they moved to lower poverty neighborhoods (Keene and Geronimus, 2011; Manjarrez et al., 2007).

While subsidized housing programs have been shown to have some salutary effects for children by preventing homelessness and increasing household disposable income for food and other essentials (Fertig and Reingold, 2007; Newman and Holupka, 2014; Wood et al., 2008), public housing is generally located in poor neighborhoods with high levels of crime, low-performing schools and higher levels of harmful exposures to environmental toxins like lead and mold (Fertig and Reingold, 2007; Krieger and Higgins, 2002; Leventhal and Newman, 2010). Little research has evaluated the effects of public housing on child health (Leventhal and Newman, 2010) Further, existing studies often are weakened by potential confounding due to selection bias and limited data availability (Fertig and Reingold, 2007).

The present study advances work bridging housing and health by combining two data sources—health system utilization records and citywide public housing records— using technologies for data linkage and spatial analysis to assess the relation between housing type and child healthcare utilization. I merged emergency and urgent care department electronic medical record data across six hospitals representing three medical systems, creating a database that includes more than 80 percent of emergency pediatric healthcare visits in the City and County of San Francisco over a five year period. My primary aim was to evaluate whether housing type—HOPE VI, non-redeveloped public housing, or nearby non-public housing—was associated with recurrent acute care medical visits in this citywide population of children. Secondly, I evaluated whether the types of health conditions experienced by pediatric patients who visited the hospital for acute medical care varied by housing type. The implications of this analysis are relevant for the design, implementation, and evaluation of public housing policies as well as efforts to reduce healthcare costs among high-risk children.

Methods

This retrospective cohort study was approved by the institutional review boards of the University of California San Francisco (IRB #12-08762), University of California Berkeley (Reliance #755), and Sutter Health (Protocol #13-04-226).

Data and population

I obtained all hospital visit data from 2007-2011 for children age 0 to 18 from three medical systems in San Francisco, CA (N=62,067). Patient data were merged within and across the three medical center databases using Link King software, version 7.1.22 (Campbell et al., 2008). Link King de-duplicates and joins individual records based on patient name, medical record number,

day of birth, gender, race/ethnicity, and address. The software uses probabilistic and deterministic matching algorithms to account for common misspellings, nicknames, transposing, and other data entry errors (Campbell, 2005). The combined dataset includes visit data from six hospital sites with emergency services, two of which also provide urgent care services in adjoined facilities.

Figure 4.1 displays the study population selection steps. I excluded visit data with a residential address that was invalid or located in a city other than San Francisco (n=1,931). All remaining addresses were geocoded in ArcGIS 10.1 using a composite address locator that incorporates address point and street segment data from the City and County of San Francisco and ESRI (Redlands, CA). After manually correcting common street name misspellings, more than 98 percent of addresses were successfully geocoded with a match score >80. To minimize variability in the dependent variable of interest, housing type, I excluded patients who had an address in a different census tract or housing type at a subsequent visit within one year after their initial hospital visit (n=1,412).

I further excluded patients who were 18 years-old at the time of their first visit or born after January 1, 2011 to ensure that each patient could have a full year of visit data within the sample (n=11,064). I also excluded patients who were assigned any diagnosis code for a complex chronic condition (CCC) within the study period (Feudtner et al., 2000, 2001). These conditions are most likely caused by genetic or other factors that do not have a strong link to housing and result in more frequent visits that produced outlier visit frequencies. CCC is defined as “any medical condition that can be reasonably expected to last at least 12 months (unless death intervenes) and to involve either several different organ systems or one system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center” (Feudtner et al., 2000; Simon et al., 2010). As expected, a very small proportion of patients (1%), were seen for such conditions.

The San Francisco Housing Authority (SFHA) provided names and addresses of public housing locations, including five properties that were redeveloped through the Federal HOPE VI Program from 1995 to 2006. All public housing locations (N=3,472 addresses) were geocoded using the same composite geocoder described above, and 100 percent of records were matched at the address or block level. Public housing and hospital visit data were merged based on the standardized addresses in the geocoding output to identify patients who lived in public housing. I used 2010 US Census boundaries to identify census tracts containing public housing addresses and excluded patients who lived outside of those tracts (n=37,930) to minimize neighborhood-level confounding. Lastly, I further limited the sample to children with public insurance at their first visit to reduce confounding by socioeconomic status (see Appendix B for additional details). The final sample included 5,711 patients.

Dependent variables

The main dependent variable was emergency and urgent care visit frequency within one year following the patient’s first such visit. I included urgent care visits because the two urgent care departments in the database are in the same building as the emergency departments, and the department that a patient is seen in at these sites is more a function of the time of day and patient load at the hospital rather than the particular health condition of the patient. Return visits within 72 hours were excluded based on literature suggesting these are frequently related to the initial

presenting complaint (Ali et al., 2012; Logue et al., 2013). I coded visit frequency dichotomously: 0 return visits vs. one or more return visits.

Secondly, I evaluated patient-level frequencies of select diagnosis categories to understand the health conditions that the study population presented with when seeking acute medical care. I first used the Diagnosis Grouping System (DGS), which includes 21 diagnosis groups that were developed specifically to create clinically sensible groupings of pediatric emergency diagnoses (Alessandrini et al., 2010). Secondly, I identified injuries by classifying ICD-9-CM codes according to a method developed by the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2010). Third, I characterized conditions that were chronic (but not complex as defined by Feudtner et al. (Feudtner et al., 2000)) based on ICD-9-CM codes in the Chronic Condition Indicator database developed by the Healthcare Cost and Utilization Project (Chronic Condition Indicator (CCI) for ICD-9-CM). Examples of non-complex chronic conditions (NCCC) are asthma, diabetes, and migraine. Lastly, I measured potentially preventable emergency visits based on a list of ambulatory care sensitive conditions (ACSC) that was most inclusive of conditions relevant to a pediatric population (Michigan Department of Community Health, 2014; Millman, 1993). Examples of included ACSC diagnosis codes are asthma, cellulitis, dental conditions, and nutritional deficiency.

Housing measure

Patients were assigned one of three housing types: non-public housing (n=3,266), HOPE VI public housing (n=368), and non-redeveloped public housing (n=2077).

Covariates

For adjusted models, I included covariates likely to affect pediatric emergency services utilization (Alpern et al., 2014; LeDuc et al., 2006; Yamamoto et al., 1995). Individual-level covariates were age (<1 year; 1-4; 5-9; 10-14; 15-17), gender, and race/ethnicity (white; Asian; Hispanic; black; other). I also included indicators of diagnosis severity: (1) maximum severity score of all diagnosis codes (1 to 5 based on the Severity Classification System (Alessandrini et al., 2012)); and (2) whether the child had received any diagnosis for a non-complex chronic condition (NCCC) based on ICD-9-CM codes across all visits (Chronic Condition Indicator (CCI) for ICD-9-CM). At the hospital level, I adjusted for whether the initial visit was to the emergency room or urgent care department, and for hospital site. Neighborhood-level covariates were the percent population below 200% federal poverty level (FPL) for the patient's census tract and an indicator of whether the patient lived in the same tract as HOPE VI public housing (for explanations of these neighborhood measures, see Appendix B).

Statistical analysis

Bivariate analyses compared characteristics by housing type, using chi-square tests for categorical variables and t-tests for continuous variables with Stata 13 software (StataCorp, College Station TX). Adjusted odds ratios and confidence intervals were estimated using generalized estimating equations (GEE) to control for clustering or correlation and generate population average coefficient estimates as opposed to the individual-level measures produced by standard logistic regression (Hubbard et al., 2010). The GEE analysis was conducted with SAS statistical software version 9.4 (SAS Institute, Cary NC) using the GENMOD procedure. I

used a logit-link function and an exchangeable correlation structure with a hospital indicator as the cluster variable.

Sensitivity analysis

I conducted three sensitivity analyses to ensure the accuracy of the results. First, I used standard logistic regression with robust variance estimates to further test for potential clustering of observations (Rogers, 1993). Secondly, I used multinomial logistic regression with robust variance estimates to test for differences in associations among categories of visit frequency: 0 return visits, 1 return visits, 2 return visits, and 3 or more return visits. Third, modified Poisson generalized linear models with robust variance (Zou, 2004) were used to generate risk ratios and confidence interval estimates to test for qualitative equality with odds ratio output in terms of effect significance and to provide alternative quantitative measures of effect that are considered more appropriate and interpretable by some scholars (McNutt et al., 2003) because of the relatively frequent occurrence of the outcome of interest (50%). All of these analyses were conducted in Stata 13 software (StataCorp, College Station TX).

Results

Summary statistics

Table 4.1 displays demographic, neighborhood, and hospital visit characteristics for the study population by housing type. Characteristics of the populations in the two different public housing types were largely comparable, except a greater percentage of HOPE VI patients were 15-17 year-olds (17% vs. 12%) or Hispanic (24% vs. 18%) and a lower percentage were infants (17% vs. 22%) compared to the patient population in non-redeveloped public housing. In contrast, the non-public housing patient population was significantly different from the public housing population for multiple age, race/ethnicity, neighborhood, and hospital visits characteristics. Non-public housing residents were significantly more likely to be an infant (25% vs. <22%), less likely to be African American (19% vs. >50%), more likely to be Hispanic (52% vs. <25%), more likely to visit the urgent care department (53% vs. <50%), and less likely to visit more than one medical system (4% vs. 7%) than both groups of public housing residents. The mean percent census tract population living below 200% of FPL also varied by housing type and was greatest for children living in non-redeveloped public housing (54%) and lowest for children in HOPE VI public housing (38%).

Health conditions

Table 4.2 summarizes the health conditions of the study population by housing type. The two public housing groups did not differ significantly for any of the health conditions. But, the public housing population was significantly different than the non-public housing population for a number of health factors. Children in either type of public housing were more likely to receive a diagnosis for a non-complex chronic condition ($\geq 18\%$ vs. 14%), injury (27% vs. 20%), trauma ($\geq 24\%$ vs. 18%), or skin diseases ($\geq 21\%$ vs. 16%) than those not in public housing. Children in public housing were less likely to receive a diagnosis for a systemic state ($\leq 20\%$ vs. 23%) or gastrointestinal diseases ($\leq 18\%$ vs. 23%) than those not in public housing.

Unadjusted results

Summary measures of emergency and urgent care visit frequency by housing type are presented in Table 4.3. The total number of visits within a year ranged from 1 to 18. Overall, among children seen for care, half did not return for emergency services within 3 to 365 days, 24% had one return visit, 12% had two return visits, and 14% had three or more return visits. Children living in non-redeveloped public housing had a significantly greater mean number of visits than those who did not live in public housing (2.21 vs. 2.06, $p=0.002$). Children living in HOPE VI public housing had an intermediate mean number of return visits (2.16) that did not differ significantly from either non-public housing residents ($p=0.26$) or non-redeveloped public housing residents ($p=0.65$). The same pattern exists using a dichotomous variable of no return visits versus one or more return visits. Children in non-redeveloped public housing were more likely than children not living in public housing to have at least one repeat visit (52% vs. 48%, $p=0.004$), while the percentage of children in HOPE VI with any number of return visits (51%) did not differ significantly from either the children not in public housing or those in non-redeveloped public housing. ($p=0.30$, and 0.67 respectively).

Adjusted results

Living in non-redeveloped public housing remained a significant predictor of recurrent acute healthcare utilization in models adjusted for demographic, health, neighborhood, and hospital characteristics. With adjustment, children who lived in non-redeveloped public housing were 37 percent more likely to have at least one repeat visit to an emergency or urgent care department compared to children who did not live in public housing (OR 1.37 [1.31-1.42], $p<0.001$) (Figure 4.2) and 39 percent more likely than children who lived in HOPE VI public housing (OR 1.39 [1.12-1.71], $p=0.002$) (not shown in figure, but detailed in Appendix B). There was no significant difference in the likelihood of at least one repeat visit for children who lived in HOPE VI public housing compared to those who did not live in public housing (OR 0.98 [.082-1.18], $p=0.849$) (Figure 4.2). Results from all sensitivity tests showed similar effect patterns (Appendix B, Table 1).

Discussion

These results suggest that housing conditions play a role in disparities in acute healthcare utilization patterns. I found that low-income children living in redeveloped HOPE VI public housing were less likely to have one or more repeat acute care visits than children living in older, more traditional public housing. This finding suggests that investments in improving both the physical infrastructure and providing enhanced community supportive services—as mandated in the HOPE VI program—for low-income families may do more than simply provide better housing; these investments may also foster better health among children and reduce healthcare costs for acute care services.

None of the evaluated health condition categories showed significant variation by public housing type, suggesting that the observed difference in visit frequency by public housing type may be the result of variation in access to primary care or health education services (e.g. chronic disease management) as opposed to differences in the incidence of particular health conditions. Both public housing population groups had similarly different distributions of health conditions compared to low-income children not living in public housing, such as higher rates of non-

complex chronic conditions, injuries, trauma, and skin diseases and lower rates of diagnoses for gastrointestinal diseases and systemic states (e.g fever, influenza). More research is needed to identify the specific drivers of each of these differences, but these preliminary comparisons demonstrate that children who live in public housing have distinct health conditions and healthcare needs compared to other low-income children.

Implications

These findings are especially salient for tax-exempt hospitals as they conduct community health needs assessments and adopt implementation strategies in line with requirements of the Affordable Care Act and for local health departments, many of which spearhead community health improvement processes. Although some select community health assessments and implementation strategies consider housing and other social and environmental determinants of health (Barnett, 2012), it is not yet the norm. For example, the most recent community health improvement plan for San Francisco states that socioeconomic conditions are not directly addressed “because these factors are broad social issues that require systematic, institutional change reaching beyond a local public health system’s primary activities”(San Francisco Department of Public Health, 2012). Evidence from this study suggests that the issue of housing might indeed be considered within the purview of health system’s activities given the connections between housing type and healthcare utilization patterns. For organizations that want to reduce healthcare costs, the finding that investments in good quality public housing may reduce expensive use of acute health care facilities by children may encourage their involvement in redevelopment efforts.

Likewise, this study also supports the inclusion of health and healthcare factors in decision-making around housing policies and programs. Only one in four eligible US households receive Federal housing assistance (Ellen and Horn, 2012), suggesting a need for expanded housing opportunities for low-income families. The US Department of Housing and Urban Development has adopted a “health in all policies” approach that promotes collaborations with health organizations, the use of health metrics, and the inclusion of health and social services into its goals and programs (Bostic et al., 2012). Local housing authorities and housing developers could benefit by following suit. For instance, housing agencies could be active collaborators in community health needs assessment and implementation processes, collect and monitor health metrics in resident surveys, and partner with community-based organizations to provide health education training and preventative services to residents.

In San Francisco and many other cities, housing authorities face budgetary challenges that limit their capacity to conduct essential inspections and maintenance to ensure that all public housing units are fit and available for habitation. By framing safe and affordable housing as an essential driver of community health, housing agencies could join forces with health services organizations to ensure that scarce resources, including those from community benefit funds, are invested in ways that maximize public health benefits for children and other vulnerable populations.

Beyond health systems and housing institutions, both the process and outcomes of this work have implications for organizations such as schools and social services providers. Like prior research (Fuda and Immekus, 2006; Shapiro et al., 2013), this study confirms that integrating data across healthcare systems provides novel insights about population-level, as opposed to simply site-specific, healthcare utilization patterns. Data joining efforts across individual

government and/or private sector institutions are likely to be equally valuable for other sectors. Integrated data analysis can help identify service utilization impacts of specific programs or policies, inform resource allocation decisions, and aid in surveillance to guide future program development (Jutte et al., 2011). For example, hospital visit and housing data could be further linked with education data to evaluate the relationships between health outcomes, housing type, and school performance to inform the development of school-based health centers and after-school programs.

Future research

More concrete evidence documenting relationships between public housing redevelopment and children's health may emerge in evaluations of pre- and post-redevelopment health outcomes at particular public housing sites. Several of San Francisco's remaining public housing properties have begun redevelopment through HOPE SF, a city-sponsored program initiated in response to lessons learned from HOPE VI revitalization projects (San Francisco Mayor's Office of Housing, 2014). The housing and hospital visit data I have assembled to-date (2007-2011) provides a baseline of the pediatric health and healthcare characteristics of this population. This historical data can be compared to post-redevelopment data to evaluate and monitor changes in children's health and inform the ongoing redevelopment processes at HOPE SF and other public housing locations.

Future research will require integrating data from additional hospitals and clinics to create a more complete population-level database of healthcare utilization in San Francisco and beyond, as well as more detailed data on housing quality and the populations served by housing programs. The nation is embarking on a "new era in housing policy" with the HOPE VI program being replaced by Choice Neighborhoods, an initiative that seeks to transform entire low-income neighborhoods into sustainable communities; a contrast to the limited public housing focus of HOPE VI (U.S. Department of Housing and Urban Development, 2011). As more low-income families are affected by housing redevelopment efforts, there is a continuing need to evaluate and communicate health impacts, especially for children.

Limitations and strengths

This chapter has several limitations. First, the unavailability of total counts of children living in public housing precludes reporting overall acute care visit rates for all children in public housing. Appendix B includes a description of available data and estimated comparisons to county and national measures.

Second, I did not have data on unit- or building-level housing quality (e.g. air quality, mold, crime, etc.) to investigate possible pathways linking housing quality to health. Although the City and County of San Francisco collects data on housing code violations, public housing residents do not regularly report violations and enforcement is inconsistent (Learning for Action, 2012).

Third, I was not able to control for household-level factors that may contribute to differences in acute care utilization and/or health outcomes, such as household income and wealth (Currie and Lin, 2007) and family structure (Bramlett and Blumberg, 2007). HOPE VI properties have a mixed-income population, and I was not able to distinguish with certainty the children living in relatively higher income households. I used public insurance as a proxy for low-income status, but this measure may not capture the nuanced effects of household income on child health.

Fourth, five percent of visits were by patients with invalid addresses. While unlikely to bias the analysis, it excludes visits by children who were homeless, living in transitional care, in juvenile hall, outside of San Francisco, or with an invalid address.

Fifth, my dataset does not include all healthcare facilities in San Francisco. The sampled hospitals treated 80% of all children seeking emergency care in San Francisco from 2007-2011 and 87% of those who were publicly insured (von Bernath, 2013).

Sixth, HOPE VI public housing residents were a relatively small proportion of the study population (6%, n=368); this reflects the small proportion of public housing units redeveloped through HOPE VI (5%) (U.S. Department of Housing and Urban Development, 2010).

Finally, the generalizability of the results may be limited because of unique characteristics of the study area. Housing costs are particularly high in San Francisco, and median household income is \$73,802 versus \$50,502 nationally). In addition, there is a low proportion of children in the city's population (13% vs. 24% nationally), and fewer children are without health insurance (4% vs 8% nationally).

This study also has considerable strengths. The data, methods, and conclusions help address persistent research gaps on the health effects of housing policies. A 2010 review of housing interventions found that only one policy, rental vouchers, had a sufficient evidence base showing positive health effects, measured in terms of reduced rates of overcrowding, malnutrition, and concentrated poverty (Lindberg et al., 2010). This research uses more direct measures of health (acute healthcare utilization rates and diagnosis codes) from electronic medical records, demonstrating that evaluations of housing policies do not have to rely solely on residential surveys and/or census data.

I partnered with three large medical systems and a local housing authority to create an integrated, patient-based, and nearly population-level database of pediatric acute healthcare visits, public housing, and socioeconomic census data. Similar “geographic health information systems” have been created elsewhere in the US (Miranda et al., 2013) and Canada (Martens et al., 2014), but my analysis is the first to my knowledge to characterize the healthcare utilization patterns and health outcomes for children in different types of public housing.

These findings reveal place-based health disparities at a finer-scale than what has commonly been reported in research that relies on health data aggregated to administrative units such as census tracts (Beck et al., 2012) or other neighborhood areas (Beck et al., 2013). I found that pediatric healthcare utilization patterns vary by housing type; this distinction would have been missed if I limited my evaluation of visit frequency and health outcomes to the neighborhood-level.

Conclusion

Through the linkage of healthcare and housing data at a city-wide scale, this chapter identified unique health characteristics of low-income children who lived in different types of public housing. My results suggest that public housing redevelopment policies may play an important role in reducing healthcare costs associated with pediatric acute care services utilization. It is both possible and necessary for healthcare providers and other institutions to expand

collaborations beyond their own sectors in order to better identify, address, and monitor the health and healthcare needs of children and other vulnerable populations.

Figure 4.1: Study sample selection steps

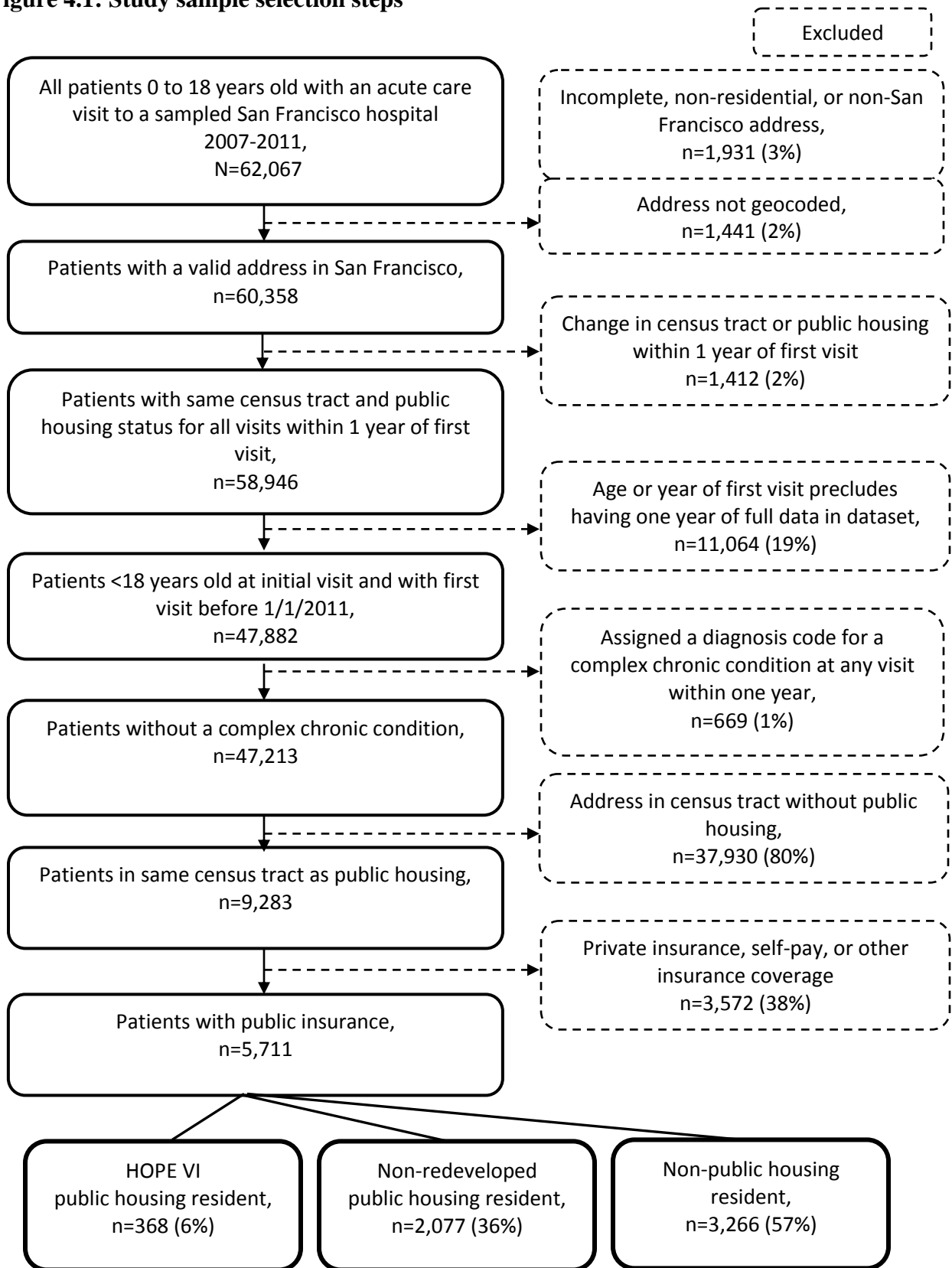
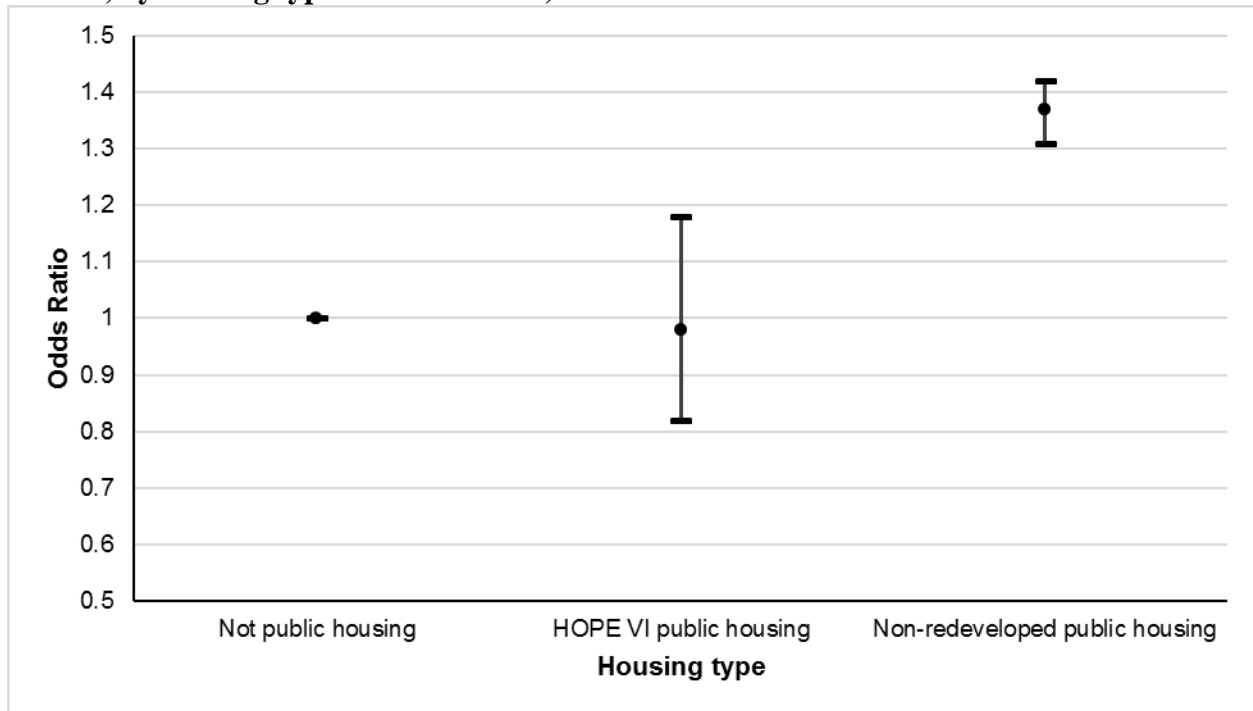


Figure 4.1 notes:

Percentages of the excluded population are based on the population total of the prior selection stage.

Figure 4.2: Adjusted model results for one or more emergency or urgent care hospital revisits, by housing type. San Francisco, CA 2007-2011



	Odds ratio	<i>p</i>	95% CI
Non-public housing residents*	-	-	-
HOPE VI public housing resident	0.98	0.849	0.82-1.18
Non-redeveloped public housing resident	1.37	<0.001	1.31-1.42

Figure 4.2 Notes:

* Reference group

Lines indicate 95% confidence intervals. Effects reflect odds of having one or more return emergency or urgent care visits within 3 to 365 days of an initial visit. Children not living in public housing are the reference group. I controlled for age, sex, race/ethnicity, maximum severity score of all ICD9 codes across all visits, any diagnosis of a non-complex chronic disease, percent tract population <200% Federal poverty level, hospital department, hospital campus, and living in the same neighborhood as HOPE VI public housing

Table 4.1: Summary statistics of study population demographic, neighborhood, and hospital visit characteristics, by housing type. San Francisco, CA 2007-2011

	Full population (N = 5,711)		Non-public housing (n = 3,266)		HOPE VI public housing (n = 368)		Non-redeveloped public housing (n = 2,077)	
	Number	% or mean	Number	% or mean	Number	% or mean	Number	% or mean
Demographic characteristic								
Age (years)								
Less than 1 ^{a,b,c}	1,332	23%	808	25%	64	17%	460	22%
1–4	1,430	25%	841	26%	83	23%	506	24%
5–9	1,205	21%	666	20%	90	24%	449	22%
10–14 ^a	1,025	18%	548	17%	70	19%	407	20%
15–17 ^{b,c}	719	13%	403	12%	61	17%	255	12%
Female	2,752	48%	1,559	48%	175	48%	1,018	49%
Race or ethnicity								
White	331	6%	201	6%	23	6%	107	5%
Asian ^b	705	12%	432	13%	32	9%	241	12%
Hispanic ^{a,b,c}	2,172	38%	1,713	52%	90	24%	369	18%
Black ^{a,b}	1,963	34%	623	19%	192	52%	1,148	55%
Other/unknown/mixed	540	9%	297	9%	31	8%	212	10%
Neighborhood characteristic								
% poverty ^{a,b,c,d}	5,711	46.34	3,266	42.51	368	37.88	2,077	53.88
HOPE VI housing in tract	1,428	25%	1,060	32%	368	100%	0	0%
Hospital visit characteristic								
First visit for urgent care ^{a,b}	2,922	51%	1,717	53%	173	47%	1,032	50%
Visit to > 1 medical system ^{a,b}	314	5%	145	4%	27	7%	142	7%

Table 4.1 notes:

^a Test of association significant at $\alpha = 0.05$ between nonpublic housing and non-redeveloped public housing groups (by *t* test or chi-square test).

^b Test of association significant at $\alpha = 0.05$ between nonpublic housing and HOPE VI public housing groups (by *t* test or chi-square test).

^c Test of association significant at $\alpha = 0.05$ between non-redeveloped housing and HOPE VI public housing groups (by *t* test or chi-square test).

^d Percent of the population with household income of less than 200 percent of the federal poverty level.

Table 4.2: Summary statistics of patient health conditions, by housing type. San Francisco CA, 2007-2011

	Full population (N = 5,711)		Non-public housing (n = 3,266)		HOPE VI public housing (n = 368)		Non-redeveloped public housing (n = 2,077)	
	Number	Percent or mean	Number	Percent or mean	Number	Percent or mean	Number	Percent or mean
Maximum severity score (1-5)*,b	5,711	2.60	3,266	2.59	368	2.68	2,077	2.61
Noncomplex chronic condition*,a,b,d	905	16%	446	14%	78	21%	381	18%
Ambulatory care sensitive condition	2,534	44%	1,431	44%	174	47%	929	45%
Injury ^{a,b}	1,320	23%	651	20%	100	27%	569	27%
Major Diagnosis Groups								
ENT, Dental & Mouth Diseases	2,270	40%	1,299	40%	147	40%	824	40%
Respiratory Diseases	1,261	22%	713	22%	91	25%	457	22%
Systemic States (e.g. fever, influenza) ^{a,b}	1,237	22%	760	23%	68	18%	409	20%
Other (e.g. administrative or follow- up)	1,202	21%	676	21%	69	19%	457	22%
Trauma (e.g. wound, injury) ^{a,b}	1,174	21%	573	18%	93	25%	508	24%
Gastrointestinal Diseases ^{a,b}	1,157	20%	758	23%	66	18%	333	16%
Skin, Dermatologic & Soft Tissue Diseases ^{a,b}	1,063	19%	508	16%	81	22%	474	23%
Musculoskeletal & Connective Tissue Diseases	391	7%	221	7%	29	8%	141	7%
Diseases of the Eye	355	6%	194	6%	22	6%	139	7%
Neurologic Diseases	214	4%	125	4%	17	5%	72	3%
Urinary Tract Diseases ^b	170	3%	84	3%	18	5%	68	3%
Genital & Reproductive Diseases	153	3%	82	3%	12	3%	59	3%
Endocrine, Metabolic & Nutritional Diseases	123	2%	80	2%	5	1%	38	2%
Allergic, Immunologic & Rheumatologic Diseases	122	2%	60	2%	10	3%	52	3%
Psychiatric, Behavioral Diseases & Substance Abuse ^a	90	2%	63	2%	6	2%	21	1%
Fluid & Electrolyte Disorders	71	1%	43	1%	2	<1%	26	1%

	Full population (N = 5,711)		Non-public housing (n = 3,266)		HOPE VI public housing (n = 368)		Non-redeveloped public housing (n = 2,077)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Toxicologic Emergencies (Including Environmental) ^a	37	<1%	10	<1%	3	<1%	24	1%
Child Abuse	35	<1%	14	<1%	6	2%	15	<1%
Circulatory & Cardiovascular Diseases	27	<1%	14	<1%	3	<1%	10	<1%
Hematologic Diseases	21	<1%	12	<1%	3	<1%	6	<1%
Neoplastic Diseases (Cancer, Not Benign Neoplasms)	1	<1%	1	<1%	0	0%	0	0%

Table 4.2 notes:

* Included as a covariate in adjusted models

^a Test of association significant at $\alpha = 0.05$ between nonpublic housing and non-redeveloped public housing groups by chi-square test.

^b Test of association significant at $\alpha = 0.05$ between nonpublic housing and HOPE VI public housing groups by chi-square test.

See chapter methods section for descriptions and citations for health condition categories. Counts are the number of patients who received a diagnosis within the category at their first visit and/or within one year of their first visit. Percentages total more than 100 because each patient can be assigned up to 10 diagnosis codes at each visit.

Table 4.3: Summary statistics of emergency and urgent care visit frequency, by housing type. San Francisco, CA 2007-2011

	Full population (N = 5,711)	Non-public housing (n = 3,266)	HOPE VI public housing (n = 368)	Non-redeveloped public housing (n = 2,077)				
Total visits								
Mean ^a	2.12	2.06	2.16	2.21				
Median	1	1	2	2				
Range	1-18	1-14	1-11	1-18				
Std. Dev.	1.70	1.63	1.70	1.81				
Revisits								
	count	%	count	%	count	%	count	%
Any ^a	2,850	50%	1,576	48%	188	51%	1,086	52%
0	2,861	50%	1,690	52%	180	49%	991	48%
1	1,352	24%	766	23%	88	24%	498	24%
2	672	12%	371	11%	42	11%	259	12%
3+	826	14%	439	13%	58	16%	329	16%

^a Test of association significant at $\alpha = 0.05$ between non-public housing and other public housing groups by *t* test or chi-square test.

CHAPTER FIVE

Conclusion

The previous chapters demonstrate both the utility and limitations of current spatial approaches to health equity research and policy. On one hand, spatial measures of food environments (Chapter 2), cumulative environmental and socioeconomic disadvantage (Chapter 3), and hospital visits and housing type (Chapter 4), bring attention to the stark and unjust health disparities that persist in too many places and populations. On the other hand, spatial measures of health determinants and health outcomes can have non-random errors that bias results (Chapter 2), omitted crucial factors that create misleading characterizations (Chapter 3), and limited population-level applicability (Chapter 4). This chapter reviews recent and emerging developments in spatial evaluations of health equity, specifies recommendations for research and policy to address the limitations of past and present spatial approaches, and proposes new directions for spatial health equity action and evaluation.

Current motivations and approaches to spatial triage are very different than those used in the past, as discussed in the zoning, redlining, and urban renewal examples in Chapter 1. Previous spatially targeted programs and policies focused on narrow understandings of “public health” and “economic development” as issues of infrastructure and economics and relied on limited measures of the environment, perceived financial viability, and/or in some cases racial discrimination. Whereas current approaches consider broad conceptualizations of the “social determinants of health”, including built, physical, economic, and social environments, and focus on measuring the extent and variety of health disparities so that investments can be targeted to areas most in need. Future opportunities for spatial analysis of health should also consider further “upstream” issues of power and politics, such as who is involved and excluded in decision-making processes for particular places, where are funds and resources coming from, and how are conflicting measures and opinions evaluated and addressed. It is essential to move beyond descriptive understandings of health disparities and also identify tangible actions and actors to prioritize and monitor progress toward achieving health equity. For instance, even an accurate, unbiased map of food stores across neighborhoods will not necessitate improved access to nutritious food; we also need to know where food is sourced from, who is responsible for decisions about pricing and selection across stores (e.g. a local store owner, regional chain, or multinational company), which institutions and laws regulate store siting and inspections in particular places, how do local perceptions about stores vary across neighborhoods, and a host of other interrelated questions.

Table 5.1 provides an overview of past, present, and emerging future trends in spatial triage approaches to health research and policy. Each column in Table 1 builds upon the previous as opposed to being mutually exclusive. For instance, data from public agencies was the primary source of spatial data in the past, but present approaches use data from public agencies (e.g. US Census, EPA, etc.) as well as private companies (e.g. InfoUSA and Dunn & Bradstreet retail data to measure food environments), non-profit research institutions (e.g. the UCLA Center for Health Policy Research leads the California Health Interview Survey, Pacific Institute has led a number of community mapping projects and created data on sea level rise projections, Kirwan Institute has worked on opportunity mapping in regions across the US), and foundations (e.g. Robert Wood Johnson Foundation funded calculations of life expectancy by zip code for the US

(Robert Wood Johnson Foundation, 2014)). Online reports and web maps often bring together resources from all of these various sources, such as DiversityData.org and DiversityDataKids.org which are funded by foundations, use data from public agencies that are analyzed by a research institution and then managed and displayed online by a private graphics and web design company. The stated purpose of DiversityData.org is to “provide a scorecard on diversity and opportunity, and allow researchers, policymakers and community advocates to compare metro areas and to help them advocate for policy action and social change” (Institute for Child Youth and Family Policy, 2014). This is similar to the goals of many “equity atlases” that have emerged over the past few years, such as in Portland, Atlanta, and Denver metropolitan areas. However, little is known about whether and how such tools and measures have been leveraged to actually influence policies and interventions to promote health equity. Below I outline how such essential research can be conducted and what policy changes are needed to better support health equity processes and outcomes.

Implications for research

Multi-scaled and multi-sourced measures

Chapter 4 demonstrates how research that integrates spatial data from multiple sources and across multiple scales can identify previously undetected place-based health disparities. Individual-level data from hospitals was combined with address-level public housing data from the local housing authority and neighborhood-level data from the US Census. I found that children who lived in non-redeveloped public housing visited the hospital for acute care more frequently than children who lived in the same neighborhood but in non-public housing or in redeveloped public housing. This disparity would not have been identified if I analyzed the data at just the neighborhood level. Similar integrated analyses could be expanded in a number of important ways by: a) looking at additional scales of difference that are relevant to housing policies and programs, such as households, buildings, housing developments, or blocks; b) collecting data across time to evaluate longitudinal changes in health in relation to changes in housing policies and programs; c) incorporating additional types of housing, such as Section 8, and additional classifications of vulnerable populations, such as those who are homeless or under custody of child protective services; and d) incorporating data from interviews, focus groups, and/or surveys to identify additional factors that may influence healthcare seeking behaviors and health outcomes.

Community inclusion and benefits

Local knowledge from community members and community-based organizations should inform all stages of place-based health research, including question generation, data collection, methods selection, analysis, interpretation, and communication. Chapter 3 highlights the valuable insights that local knowledge about risks, assets, and solutions can contribute to spatial understandings of disadvantage and resilience. Community-based participatory research is one often-cited approach for incorporating local knowledge. But, there is a need for additional modes and models of “transdisciplinary” research that consider the interconnectedness of issues related to health equity, such as employment, income, education, built environment, and physical environment.

For instance, while I was surveying food stores in West Oakland, a woman outside a store said to me, “Hey, what are you doing? Why don’t you give me that job? It looks easy enough, and I

really need to make some money.” Although I was conducting research in her neighborhood to evaluate disparities in the availability of healthful foods (Chapter 2), the issue of greatest importance to her was unemployment because without a job she was not able to buy food. Future health equity research should strive to ensure that both the research process and outcomes are in line with health equity principles and objectives, such as by prioritizing training and employment opportunities for youth and unemployed adults, providing living wages to research staff, incorporating community capacity building into the research design, connecting community-based organizations to software and other research tools at universities, and sharing data and research results in multiple forms accessible to diverse populations.

Protecting privacy and sensitive information

A third important issue that should be considered in future health equity research is privacy. I interviewed a City of San Francisco employee about new public housing programs in the city, and she expressed great concern about the protection of individual information after I described my work with medical record and housing data (Chapter 4). “You have names?” she said, “From a research perspective, I’m sure that is great. But from a services perspective, that is concerning because families don’t know you have that data.” In light of continually expanding sources of personal spatial data used for health research, such as electronic medical records with home addresses, geotagged social media posts, and mobile phone applications with GPS tracking, there is an ongoing need to a) evaluate and refine methods for protecting individual identities and sensitive information, b) understand public perceptions about risks associated with sharing their personal information, and c) ensure that institutional review board and related patient-protection laws and policies adapt to emerging technologies and research opportunities.

Communication

Lastly, more research is needed about how to more effectively communicate health equity research findings to diverse audiences, especially policymakers. In a recent review of information used to inform obesity related legislation in Minnesota, research evidence was only mentioned in 41% of legislative materials, and none of it referenced disparities in obesity by race/ethnicity, socioeconomic status, or geography (Gollust et al., 2014). However, 92% of legislative materials used “non-research based information, such as expert beliefs, constituent opinion, political principles, and anecdotes” (Gollust et al., 2014). Combining qualitative and quantitative evidence in discussions about the causes and consequences of health disparities may help prioritize health equity on policy agendas.

Implications for policy

Data collection and management

Numerous ideas for additional research associated with this dissertation were stymied by limited data availability from public institutions. Many public agencies I contacted about data requests responded with one, or a combination, of three limitations that prevented them from sharing their data:

Limitation 1: They do not have available staff resources to compile the spatial data I requested. For instance, when I requested data on the number of children who live in public housing developments in San Francisco, a San Francisco Housing Authority (SFHA) employee

responded, “Have you read the news lately? We’re imploding on ourselves right now. We have few staff and little capacity, but I’ll see what I can do.” Only after many phone calls and a formal public records request to three senior-level agency representatives was I able to finally receive any response to my relatively simple data request.

Limitation 2: They do not collect or maintain spatial data. Despite being tasked with implementing policies and programs to serve particular places and populations, many public agencies do not measure or monitor the spatial impact of their actions. For instance, I requested data on city-level measures of detention, probation, and recidivism from a county Probation Department, and the Chief Probation Officer said, “We have an extraordinarily outdated mainframe system with no way to query and extract the type of information you are asking for...I wish we had this information to share, and I’m embarrassed that we don’t. We don’t have an effective system to pull up that information.”

Limitation 3: They do not see the value in internally evaluating or externally sharing data for spatial health equity analysis. When I requested electronic health record data from a county health department, the county Director of Public Health said, “We would need a really good reason to ask for that [medical record] data, and I just don’t see how the billing department could be convinced that it is worth their time to share with us.” Oftentimes data that is collected for non-health focused purposes, such as billing or regulation compliance, can be very valuable for health equity policies and programs that seek to understand and address underserved places and populations.

To address these limitations, there is a need to direct additional resources toward creating, maintaining, and sharing existing and new spatial data. I identify five baseline data collection and management goals for public agencies and other social service institutions that would support future policy development and evaluation efforts. First, data should be collected to enable fine-scale spatial joining and analysis. Address-level data, as opposed to city or zip code level, is the most versatile because it can be aggregated up to other scales such as census units or other neighborhood and regional measures. Second, data should be archived over time, at least annually, to enable longitudinal analysis. I was unable to evaluate changes in the population of children in public housing over time because the SFHA does not maintain historical data. Third, data should be maintained at the individual-level. This requires assigning one unique identification number to each individual and additional unique identification numbers for each visit, social service encounter, etc. Some of the hospital visit data I analyzed had different medical record numbers for records that were clearly for the same individual based on name, age, race/ethnicity, and address. Fourth, data and detailed metadata should be publicly available to the extent possible while still protecting individual identities in accordance with HIPAA and IRB requirements. At the very least, institutions should fully disclose details about the data that they collect so the public and research community is aware of what data is collected or missing. Fifth, data should be integrated across organizations to characterize populations, not just the service area of single institutions. This last quality requires collaboration within and across sectors.

Intra- and inter-sector collaboration

As shown in chapter four, intra-sector collaboration, such as integrating data across healthcare providers, can provide novel insights about population-level, as opposed to simply site-specific,

healthcare utilization patterns. Data joining efforts should be expanded to include other sectors, such as education and social services, to further enumerate the populations that utilize particular services and need-based resource allocations. Essential intra- and inter-sector data collaborations could be more easily expanded by establishing long-term, institutionalized data sharing and data management agreements rather than ad-hoc, single-project exchanges. Cross-sector collaborations should include more than just sharing of files and should also include building and maintaining relationships to support the accurate interpretation and appropriate analysis of common data interests. Health-in-all-policies strategies, such as those adopted by the State of California and the City of Richmond (Corburn et al., 2014), can help facilitate collaboration and coordination across sectors and the explicit consideration of health and health equity issues in decision-making processes.

Adaptive interventions

Improved data collection and management, combined with intra- and inter- sector data sharing and analysis, can provide ongoing guidance for, and evaluation of, health equity policies and programs. Integrated data can be used to more accurately target resources for place-based public health interventions for vulnerable populations. However, definitions of “need,” “disadvantage,” “vulnerability,” “risk,” and other commonly used characterizations of communities must adapt to new information and public input to ensure they remain accurate and relevant. Furthermore, the implementation strategies of place-based policies and programs should remain responsive to ongoing evaluation and input from diverse stakeholders. “Adaptive health equity governance” (Corburn and Cohen, 2012) requires inclusive and participatory processes that recognize complexity and the need for iterative evidence-based decisions. The civic engagement strategies discussed in Chapter 3, such as education and mentorship pipeline programs to diversify elected and appointed leaders and funding for community liaisons to facilitate ongoing collaboration across stakeholders, can be applied to other health equity policies besides climate change.

Final remarks

This dissertation has focused on spatial measures of health. But, it is important to note that not all problems or solutions are necessarily spatial. I agree with other scholars who argue that systems of power and politics, as opposed to characteristics of places and people, have the greatest influence on health and health disparities. Nancy Krieger, a social epidemiologist, argues that “We already have substantial evidence that health inequity is neither natural nor inevitable but significantly the product of politics...Power, after all, is at the heart of the matter—and the science of health inequities can no more shy away from this question than can physicists ignore gravity or physicians ignore pain”(Beckfield and Krieger, 2009). And Sarah Elwood, a geographer, identifies three primary elements that shape autonomy and authority: spatial politics, institutional politics, and knowledge politics (Elwood, 2006). Spatial measures alone therefore provide a limited representation of the negotiations and decisions that shape our environments. However, I contend that the effects of inequitable systems of power and politics manifest spatially, and place-based understandings of disparities can motivate and engage diverse constituents to change the inequitable status quo.

To create a more equitable future that allows everyone to achieve their highest level of health, spatial triage approaches to policy need to be more inclusive in terms of what information is considered, who makes decisions, and how change is implemented. And triage, is of course just

the first step to address existing disparities in health determinants and outcomes. Similar to how many healthcare providers now prioritize patient-centered care as an alternative to traditional treatment programs that only value physician expertise, there is a need for health equity policies to deliver community-centered care that is built upon local voices and visions for action.

Table 5.1: Past, present, and future trends in spatial triage approaches to health research and policy

	PAST	PRESENT	FUTURE
Purpose	“Public health,” “Economic development”	“Identify health disparities”, “Target investments”, “Provide a snapshot”	“Prioritize health equity”, “Measure returns on investments”, “Surveillance/monitoring”
Process	“Expert” driven; minimal or no community engagement	Public meetings; advisory boards; limited accountability	Diverse and representative leadership; community liaisons and long-term collaboration; iterative and responsive
Scope	Environmental; financial; racial	Broad conceptualizations of the “social determinants of health”	Power and politics
Scale	Parcels, neighborhoods	Zip codes, census tracts, counties/regions	Networks of institutions (e.g. Accountable Care Organizations), households, and individuals
Sources	Public agencies	Private companies; non-profit research institutions; foundations	Community-based organizations; healthcare and social service providers; individuals
Methods	Limited categorizations (e.g. deteriorated vs. maintained) based on single source of data	Comparative categorizations (e.g. percentiles) based on combination of multiple data sources; cross-sectional	Customizable metrics and comparisons based on integration of multiple data types and sources across spatiotemporal scales; longitudinal
Access	Paper maps and tables	Online reports; static digital databases; pre-defined visualizations	Indexed, updated, and archived digital databases; open source and dynamic web-based analysis

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APPENDIX A: Food store survey

Northern CA Retail Food Environment Store Survey

Adapted from the CX³ Food Availability and Marketing Survey created by the California Department of Public Health

A. STORE INFORMATION

1) Store Name

a. Provided (CONAME/NETS/county): _____

b. Actual (on storefront): _____

2) Store Address (#, street, city, zip)

a. provided: (NETS/county/Google): _____

b. actual (on storefront): _____

3) Store Location Description

a. Streets (i.e. corner of X St. and Y St or on X St in between Y St and Z St): _____

b. Side of street (circle one or more): North East South West

Date & Time Visited: _____

GPS Waypoint: _____

Surveyor Name(s): _____

- Disposition: (circle one)
- 1 Completed
 - 2 Partial
 - 3 Denied / No data
 - 4 Denied / Exterior only
 - 5 Store not found
 - 6 Store closed
 - 7 Store not visited
 - 8 Inaccessible

B. STORE EXTERIOR

	Circle One
4) Are there any produce bins on the sidewalk in front of the store?	1 - Yes 0 - No
5) Are other products displayed on the sidewalk in front of the store or inside the store <i>next to</i> the window so they are clearly visible from the outside? a. Please check all that apply: __ soda __ water __ other. (specify) _____	1 - Yes 0 - No ← If Yes
6) Are there vending machines on the sidewalk in front of the store? a. Please check all that apply: __ soda __ water __ other. (specify) _____	1 - Yes 0 - No ← If Yes
7) Is there advertising (banners, posters, temporary signs, etc.) on the storefront? a. Describe: _____	1 - Yes 0 - No ← If Yes
8) Are there any images of healthy food (e.g. tomato, apple) and/or beverages (e.g. milk), painted/displayed on doors or windows of the storefront?	1 - Yes 0 - No
9) Are there any images of un-healthy food (e.g. hamburger, hot dog) and/or beverages (e.g., soda, shake) painted/displayed on doors or windows of the storefront?	1 - Yes 0 - No
10) Are there permanent bars/chains on the windows or doors? (do not include sliding or rolling chains or bars)	1 - Yes 0 - No
11) If the store sells alcohol, is more than 1/3 of the total window area covered by any type of advertising?	1 - Yes 0 - No 9 - N/A (no alcohol)

C. STORE INTERIOR

12) Number of cash registers throughout store (staffed and unstaffed, for grocery items only) _____

13) Approximate area of store, in paces (food shelves/aisles area) : _____ x _____

14) Circle the number that best describes overall availability of fresh produce and meats inside and outside the store.

	None	Limited (1-3 types)	Moderate variety (4-6 types)	Wide variety (7 or more types)
a. Fresh fruit	1	2	3	4
b. Fresh vegetables	1	2	3	4
c. Raw meat/seafood	1	2	3	4

15) Circle the number that best describes the overall quality of the fresh fruit.

0	1	2	3	4
None sold	All or most of fruit is of poor quality (brown, bruised, overripe, wilted)	Mixed quality; more poor than good	Mixed quality; more good than poor	All or most of fruit is of good quality (very fresh, no soft spots, excellent color)

16) Circle the number that best describes the overall quality of the fresh vegetables.

0	1	2	3	4
None sold	All or most of vegetable is of poor quality (brown, bruised, overripe, wilted)	Mixed quality; more poor than good	Mixed quality; more good than poor	All or most of vegetable is of good quality (very fresh, no soft spots, excellent color)

17) Record if the following items are available in the store.

Food Item	Circle one
a. Milk – (skim, low fat, or reduced fat), plain white (<u>not</u> flavored)	1 - Yes 0 - No
b. Soy beverage, plain, with no added sugar or sweeteners	1 - Yes 0 - No
c. Cheese	1 - Yes 0 - No
d. Eggs	1 - Yes 0 - No
e. Tofu, plain	1 - Yes 0 - No
f. Whole wheat bread	1 - Yes 0 - No
g. Brown rice	1 - Yes 0 - No
h. High fiber cereal (≥ 3 grams fiber, ≤ 12 grams sugar per serving)	1 - Yes 0 - No
i. Oatmeal (plain)	1 - Yes 0 - No
j. Tortillas, soft corn or whole wheat (no lard)	1 - Yes 0 - No
k. Beans, dried or canned with no added fats, sugar, or sweetener	1 - Yes 0 - No
l. Tuna (light), salmon, or sardines canned in water	1 - Yes 0 - No
m. Any canned fruit packed in 100% fruit juice	1 - Yes 0 - No
n. Any canned vegetable with no added fats, sugar, or sweetener	1 - Yes 0 - No
o. Any frozen fruit with no added fats, sugar, or sweetener	1 - Yes 0 - No
p. Any frozen vegetables with no added fats, sugar, or sweetener	1 - Yes 0 - No
q. Baby food, jarred, single fruit, single vegetable, or single meat	1 - Yes 0 - No

18) Please mark which of these most accurately describes the store:

_____ Large grocery store (not part of a large chain) - a large store that sells food and other items, including canned and frozen foods, fresh fruits and vegetables, and fresh (raw) and prepared meats, fish, and poultry. It may be part of a small regional chain of fewer than 5 stores or may be independent. (This type of store also has twenty or more employees and at least 4 cash registers).

_____ Small Market - usually an independent store that may sell food including canned and frozen foods, fresh fruits and vegetables, and fresh (raw) and prepared meats, fish, and poultry as well as convenience items and alcohol. This type of store has fewer than 20 employees and three or less cash registers.

_____ Convenience - a store that sells convenience items only, including bread, milk, soda, snacks and may sell alcohol and gasoline. These stores do not sell fresh (raw) meat. These stores also are known as food marts.

_____ Other - Liquor Store, bakery, donut shop, meat or fish markets (predominantly selling fresh/raw meats), or other specialty stores.

Please specify and describe: _____

APPENDIX B: Children's health and housing details

Methodological details

Public insurance

By limiting the study population to children with public insurance, my intention was to a) limit confounding by socioeconomic status; and b) limit the analysis to children who have most likely had a prolonged “exposure” to the variable of interest: living in public housing. After redevelopment, HOPE VI properties became mixed-income communities; some (20%-60%) former residents returned, while other units were occupied by “new” middle-income families who are more likely have private insurance. Although some uninsured children are likely low-income, some may be middle- or upper-income and choose to self-pay. I ran two additional models looking at 1) the full population of children in the same tract as public housing with an indicator variable for insurance status (private, public, uninsured, other/unknown) and 2) the full population in San Francisco, also with an indicator variable for insurance status. Results were similar to those reported for the publicly insured population. I opted to focus on the results for publicly insured patients because publicly insured patients tend to have distinct healthcare seeking behaviors and experience worse health outcomes compared to privately insured children. My intention is to draw more research and policy attention to this vulnerable population subgroup.

Census Data

I utilized data from the US Census Bureau to evaluate citywide and neighborhood-level measures of poverty rates and population counts. American Community Survey 5 year estimates (2007-2011)³ provided indicators of poverty rates that aligned with the study time period. I used the measure “population below 200% of federal poverty level” instead of the more commonly used measure of below 100% of federal poverty to better align with low-income measures used by the SFHA to determine public housing eligibility. The federal poverty level in 2011 for a family of 3 people (two adults and one child) was \$18,106. In contrast, the threshold for “low-income” set by the SFHA for a family of three in 2011 was \$76,950 (80% of area median income), and the threshold for “very low-income” and “extremely low-income” were \$48,100 and \$28,850 (50% and 30% of area median income). A measure of the population below 200% of the federal poverty level (\$36,212 for a family of three) is therefore a more accurate measure of poverty for the study area.

HOPE VI indicator variable

I included an indicator variable for whether the patient lived in the same tract as HOPE VI public housing to account for confounding by neighborhood quality. There is evidence to suggest that the neighborhoods where HOPE VI developments are located in San Francisco have distinct characteristics compared to other low-income neighborhoods, such as higher rates and perceptions of crime and lower social cohesion.^{4,5}

³ http://www.census.gov/newsroom/releases/archives/news_conferences/20121203_acs5yr.html

⁴ Buron, L., Popkin, S., Levy, D., Harris, L., & Khadduri, J. (2002). *The HOPE VI Resident Tracking Study A Snapshot of the Current Living Situation of Original Residents from Eight Sites*. Washington, DC.

Data on children in public housing

The SFHA reports that they do not maintain archived versions of their resident database, and they could only provide current (February 2014) counts, which totaled 2,731 for children 0 to 17 years old. The only counts of children in public housing relevant to the study time period that I was able to obtain were from a 2011 report by the San Francisco Human Services Agency (HSA) that analyzed SFHA data and reported a count of 3,136 children in public housing.⁶ However, counts of children in public housing from the SFHA resident database are subject to undercounting because they only include children who are on the lease. The HSA matched data across social services organizations for residents at one public housing development and found an overall undercount rate of 22% for children, ranging from 50% for kids <1 year old, 27% for kids 2-5, and 14% for kids 6 to 12 and 13 to 17.^b These drastic differences make it difficult to accurately quantify the magnitude of rate differences between subgroups of children who live in public housing and the rest of the population. Furthermore, neither the HSA nor the SFHA collect regular counts of children who live in HOPE VI properties, which are managed by separate private and non-profit entities.

Results Details

National and City-level comparisons

Looking at a subsample of visits in 2010, I compared the emergency utilization rates in the sample to national and citywide measures. Nationally, 22% of all children under 18 years had at least one emergency department visit and 8% had two or more visits.⁷ Estimates from my sample, which include most but not all emergency visits in San Francisco, show that 19% of all children in San Francisco (19,910 out of 107,524) had at least one emergency visit to a hospital and 6% (6,533) had two or more visits. Of these patients with a visit in 2010, 1,699 (9%) lived in public housing, whereas 3 to 6% of all children in San Francisco live in public housing. There are limited data available on the total count of children who live in public housing. However, if I generously assume that the most applicable available count from 2011 (n=3,136) is just half of the total population in 2010, I estimate that the visit rate for children in public housing is at least (but likely more than) 27% ($1,699/(3,136*2)$), and 12% had two or more visits. Although the precise magnitude of the difference in visit rates is uncertain, it is clear qualitatively that children in public housing in San Francisco have much higher rates of emergency department utilization compared to other children in San Francisco and the nation.

⁵ Seto, E., Chao, C., Dill, L., Gilhuly, K., Kontgis, C., Breslar, J., & Negev, M. (2009). *HOPE VI to HOPE SF San Francisco Public Housing Redevelopment: A Health Impact Assessment*. Berkeley, CA.

⁶ Gerth, E. (2012). *Serving Public Housing Residents in San Francisco Recommendations to Support HOPE SF and Beyond*. San Francisco, CA. Retrieved from <http://www.sfhsa.org/asset/ReportsDataResources/ServiceDeliveryinPublicHousingGerth.pdf>

⁷ National Center for Health Statistics. (2011). *Health, United States*. Washington, DC. Retrieved from [http://www.cdc.gov/nchs/data/11.pdf](http://www.cdc.gov/nchs/data/hus/11.pdf)

Table 4.A: Modeled adjusted effects of public housing on hospital visit frequency, main model (GEE) and sensitivity tests. San Francisco CA, 2007-2011

Population in same tract as public housing and with public insurance (n=5,711)

Reference group: non-public housing residents

Model type	Outcome comparison	Effect type	HOPE VI public housing			Other public housing			Non-public housing		
			Effect value	<i>p</i>	95% CI	Effect value	<i>p</i>	95% CI	Effect value	<i>p</i>	95% CI
Logistic regression	2+ visits vs. 1 visit	OR*	0.98	<i>0.897</i>	0.75-1.28	1.36	<i><0.0001</i>	1.17-1.58	-	-	-
Multinomial logistic regression	2 visits vs. 1 visit	RRR*	0.94	<i>0.720</i>	0.69-1.29	1.23	<i>0.017</i>	1.04-1.46	-	-	-
	3 visits vs. 1 visit	RRR*	0.93	<i>0.724</i>	0.62-1.40	1.48	<i>0.001</i>	1.18-1.87	-	-	-
	4+ visits vs. 1 visit	RRR*	1.17	<i>0.440</i>	0.78-1.77	1.61	<i><0.0001</i>	1.26-2.04	-	-	-
Modified Poisson GLM	2+ visits vs. 1 visit	RR*	0.99	<i>0.913</i>	0.89-1.11	1.13	<i><0.0001</i>	1.06-1.20	-	-	-
GEE	2+ visits vs. 1 visit	OR	0.98	<i>0.849</i>	0.82-1.18	1.37	<i><0.0001</i>	1.31-1.42	-	-	-
Reference group: HOPE VI public housing residents											
Logistic regression	2+ visits vs. 1 visit	OR*	-	-	-	1.39	<i>0.031</i>	1.03-1.87	1.02	<i>0.897</i>	0.77-1.33
Multinomial logistic regression	2 visits vs. 1 visit	RRR*	-	-	-	1.31	<i>0.130</i>	0.92-1.84	1.05	<i>0.720</i>	0.78-1.44
	3 visits vs. 1 visit	RRR*	-	-	-	1.60	<i>0.048</i>	1.00-2.54	1.08	<i>0.724</i>	0.71-1.63
	4+ visits vs. 1 visit	RRR*	-	-	-	1.37	<i>0.178</i>	0.87-2.15	0.85	<i>0.440</i>	0.57-1.28
Modified Poisson GLM	2+ visits vs. 1 visit	RR*	-	-	-	1.13	<i>0.044</i>	1.00-1.28	1.01	<i>0.913</i>	0.90-1.12
GEE^	2+ visits vs. 1 visit	OR	-	-	-	1.39	<i>0.002</i>	1.12-1.71	1.01	<i>0.849</i>	0.85-1.22

Table 4.A Notes

* With robust standard errors

Bold values are significant ($p < 0.05$)

All models use Stata 13 software, except for the GEE models which use SAS v. 9.4. Covariates in all models are age category, sex, race/ethnicity, maximum severity score of all ICD9 codes across all visits, any diagnosis of a non-complex chronic disease, tract percent population <200% poverty, hospital campus, urgent care visit, and living in the same neighborhood as HOPE VI. Abbreviations: Generalized linear model (GLM); generalized estimating equation (GEE); odds ratio (OR); relative risk ratio (RRR); risk ratio (RR)