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Sexual Orientation, Gender, and Environmental Injustice: Unequal Carcinogenic Air Pollution Risks in Greater Houston

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Abstract

Disparate residential hazard exposures based on disadvantaged gender status (e.g., among female-headed households) have been documented in the distributive environmental justice literature, yet no published studies have examined whether disproportionate environmental risks exist based on minority sexual orientation. To address this gap, we use data from the US Census, American Community Survey and the Environmental Protection Agency at the 2010 census tract level to examine the spatial relationships between same-sex partner households and cumulative cancer risk from exposure to hazardous air pollutants (HAPs) emitted by all ambient emission sources in Greater Houston (Texas). Findings from generalized estimating equation analyses demonstrate that increased cancer risks from HAPs are significantly associated with neighborhoods having relatively high concentrations of resident same-sex partner households, adjusting for geographic clustering and variables known to influence risk (i.e., race, ethnicity, socioeconomic status, renter status, income inequality, and population density). However, HAP exposures are distributed differently for same-sex male versus same-sex female partner households. Neighborhoods with relatively high proportions of same-sex male partner households are associated with significantly greater exposure to cancer-causing HAPs while those with high proportions of same-sex female partner households are associated with less exposure. This study provides initial empirical documentation of a previously unstudied pattern, and infuses current theoretical understanding of environmental inequality formation with knowledge emanating from the sexualities and space literature. Practically, results suggest that other documented health risks experienced in gay neighborhoods may be compounded by disparate health risks associated with harmful exposures to air toxics.

Keywords

environmental justice; sexuality; gender; air pollution; health disparities

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Introduction

Emerging concern for social inequalities in the distribution of hazardous environmental pollutants over the past several decades has spawned a global social movement for environmental justice (EJ) and a large body of research (Walker 2012). An extensive quantitative literature has tested for distributive patterns of environmental injustice by applying spatial analytic and statistical techniques. Many axes of social oppression have been examined, including race, class, and to a lesser extent, age, immigration status, and gender. Although results vary across analyses, the vast majority of these studies have found that social groups at the disadvantaged poles of those axes of oppression experience disproportionate exposure to toxic pollution (Chakraborty et al. 2011; Mohai et al. 2009).

Disparate residential exposures based on disadvantaged gender status (e.g., among female-headed households) have been documented in the distributive EJ literature (Downey 2005; Grineski et al. 2015a), yet no published studies have examined whether disproportionate environmental risks exist based on minority sexual orientation. The presence of this knowledge gap is surprising since there is a longstanding geographical literature focused on the marginalization of lesbian, gay, bisexual, and transgender (LGBT) people and the sociospatial formation of gay urban districts in the US (and elsewhere across the world) (Adler and Brenner 1992; Brown 2014; Castells 1983; Hubbard 2011), and a more recently emerging body of work focused on the sexuality of environmental domination and alternative queer ecologies (Gandy 2012; Newman et al. 2004; Sandilands 2002). Additionally, applicable spatial data on sexual orientation for partner households are collected by the US Census Bureau and freely available to analysts interested in examining relationships between same-sex partnering and other variables of interest (Baumle et al. 2009; Black et al. 2000; Gates and Ost 2004; Hayslett and Kane 2011; O'Connell and Feliz 2011).

Our specific research aim is to test for disparities in exposure to hazardous air pollutants (HAPs) based on the census tract composition of same-sex partner households as well as the disaggregated composition of same-sex male and same-sex female partner households in the Houston–Sugar Land–Baytown, Texas Metropolitan Statistical Area (hereafter referred to as Greater Houston). To accomplish this, we use US census tract-level data on population characteristics and chronic cancer risk estimates of ambient exposure to HAPs from the US Environmental Protection Agency (EPA). We adjust for the effects of geographic clustering and a suite of variables known influence exposure to HAPs at the neighborhood level, specifically median household income, income inequality, population density, and the proportions of census tract populations that are black/African American or Hispanic/Latino and housing units that are renter-occupied. We address two research questions: (1) Are cancer risks from outdoor HAP exposures distributed inequitably with respect to the neighborhood composition of same-sex partner households, adjusting for geographic clustering and relevant covariates? (2) Are cancer risks from HAP exposures distributed differently for neighborhoods with high concentrations of same-sex male versus same-sex female partner households?

Gender, Sexuality and Distributive Dimensions of Environmental Injustice

Studies of environmental justice (EJ) are primarily concerned with examining the material effects of inequality—produced through social structures and discourses—and reflected in the uneven distribution of environmental harm and privilege in societies. EJ research has traditionally focused on race and class, although scholars have more recently examined other intersecting axes of inequality and the environment. Of particular relevance here is gender, a category that has received focus in the EJ literature. It has received attention "…since women are often physically and socially relegated to some of the most toxic residential and occupational spaces in communities and workplaces" (Pellow and Brehm 2013: 236). Although the role of gender oppression in environmental inequality formation remains under-theorized and has been a focus of too little empirical analysis, studies have documented how women experience and resist discriminatory environmental policies in workplaces, residential areas, and other spaces (Buckingham and Kulcur 2010). In terms of the distributive EJ literature, studies have documented the disproportionate exposure of female-headed households to environmental harm in the US and abroad (Downey 2005; Grineski et al. 2015a), which reflects how the intersection of oppressive racial, class and gender constructions may unjustly burden women with acute pollution exposures.

There is also an emerging strand of work in the broader arena of EJ research that has explored the gendered and sexualized ideologies of socio-environmental domination, which shape imaginaries, state and corporate practices and activist resistance, and are entwined in the (re)production of unjust environmental formations (Adamson et al. 2002). That line of inquiry dovetails with work focused on the sexuality of exploitative human-environmental relations and alternative queer ecologies (e.g., Gandy 2012). This body of scholarship is concerned with theorizing and destabilizing linkages between sexually oppressive patriarchal and heteronormative ideologies, social domination, and environmental harm. And while this work offers an important lens to augment perspectives on EJ and has informed the emerging movement for emancipatory queer ecologies, it has not yet catalyzed distributive EJ research. The fact that the importance of sexuality to environmental degradation has been established by theorists and within the normative domain of EJ activism suggests that systematic empirical research on disparate environmental exposures based on sexual orientation is overdue.

Since no such distributive EJ studies exist, there is a tenuous empirical basis for conceptualizing the sexuality of unjust environmental exposures in cities. A tenet of the sexualities and space literature is that sexuality is as fundamental to the production of sociospatial orders as the categories of class, race or gender (Hubbard et al. 2015). Theoretical frameworks for the sexual structure of cities with particular regard to the locational dimension of LGBT residence have been proposed. Castells (1983) conceptualized the city as a highly unjust terrain of conflict where groups mobilize to harness collective resources in a context organized by and for the capitalist elite. He asserted that the creation of gay male residential districts in particular served both 'defensive' and 'progressive' purposes. While gay districts formed in response to social marginalization and were framed as deviant via dominant heteronormative discourse on one hand, they enabled the collective mobilization of homosexual identities for socio-culturally empowering ends and provided autonomy as well as safety for gay men on the other (Knopp 1995). Across myriad cities, gay neighborhoods also provided electoral leverage in politics by spatially concentrating blocs of gay and allied voters (Davis 1995).

In terms of the locational dimension of LGBT residence in cities, Levine (1979) and Collins (2004) offered general models, each of which incorporates the strong tendency for gay neighborhoods to form in socially marginalized city spaces. These models were derived based on the historical-geographical emergence of such neighborhoods in major cities of North America, Europe, and Australia post-WWII (Hubbard et al. 2015), when childless partnered and single gay (white) people flocked to inner-city neighborhoods in pursuit of a supportive community as well as affordable residence (Adler and Brenner 1992; Castells 1983). Hubbard et al. (2015: n.p. available) observe:

> In many such cities during 1970s and 1980s, de-industrialisation and decentralisation meant that inner-city neighbourhoods were somewhat marginal and rundown, providing a location where those 'alternative' lifestyles could co-exist with other marginal groups – e.g. sex workers, drug addicts and the chronically unemployed…Despite the somewhat seedy and destitute nature of such districts, gay men and lesbians were able to find relatively safe locations to escape the largely homophobic nature of public urban spaces.

Hubbard (2011) asserts that this sociospatial pattern has been produced through structurally constrained residential locational decision-making among gay people in cities dominated by heteronormative ideology, wherein the regulatory apparatus of the state has served to enforce boundaries between 'queer' urban spaces and suburban areas that are exclusionary to those failing to abide by prevailing sexual norms. This perspective is supported by accounts of the heteronormative NIMBYism that has targeted for exclusion locally unwanted land uses (LULUs) associated with non-conforming sexual identities, including bars, clubs and community spaces developed by LGBT residents (Doan 2011). From an EJ perspective, a key implication of the sexualities and space literature is the enduring tendency for dominant groups to mobilize NIMBYism as a means to exclude LGBT people, businesses and institutions from their own heteronormative residential landscapes. We hypothesize that this has led to the concentration of LGBT residents in urban environments that are simultaneously socially marginal and highly polluted, since NIMBYism is predicated on the banishment of all LULUs—including sources of toxic pollution—to marginal urban spaces.

The sexualities and space literature also suggests that patterns of environmental exposures based on residential location may vary substantially for gay males vis-à-vis lesbians. Castells (1983) assumed that an inherently male territoriality drove the formation of gay neighborhoods, and that these spaces were thus structured along patriarchal lines, although this has been challenged by Adler and Brenner (1992) among others. Indeed, gay male neighborhoods have been known to exclude lesbians via escalating housing costs and by privileging masculine ideals and even feminine heterosexuality, while disempowering female homosexuality and other non-same-sex-male sexualities (Casey 2003; Doan 2007; Taylor 2008). Qualitative studies indicate that lesbians tend to establish separate social networks and develop enclaves of their own, often in socially and culturally mixed areas of cities (Adler and Brenner 1992; Valentine 1993). Additionally, lesbian couples are more likely to have children than gay male couples (Black et al. 2000), and hence may be more likely seek residence in ‘child-friendly’ suburbs. Recent quantitative analyses of same-sex partner households align with qualitative findings, and indicate that same-sex male partner households are more segregated from different-sex partner households than same-sex female partner households and that the two groups occupy significantly overlapping yet distinct residential spaces (Deng 2015; Spring 2013). Overall, the spatial patterning of residence among lesbian partners in cities seems to vary from that of gay male partners. From an EJ perspective, this supports the hypothesis that levels of exposure to urban pollution may vary between neighborhoods composed of relatively high concentrations of same-sex male versus same-sex female partner households, with gay male partnering likely associated with more acute environmental exposures due to increased clustering within polluted inner-city spaces.

Greater Houston: Environmental Injustice and LGBT Geography

Greater Houston is appropriate for this research because of its social diversity, as well as its persistent problems with air pollution. This ten-county metropolitan statistical area (MSA) located in Texas is bordered on the southeast by the Gulf of Mexico and intersected by several major interstate highways (Figure 1). With a total population of about 5.9 million in 2010, it is the largest MSA in Texas and the sixth largest in the United States. Whites account for about 39.7 percent of the population, with Hispanics (35.3 percent) and blacks (16.8 percent) representing the two largest minority groups. Approximately 1.0% of partner households in Greater Houston are same-sex partner households. Airborne emissions from numerous point and mobile sources have contributed to elevated levels of ambient exposure to HAPs in Greater Houston. Four counties in Greater Houston (Harris, Galveston, Montgomery, and Fort Bend) are ranked in the top 10 percent of all US counties and the top 5 percent for counties in Texas, in terms of cumulative cancer risk from HAP exposure (Chakraborty et al. 2014).

HAPs are a well-documented health threat in Greater Houston (Lupo et al. 2011; Scheurer et al. 2014). The area is home to the world’s largest petrochemical industrial complex, which includes 200 facilities. Houston is also notorious for being the only major city in the US without zoning as an element of land use planning. The city has been historically and geographically structured according to a laissez-faire philosophy in which zoning is seen as a violation of private property rights. This urban development approach has prioritized minimizing costs for potential investors to locate in Greater Houston but has created less than ideal social and environmental conditions, which have tended to disproportionately burden socially marginalized groups.

The suitability of Greater Houston for EJ analysis has been emphasized in previous studies that report serious distributional inequities for various pollution sources (Bullard 1990; Chakraborty et al. 2014; Collins et al. 2015a; Grineski et al. 2015b; Hernandez et al. 2015). In a census tract-level analysis of Greater Houston, Chakraborty et al. (2014) found positive and significant associations for the percentages of the population that were non-Hispanic black and Hispanic, the percentage of housing units that were renter-occupied, and income inequality (Gini index) with cancer risks from HAPs; they also found an quadratic (nonlinear) relationship between median household income and cancer risk from HAPs, indicating that low-income neighborhoods were exposed to the lowest risk, middle-income neighborhoods to the highest risk, and high-income neighborhoods to lower risk.

While no prior published research has investigated distributive EJ implications of same-sex partnering in Greater Houston or elsewhere, it is important to describe the LGBT geography of Greater Houston neighborhoods to ground our analysis. Like many other US metro areas, Houston has a large and diverse LGBT population, which has historically-geographically responded to stigmatization and marginalization through the development of gay spaces, where they have sought and gained substantial political empowerment.

The historic core of Greater Houston's LGBT community is the Montrose neighborhood, which is located in the Inner Loop of central Houston (i.e., the inner-city zone contained within Loop Interstate Highway 610; see Figure 1), along with several other neighborhoods emerging in popularity with the LBGT community over the past fifteen years. Montrose was initially established as a gay neighborhood in the 1970s, when homosexual men in particular began to gentrify the neighborhood. By 1985, the culture and politics of the neighborhood were heavily influenced by the LGBT community. A local estimate indicated that, by 1990, 19 percent of Montrose residents were homosexual (Oaklander 2011).

Beginning in the late 1970s, members of Houston's gay community, especially males, sought residence in Montrose as a means to enhance their social and political power. Statewide in Texas, the gay community was making its most visible political inroads in Montrose. Gay Houstonians based in Montrose took their liberation politics especially seriously due to the antagonism from the Christian right in the region (Ennis 1980). They used bloc-voting to ensure that they secured their preferred representatives. As a symbolic culmination of the LGBT empowerment project emanating from Montrose, in 2010, Annise Parker, a lesbian woman and longtime Montrose resident, was voted Mayor of Houston, making it the first large American city to elect an openly homosexual person as mayor (McKinley 2009).

Echoing the recent scholarly literature singing the swan song of gay neighborhoods in cities throughout the world (Brown 2014), local media reports suggest that decentralization of Greater Houston's LGBT population has occurred over the past fifteen years largely in response to increasing heteronormative acceptance (Oaklander 2011). In the 2000s, LGBT Houstonians began dispersing to the nearby neighborhoods of Westbury (Holley et al. 2013) and Riverside Terrace (Shilcutt 2013), and by the 2010s to Houston Heights as well as a few suburbs of Greater Houston. Additional Inner Loop neighborhoods attracting LGBT people include Bellaire and Rice Military, while Greater Houston suburbs on the LGBT residential radar screen include Galveston, Pearland, Sugar Land, and Missouri City. With decentralization, a local estimate indicates that less than 8 percent of the Montrose population was gay as of 2011 (Oaklander 2011), which is still well above the estimate of ~2.5 percent for Greater Houston as a whole (Gates 2006).

Data and Methods

Our analysis links the spatial distribution of risks associated with carcinogenic HAPs to socio-demographic characteristics of the population at the census tract level in Greater Houston. Here, we describe the dependent, explanatory and control variables and the statistical methods used in our analysis.

Dependent Variable: Cancer Risks from Hazardous Air Pollutants

Our variable for assessing risks from exposure to chronic pollution is cumulative cancer risk from HAPs emitted by all ambient emission sources. HAPs include 187 specific substances identified in the Clean Air Act Amendments of 1990 that are known to or suspected of causing cancer and other serious health problems (EPA 2016). To measure cancer risks from chronic exposure to HAPs, we use data from the US EPA's 2011 National Air Toxics Assessment (NATA), which was released in 2015 (EPA 2016). The NATA is an important tool for estimating health risks associated with chronic exposure to various sources of HAPs, and a reliable data source for EJ research on air pollution (Collins et al. 2015a, 2015b).

The 2011 National Emissions Inventory is used to obtain information on HAP emissions in the 2011 NATA and the methodology used to generate estimates of cancer risk comprises several steps (for details, see EPA 2016). The 2011 NATA estimates potential cumulative risks to public health from HAP exposure following the EPA's risk characterization guidelines that assume a lifelong exposure to 2011 levels of air emissions. Cancer risks in the 2011 NATA, which we use here, are derived using unit risk estimates, an upper bound estimate of an individual's probability of contracting cancer over a lifetime of exposure to a concentration of one microgram of the pollutant per cubic meter of air. For each census tract, the individual lifetime cancer risk associated with each HAP is calculated by combining exposure concentration estimates with available UREs and inhalation reference concentrations. Although the type of cancer and available evidence varies by pollutant, the cancer risks of different HAPs are assumed to be additive and are summed to estimate an aggregate lifetime cancer risk for each census tract, measured in persons per million. These risk estimates are considered to be upper-bound estimates of the probability that an individual will contract cancer over a 70-year lifetime as a result of exposure to HAPs. A lifetime cancer risk of one in a million, e.g., implies that one out of a million equally exposed people would contract cancer if exposed continuously to that specific concentration over 70 years. This would be an excess cancer risk in addition to other cancer risks borne by a person not exposed to these HAPs.

The 2011 NATA risk estimates for this study were obtained directly from the EPA for all census tracts (based on 2010 boundaries) in Greater Houston. Estimates of cumulative lifetime cancer risk (persons per million) include risks associated with inhalation exposure to HAPs released by major stationary sources (e.g., large waste incinerators, factories), smaller stationary sources (e.g., dry cleaners, small manufacturers), on-road mobile sources (e.g., cars, trucks), nonroad mobile sources (e.g., airplanes, trains, lawn mowers, construction vehicles), and background concentrations (i.e., contributions from distant or natural sources). The NATA risk estimates do not consider residents' length of residence in census tracts, nor do they consider the space-time patterning of residents' movements across a range of outdoor and indoor environmental contexts within and beyond their census tracts of residence. Thus, while NATA risk estimates are quantified in terms of cumulative lifetime exposure to HAPs, for the purposes of this EJ analysis, they provide estimates of relative cancer risk attributable to outdoor residential HAP exposures.

Explanatory Variables: Same-Sex Couples Partnered in Households

We used a set of socio-demographic variables derived from the 2010 Decennial Census and the 2008–2012 American Community Survey (ACS) estimates for Greater Houston at the census tract level. Data for the same-sex partner household explanatory variables—as well as the population density, proportion non-Hispanic Black, proportion Hispanic and proportion renter-occupied homes control variables—were derived from the 2010 Decennial Census. Data for variables not available through the 2010 Decennial Census were derived from the 2008–2012 ACS. This includes data for the median household income and income inequality (Gini index) control variables, as well as the median year of housing construction and median value of owner-occupied housing units clustering variables. To ensure stable percentage estimates for all our variables, we use the 1,023 census tracts in Greater Houston with at least 500 persons, 200 households, and complete data for all analysis variables; 53 census tracts were excluded.

In terms of our same-sex partner household variables, beginning with the 1990 US Decennial Census, an “unmarried partner” response option has been included with other responses (e.g., wife, son, grandfather) to the questionnaire item about the “relationship to the householder,” i.e., the person in the household who is designated as “Person #1” (Baumle et al. 2009). The “unmarried partner” response option permits identification of persons in the household who are unrelated to but have a “marriage-like” relationship with Person #1. Comparisons have been undertaken with nationally representative non-census datasets, and researchers have concluded that gay male partners and lesbian partners are undercounted in census data, but that their characteristics and geographic variation are similar to those reflected in other datasets (Black et al. 2000; O’Connell and Feliz 2011; Baumle et al. 2009).

The 2010 Census enumerated 901,997 same-sex partner households in the US, which was a 52 percent increase from the 2000 Census tally. After examining the situation (O’Connell and Feliz 2011), Census Bureau officials announced that more than one-in-four same-sex partners counted in the 2010 Census were likely opposite-sex partners (Cohn 2011). To address the error, Census Bureau researchers developed an indirect correction method, which provided more accurate estimates of same-sex partner households (O’Connell and Feliz 2011). Based on application of this correction method, the Census Bureau released a set of revised state-level estimates of same-sex couple households from the 2010 Census. These corrected estimates indicate that in 2010 there were 646,464 same-sex couple households in the US; the corrected estimates align closely with results of the 2010 ACS.

Since the Census Bureau did not re-tabulate corrected estimates for the 2010 Census data at sub-state geographical levels, we employed established methods to downscale corrected estimates to the tract level. Gates (2013) developed a procedure for estimating accurate numbers of same-sex partner households at the county level using the 2010 Census corrected state-level estimates as a base, which has been employed by others (e.g., Spring 2013). Poston and Chang (2013) observed the tendency for Gates's (2013) procedure to generate inaccurate zero estimates for the numbers of same-sex male couples in many counties and so they recalculated more accurate proportions at the county level.

Drawing off Poston and Chang (2013) and Deng (2015), we first generated estimates of the counts of households comprised of (1) same-sex partners, (2) same-sex male partners, and (3) same-sex female partners for all Greater Houston census tracts. The multi-step procedure is detailed by Deng (2015), and involves (1) applying the 2010 Census questionnaire mail-in rate to estimate an error rate of same-sex partner miscoding for each census tract; (2) applying that error rate to develop temporary numbers of same-sex male and same-sex female partner households for each census tract; (3) applying those two temporary variables to create adjusted proportions of same-sex male and female partner households for each census tract; (4) applying those proportions for each census tract to the county-level corrected estimates from Poston and Chang (2013) to develop same-sex male and female partner household estimates for each census tract; (5) calculating uncorrected proportions of same-sex male and female partner households in each census tract by using the original 2010 Census numbers of same-sex male and female partner households for each census tract; and (6) applying the uncorrected proportions to the corrected estimates of same-sex partner households for each census tract to obtain corrected counts of same-sex male and female partners in each census tract.

Next, we generated proportion variables for the three count variables (i.e., same-sex partner households, same-sex male partner households, and same-sex female partner households) by dividing each by the total number of partner households in each census tract. Each proportion variable exhibited very high positive skewness and kurtosis, with the majority of tracts having near zero proportions of same-sex partner households. Finally, to transform the proportion variables for statistical analysis, we created three dichotomous indicators of same-sex partner household enclaves by using K-means cluster analysis to classify all census tracts into two clusters of high versus low proportions of (1) same-sex partner households, (2) same-sex male partner households, and (3) same-sex female partner households. Rather than select arbitrary thresholds to dichotomize each continuous variable, K-means cluster analysis was used to assign each census tract to one of two clusters (with each cluster having a mean yielding the least within-cluster sum of squares), based on a natural break in the values for each of the three proportion same-sex partner household variables. Through K-means cluster analysis of the proportion of partner households including same-sex partners, 41 census tracts were assigned to a high cluster (with 4.30 to 19.69 percent of all partner households including same-sex male or female partners) and 982 census tracts to a low cluster (with < 4.30 percent). For the proportion of partner households including same-sex male partners, K-means cluster analysis classified 35 census tracts in a high cluster (with 3.13 to 17.07 percent same-sex male partner households) and 988 in a low cluster (< 3.13 percent); and with respect to the proportion of partner households including same-sex female partners, K-means cluster analysis assigned 108 census tracts to a high cluster (with 1.10 to 3.58 percent same-sex female partner households) and 915 to a low cluster (< 1.10 percent).

Control Variables

We focused on selecting control variables relevant to Greater Houston that have been found to have significant effects across numerous previous EJ studies, including Chakraborty et al. (2014). To adjust for the effects of race/ethnicity, our analysis includes the proportion of individuals identified as non-Hispanic black and the proportion of individuals identified to be of Hispanic or Latino origin (of any race) (Chakraborty et al. 2014). To adjust for socioeconomic status, we included median household income, income inequality (based on the Gini index), and the proportion of renter-occupied housing units. We include median income and median income squared in the model because the relationship may be curvilinear, following a negative parabolic (i.e., inverted U-shaped) curve (Chakraborty et al. 2014; Boer et al. 1997). In terms of income inequality, we include Gini index scores (as per Chakraborty et al. 2014), which provide summary measures of income inequality ranging from zero (perfect equality) to one (perfect inequality). Housing tenure was included because renter occupancy typically indicates greater housing instability, political disengagement, and reduced household resources and wealth compared to owner occupancy. Population density was also included as a control variable based on the assumption that densely populated areas are more likely to contain pollution-generating activities that increase risk estimates (Chakraborty et al. 2014), and because gay districts have typically been created in high-density urban cores.

Statistical Methodology

Generalized estimating equations (GEEs) with robust (i.e., Huber/White) covariance estimates extend the generalized linear model of Nelder and Wedderburn (1972) to accommodate clustered data. GEEs have been used in analyses to address geographically clustered data (Root 2012), including recent EJ studies (Collins et al. 2015a, 2015b). They provide a general method for the analyses of clustered variables, and relax several assumptions of traditional regression models (Liang and Zeger 1986; Zeger and Liang 1986). GEEs imply no strict distribution assumptions for independent variables and are appropriate for use with non-normally distributed dependent variables, which is the case here. Thus, GEEs enable us to test alternative theoretical explanations for environmental inequalities in reference to a non-normally distributed dependent variable, while accounting for geographic clustering. For our purposes, GEEs are preferable to other modeling approaches that account for non-independence of data (e.g., mixed models with random effects). This is because GEEs estimate unbiased population-averaged (i.e., marginal) regression coefficients, even with misspecification of the correlation structure when using a robust variance estimator (Liang and Zeger 1986; Zeger and Liang 1986), which is appropriate for analyses of general patterns of environmental inequality across subpopulations. Additionally, because our focus is on determinants of HAP cancer risk at the neighborhood level, not multilevel effects, GEEs are appropriate because the intracluster correlation estimates are adjusted for as nuisance parameters and not modeled (as in multilevel modeling approaches).

Clusters of observations must be defined in order to fit a GEE model. It is assumed that observations from within a cluster are correlated, while observations from different clusters are independent. GEEs used in the final models had clusters of census tracts defined based on median year of housing construction by median value of owner-occupied housing units. To accomplish this, census tracts were assigned to one of eight median year of housing construction categories, which correspond with the response options for an ACS instrument "Housing" item ("About when was this building first built?": "2000 or later", "1990 to 1999", "1980 to 1989", "1970 to 1979", "1960 to 1969", "1950 to 1959", "1940 to 1949", and "1939 or earlier") (US Bureau of the Census 2011); they were also assigned to one of four median value of owner-occupied housing units quartiles: less than $91,100, $91,100 to $120,400, $120,500 to $179,500, and greater than $179,500. This cluster definition method was selected over other alternatives because it reflects the urban developmental context within which residents of census tracts are situated. Using these two variables to define clusters is theoretically informed, since they correspond with temporal and economic dimensions of the built-environment across urban space that are associated with the historical-geographical formation of environmental injustice (Bolin et al. 2005; Pulido 2000). Additionally, this choice was statistically informed by results of a sensitivity analysis of five alternative cluster definitions involving combinations of year of housing construction, value of owner-occupied housing units, and county, which indicated that the median year of housing construction by median value of owner-occupied housing units cluster specification yielded the best GEE model fit, based on QIC (quasi-likelihood under the independence model criterion) and corrected QIC (i.e., QICC) values.

GEEs require the specification of an intracluster dependency correlation matrix (Liang and Zeger 1986; Zeger and Liang 1986). While other statistical techniques may account for the intracluster correlation, especially when the dependent variable is normally distributed, GEEs offered the additional advantage of not requiring the correct specification of the correlation matrix in order to reach unbiased statistical conclusions about the covariates' effects, given that the robust estimation of standard errors be applied (as is the case in our analysis). In this case, we specified the exchangeable correlation matrix, which assumes constant intracluster dependency (i.e., compound symmetry), so that all the off-diagonal elements of the correlation matrix are equal (Collins et al. 2015a).

Our analysis approach included the following three steps. First, we used bivariate Spearman's correlations to examine statistical relationships for our explanatory and control variables with our dependent variable, given the nonparametric distributions of several analysis variables. Second, we specified a GEE to addresses our first research question by analyzing our dependent variable as a function of the same-sex partner household enclave variable and the control variables. To select the best fitting model, we estimated a series of GEEs by varying the model specifications. Because our dependent variable is continuous, we tested normal, gamma and inverse Gaussian distributions with logarithmic and identity link functions for a total of six models. The selection of an identity link function means the relationships between the independent variables and dependent variable are predicted directly, while use of a logarithmic link function means that those relationships are predicted based on a natural log function (Garson 2012). GEEs do not support model fit statistics that indicate the proportion of variance explained. Instead, QIC (quasi-likelihood under the independence model criterion) fit statistics, which are interpretable similar to the Akaike's information criterion (AIC) as applied to generalized linear models (i.e., smaller values indicate better fit), are used to select the best fitting model. In this case, the GEE specification that yielded the lowest QIC value was the inverse Gaussian distribution with a logarithmic link function. Finally, in order to address our second research question, we specified GEEs to analyze our dependent variable as a function of the two disaggregated explanatory variables (i.e., same-sex male and same-sex female partner household enclaves) and the control variables. We also used an inverse Gaussian distribution with a logarithmic link function for the GEE reported here, since QIC tests indicated that this model specification fit better than the alternative distribution and link function options. Finally, we examined possible multicollinearity among the analysis variables; based on variance inflation factor, tolerance, and condition index criteria, inferences from the GEEs are not affected by multicollinearity. Note that all independent variables were standardized before inclusion in the GEEs.

Results

Descriptive statistics for the entire set of variables used in this study are provided in Table 1. The spatial distribution of exposure to NATA cancer risk (dependent variable) in Greater Houston is depicted as a classified choropleth map in Figure 2. Census tracts are grouped into quintiles based on NATA cancer risk. Tracts facing the greatest cancer risk are concentrated in the most densely populated areas of this region (e.g., Harris County), and along a corridor near the ship channel that runs east of the city center to the Gulf of Mexico.

In terms of the explanatory variables, based on our corrected count data for census tracts, there were 11,204 same-sex partner households in Greater Houston in 2010, representing 1.00 percent of all partner households; of those, 5,686 were same-sex male and 5,518 same-sex female partner households. Figures 3–5 depict the spatial distributions of the each of the three dichotomous same-sex partner household explanatory variables across Greater Houston census tracts. Figures 3–5 also depict Houston's Inner Loop, where 73 percent of census tracts classified as same-sex partner household enclaves through K-means cluster analysis are located (Figure 3). Most of these census tracts, which contain the highest proportions of same-sex partner households in Greater Houston, align with districts identified by other sources (noted above) as being gay-friendly. It is also noteworthy that the same-sex male partner household pattern (Figure 4) exhibits far more clustering within Inner Loop neighborhoods, while the pattern for same-sex female partner households (Figure 5) is relatively dispersed across urban space. Whereas 83 percent of census tracts classified as same-sex male partner household enclaves through K-means cluster analysis are located within the Inner Loop, this area contains only 30 percent of census tracts classified as same-sex female partner household enclaves.

Bivariate Analysis

The Spearman's correlation coefficients for the explanatory/control variables with cancer risk from HAPs are presented in Table 2. In terms of the explanatory variables, the same-sex, same-sex male, and (to lesser extent) same-sex female partner enclave indicators exhibit positive and significant correlations with cancer risk from HAPs. Each other control variable is correlated with HAP cancer risk in the expected direction except for non-Hispanic black.

Multivariate GEE Analysis

Results for the two GEEs are summarized in Tables 3 and 4. Standardized regression coefficients (see the "Beta estimate" column) are provided to compare the relative strength of the associations. In the first GEE (Table 3), the same-sex partner household enclave indicator exhibits a positive and statistically significant relationship with cancer risk from HAPs, and the standardized coefficient (0.105) is the second largest among the independent variables, meaning it is a relatively strong predictor of HAP cancer risk. In the second GEE (Table 4), the same-sex male partner household enclave variable has a positive and significant association with risk, while the indicator for same-sex female partner household enclaves shows a negative and non-significant (p=0.170) relationship with cancer risk from HAPs. The standardized coefficient for the same-sex male partner household enclave variable (0.114) is larger than those of any control variable, indicating it is the strongest predictor of HAP cancer risk in the second GEE.

Since the GEEs reported here do not model the dependent variable as a linear function of the independent variables (they instead use a logarithmic link function), easily interpretable effect sizes for the independent variables cannot be determined based on the information reported in Tables 3 and 4. However, if the first GEE (Table 3) is modeled using a linear (identity) link function, then same-sex partner household enclaves are estimated to have HAP cancer mortality risks that are 4.842 greater (in persons per million) than other census tracts (adjusting for other variables and clustering). When the second GEE (Table 4) is modeled using a linear link function, then same-sex male partner household enclaves are estimated to have HAP cancer mortality risks that are 5.344 greater than other census tracts (adjusting for other variables and clustering).

Note that each control variable exhibits a nearly identical relationship with HAP cancer risk between the first and second GEE (Table 3 and 4). Both race/ethnicity variables show positive and significant relationships with cancer risk from HAPs. The proportion of renter-occupants has a positive and significant effect on risk, while population density and income inequality indicate positive but statistically non-significant associations with risk. Although median household income depicts a positive and significant relationship, the squared term is negative and nearly significant. This result suggests a quadratic association between median household income and cumulative cancer risk from HAPs.

We also conducted sensitivity analyses using continuous variables for the proportions of same-sex, same-sex male and same-sex female partner households by census tract (which exhibited high skewness and kurtosis), in place of the three corresponding dichotomous indicators of same-sex partner household enclaves. Results for both GEEs were identical to those reported in Tables 3 and 4 in terms of the direction and significance of the statistical relationships.

Discussion

With respect to our research questions, findings from the GEE analysis demonstrate that cancer risks from HAPs in Greater Houston are distributed inequitably with respect to the neighborhood-level composition of same-sex partner households, adjusting for geographic clustering as well as a suite of variables known to influence air pollution risk. The same-sex partner household enclave variable was a powerful predictor of HAP cancer risk relative to other independent variables. Findings also indicate that neighborhood-level HAP exposures are distributed differently between same-sex male versus same-sex female partner household enclaves, such that the same-sex male partner household enclave variable accounts for the relatively powerful effect of the composite same-sex partner enclave variable on HAP cancer risk. Gay male partner enclaves are associated with significantly more exposure to cancer-causing HAPs while gay female partner enclaves are associated with less, adjusting for geographic clustering and relevant covariates. Moreover, the large effect sizes of the same-sex (composite) and same-sex male partner enclave variables on HAP cancer risk indicate that results are of public health significance. These findings are important, since this is the first study of unjust environmental exposures by sexual orientation. Several relevant points emerge from the analysis.

First, our understanding of the historical-geography of Greater Houston points toward the post-WWII clustering of LGBT people within highly polluted Inner Loop neighborhoods—due to heteronormative marginalization and the pursuit of community support and empowerment—as the primary factor shaping environmental injustices experienced by same-sex couples circa 2010. Although it risks conflating divergent experiences and erasing the particular intersections of oppression felt by LGBT people of color (Haritaworn 2008), we assert that parallel formations of environmental injustice have been generated for sexual minorities in Greater Houston as have been documented for racial minorities in cities throughout the US (e.g., such as blacks/African Americans and Hispanics/Latinos). A number of historical-geographical studies focused on specific urban areas have revealed the contextual dynamics of oppression that have subjected particular racialized groups to persistent environmental injustices (Bolin et al. 2005; Pulido 2000). For example, in Phoenix, Arizona—a US Sunbelt metropolis that exhibits structural similarities to Greater Houston—Bolin et al. (2005) excavated the historical-geographical production of a contaminated inner-city zone (i.e., “South Phoenix”), focusing on how racial categories and attendant social relations were constructed by dominant White-Anglos in the late 19th and early 20th century to produce a stigmatized space of racial exclusion and economic marginality. By the 1920s race and place were discursively and materially entwined in a mutually reinforcing process of social stigmatization and environmental degradation in South Phoenix. This produced a durable zone of mixed racial minority residential and industrial land uses. Thus, a process constituted by racial and class privileges reflected in a wide range of NIMBYistic planning and investment decisions has worked to segregate LULUs and racial minorities from dominant White-Anglo Phoenicians in a manner that has structured a persistent pattern of environmental injustice (Bolin et al. 2005). We suspect that a parallel process has been instantiated in Greater Houston involving the social stigmatization of sexual minorities, their spatial exclusion with other unwanted people and land uses in marginal inner-city spaces, and their disproportionate exposure to toxic pollution. However, in contrast to polluted racial minority inner-city spaces, which were produced with the inception of US Sunbelt urbanization, evidence suggests that sexual minorities channeled into this historical-geographical process mid-stream, following WWII, as their marginal status socio-spatially mapped them within an extant formation of environmental injustice.

Second, any shifts toward heteronormative acceptance of alternative sexualities, societal assimilation, and spatial decentralization of LGBT residence over the past fifteen years (Spring 2013) have apparently not ameliorated the sexualized patterning of environmental injustice in Greater Houston. Thus, while scholars of sexuality and space are currently focused on the decline of gay neighborhoods and dispersal of LGBT people across metropolitan space (Brown 2014; Ghaziani 2015; Hubbard et al. 2015), in Greater Houston, LGBT residents (especially same-sex male partners) beyond Montrose are still concentrated in proximate neighborhoods within and just beyond the Inner Loop and in a few peripheral 'islands' (e.g., Galveston, see Figure 3). And while one could point to recent City of Houston Mayor Annise Parker (a lesbian) as a sign of progress based on political empowerment, the local struggle for social justice continues, as ongoing conflicts problematize assumptions about heteronormative acceptance of the LGBT community. For example, in 2002, voters in the City of Houston passed Proposition 2, which outlawed city government from giving benefits to same-sex partners of municipal employees (Quittner 2002). In 2015, the Houston Equal Rights Ordinance (HERO) was repealed by an overwhelming voting margin (Lozano 2015). This happened after groups affiliated with the Christian right gathered 50,000 signatures to put it to a vote by fixating on the fact that HERO allowed transgender women to use women's restrooms (Du 2012). The HERO case reflects the persistence of discriminatory attitudes toward the LGBT community in Houston.

One only needs to peruse residential locational guidance provided to incoming Greater Houston LGBT transplants by members of the local LGBT community via the Internet to realize that a very small selection of neighborhoods, located mostly within the Inner Loop, come recommended. The ambivalent situation for LGBT people in Houston may be consistent with the general trend, as sexualities and space scholars have asserted that new 'rights to the city' are limited to "homonormative LGBT people embodying middle-class and normatively gendered demeanours" (Hubbard 2015: n.p.), while those who do not fit homonormative LGBT identities (e.g., those who identify as queer or trans*) continue to experience exclusion (Nash 2011, 2013; Nash and Bain 2007). In any case, environmental injustices based on sexual orientation produced in Greater Houston during the latter half of the 20^{th} century have evidently not been ameliorated over the past fifteen years. It remains unclear based on our cross-sectional analysis results, however, whether the pattern of disproportionate exposure to cancer-causing HAPs has become less pronounced as a result of LGBT population dispersal.

Third, the sexualities and space literature as well as our understanding of the historical geography of Greater Houston suggest that the clustering of gay male couples within polluted Inner Loop neighborhoods, in comparison to the more dispersed pattern of residence for lesbian couples across metropolitan space, is the primary reason for the gendered distribution of cancer risk from HAPs experienced among same-sex couples today. By all accounts, the production of Montrose as a Houston's gay neighborhood in the 1970s was driven more by homosexual males than lesbians, as was the case with gay neighborhoods in many other cities, but more research is needed to adequately explain this finding. It remains an open question as to whether this is attributable to gender-specific push factors, such as the privileging of masculine ideals and the disempowerment of female homosexuality, the greater likelihood for lesbian couples to have children and thus seek more child-friendly neighborhoods away from the inner-city, and/or the economic exclusion of lesbian couples (who tend to be of lower socioeconomic status compared to gay men) via escalating housing costs from gentrifying Inner Loop neighborhoods (e.g., Montrose). In reference to our statistical results, it is important to note that the same-sex female partner household enclave variable exhibits a significant bivariate correlation with increased exposure to cancer-causing HAPs; however, that relationship becomes negative when adjusting for geographic clustering and other variables (including same-sex male partner household enclaves). Quantitative longitudinal analysis, coupled with qualitative historical-geographical analysis, would help disentangle the multiple possible mechanisms and support more precise explanation for this gendered pattern.

Fourth, in terms of the control variables, we found that non-Hispanic Blacks, Hispanics, and renter-occupants are significantly more likely to reside in neighborhoods with cancer risk from HAPs, which is consistent with previous studies of HAP cancer risks in Greater Houston (Collins 2015a; Chakraborty et al. 2014). The relationship we found between income and HAP cancer risk in Greater Houston is more complicated. While the bivariate correlation suggests a significant and negative association between median household income and risk exposure, it ceases to remain linear when we account for the effects of other variables and geographic clustering. The quadratic term in both GEEs points to the presence of an inverted U-shaped relationship between income and risk. According to Chakraborty et al. (2014), this suggests that lower income tracts include fewer land use activities (e.g., commercial, industrial, or transportation) that emit HAPs, and, conversely, that higher income tracts include residents with capacities to avoid and/or resist land use activities that generate HAPs. Thus, while not the focus of our study, these findings contribute to the mounting evidence regarding environmental injustices in Greater Houston based on race-, ethnicity- and class-based oppression.

Conclusions

This study offers novel insights into relationships between sexual minority status and harmful environmental exposures. It contributes to the knowledge base by providing initial empirical documentation of a previously unstudied and unrecognized pattern. It also infuses current theoretical understanding of environmental inequality formation, which has been dominated by race- and class-based explanatory frameworks, with knowledge emanating from the sexualities and space literature.

While this represents the first study of distributional environmental injustice based on sexual orientation, it has limitations which should be addressed in future work. First, although our analysis of carcinogenic HAP exposures is based on estimates provided by the EPA’s 2011 NATA, there are limitations associated with this dataset. The NATA includes risks from only direct inhalation of HAPs and excludes exposure from other pathways such as ingestion or skin contact. The NATA risk estimates only include individual and additive health effects; synergistic interactions among pollutants remain unmeasured. The assessment does not include exposure to HAPs generated indoors. Additionally, interpretation of the public health implications of the disproportionate cancer risks from HAPs quantified here should be tempered, since the NATA offers a cumulative lifetime exposure measure, yet we know that people do not remain in their 2010 census tracts of residence throughout their lifetimes. Since the NATA data inadequately characterize the range of environmental contexts that influence people's exposures to HAPs, reliance on this dataset in EJ research is bound to generate inferences regarding disproportionate exposures that are confounded by the uncertain geographic context problem (UGCoP; Kwan 2012). Future EJ studies should seek to examine disproportionate exposures based on approaches designed to mitigate the confounding effects of the UGCoP, e.g., by employing contextual units and measurement techniques that take spatiotemporal variation in both HAP levels and people's daily movement into account (Kwan 2012). Finally, future research on EJ and sexual orientation should examine different types of environmental risks.

Second, the same-sex partner variable we employ has limitations when treated as a proxy for LGBT people (Brown and Knopp 2006). Most importantly, it underestimates the size of the LGBT population as it excludes those who are not partnered, and it is estimated that only one quarter of gay men and two fifths of lesbians are in relationships at any given time (Ghaziani 2015). It also excludes those who do not live with their partner, those who are unwilling to self-report via census questionnaires as members of a gay or lesbian couple, those who identify as bisexual and/or transgender, and those who are homeless (Doan 2007; Doan and Higgins 2011; Hayslett and Kane 2011). The numeric extent of these exclusions is notable, as estimates for Greater Houston indicate that the total population of gay, lesbian and bisexual individuals exceeds 150,000 (Gates 2006), while the number of gay male and lesbian individuals living with partners in households based the corrected census data estimates we analyzed is 22,408. Keeping those limitations in mind, it is important to recognize that same-sex partnering in households is a highly visible expression of minority sexual orientation (in contrast to being LGBT single or in the closet) and is thus an important residential indicator of the status of the LGBT community in social justice terms. Future research should seek to employ new data sources that provide more encompassing information on LGBT residence beyond the presence of gay male and lesbian partner households. Additionally, future research should take into account the effects of legalization of civil partnership and gay marriage in some jurisdictions upon the patterning of harmful environmental exposures by sexual orientation.

Third, while we were able to examine and document neighborhood-level disparities in environmental exposures for same-sex partner households by gender, we were unable to examine other axes of difference within the LGBT community—according to race, class, disability, age, life course, etc.—which are known to provide bases for residential exclusion from gay neighborhoods or be associated with residential selectivity. This is important, since numerous scholars have observed that gay neighborhoods are dominated by white, middle-class, gay male interests, and tend to marginalize lesbians, LGBT people of color, older LGBT people, as well as those of lower socioeconomic status and/or with disabilities (Duggan 2002; Nero 2005; Tucker 2009). Unfortunately, disaggregated US Census data for same-sex partner households are not publicly available based on most such axes of difference. Future EJ research should develop methods for examining the effects of intersecting axes of oppression upon harmful environmental exposures across different groups of LGBT people.

Fourth, our study focused primarily on assessing current risk disparities based on sexual orientation in Greater Houston. Our quantitative analysis results cannot be used to deduce the sequence of events that led to increased pollution exposures in specific neighborhoods that contain relatively high concentrations of same-sex partner households. Qualitative historical-geographical and quantitative longitudinal research is necessary to develop more detailed explanations for the types of unjust patterns revealed here. In the context of Greater Houston, our findings represent an important starting point for more detailed analysis of the causes and consequences of environmental injustice based on sexual orientation.

Finally, our study results are practically important, since they provide initial documentation of an environmental health risk factor with disproportionate effects on a socially marginal population that is burdened by other public health risks in the US. Since the residential pattern of same-sex partnering among males is specifically responsible for driving the more general pattern of environmental injustice we found, the practical relevance of this study is most applicable to health risks faced by gay men. As Brown (2014) notes, there has been growing interest in public health scholarship on gay neighborhood effects upon the health of individual gay men. For example, studies have found that living in areas with high concentrations of gay people may independently predict behavioral health risks, such as unprotected sex and substance abuse, for gay men (Carpiano et al. 2011; Egan et al. 2011; Buttram and Kurtz 2013). Our findings suggest that those health risks experienced in gay neighborhoods may be compounded by disparate health risks associated with harmful exposures to air toxics. More studies that test for unjust environmental health risks based on LGBT residence are needed; and where patterns of injustice are found, appropriate public health interventions to address compounding health disparities should be developed and implemented.

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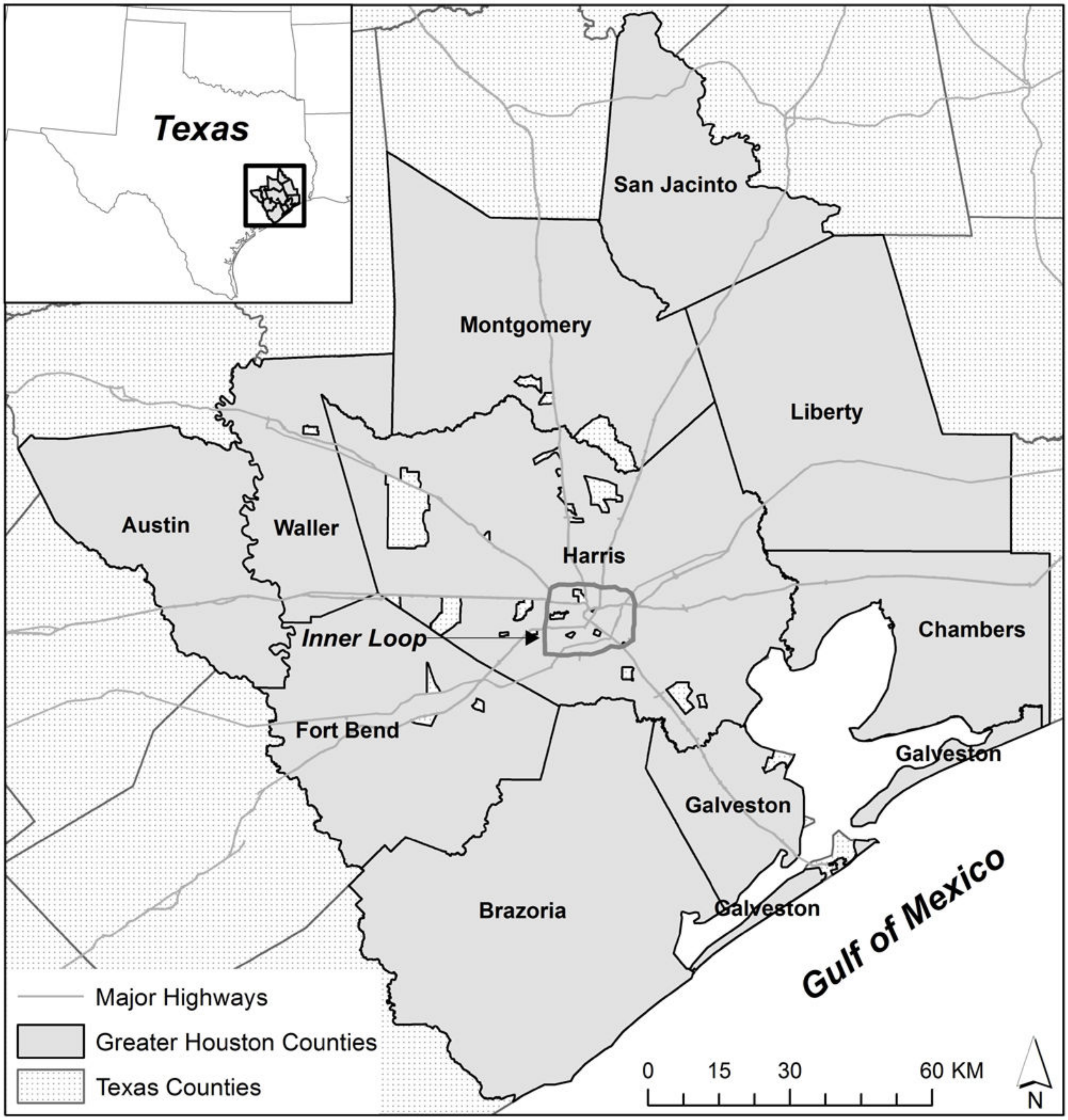

Figure 1.
Location of the Greater Houston, Texas study area.

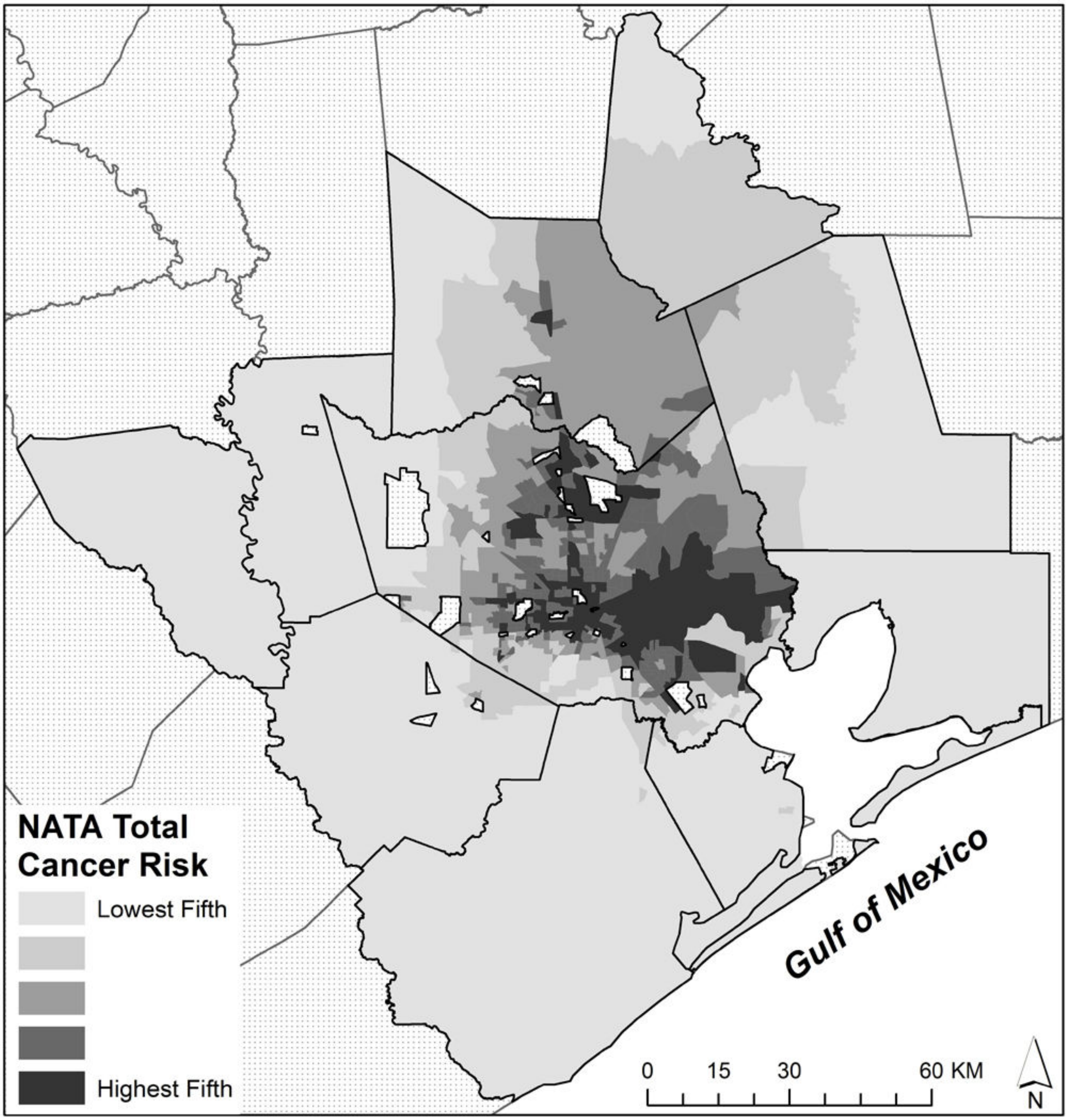

Figure 2.

Distribution of cancer risks from hazardous air pollutants by census tract, Greater Houston.

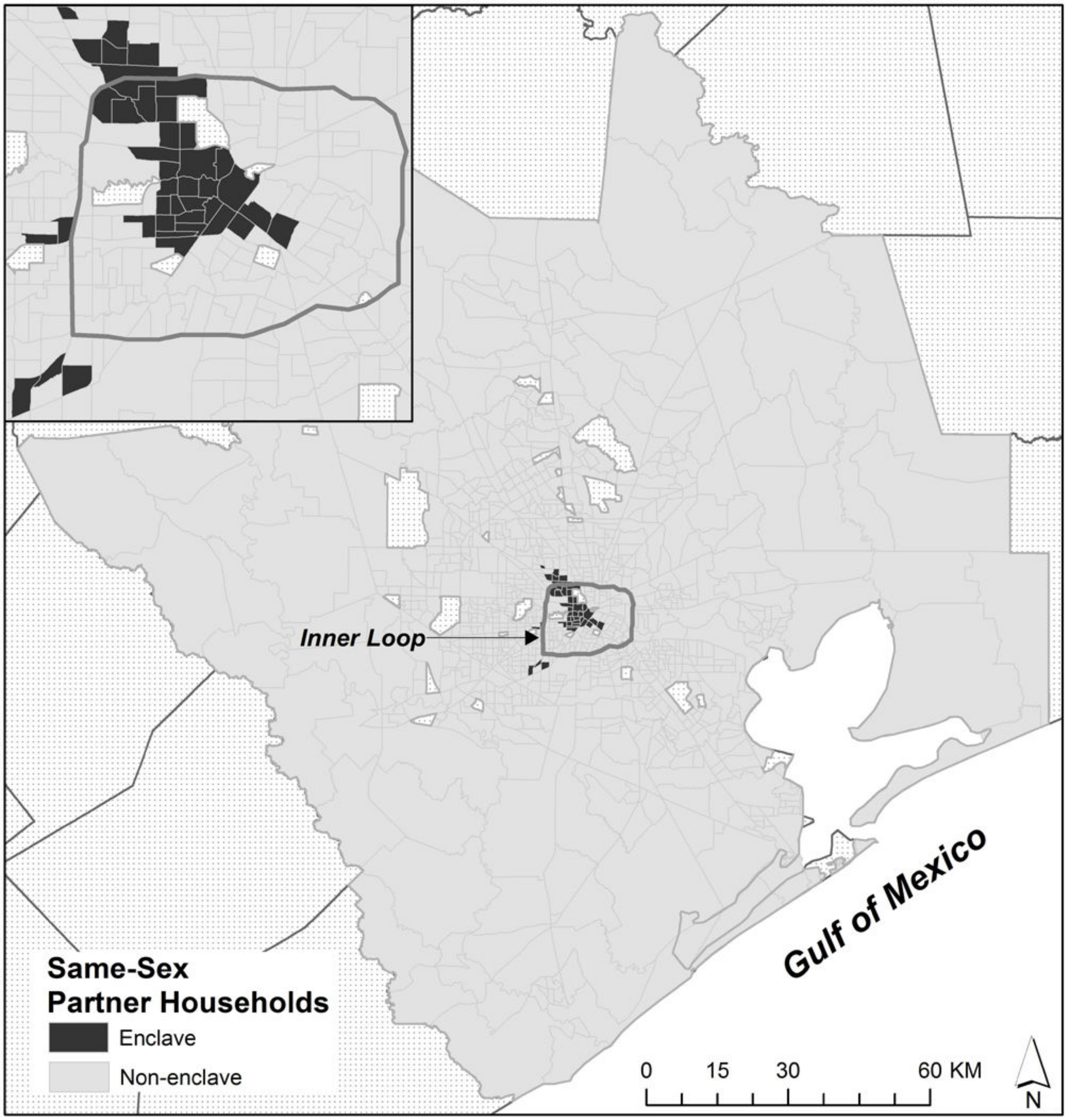

Figure 3.
Distribution of same-sex partner household enclaves, Greater Houston.

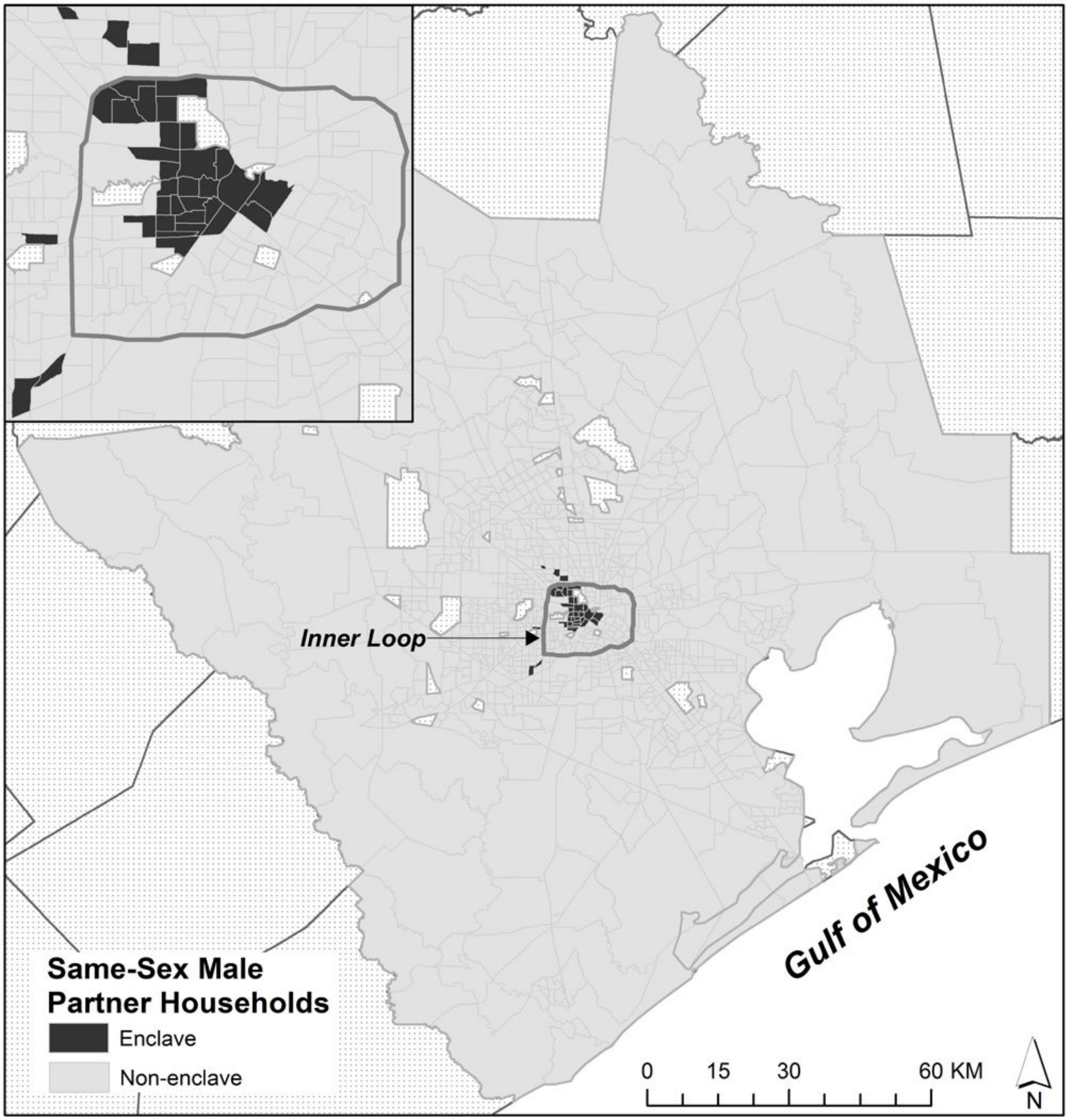

Figure 4.
Distribution of same-sex male partner household enclaves, Greater Houston.

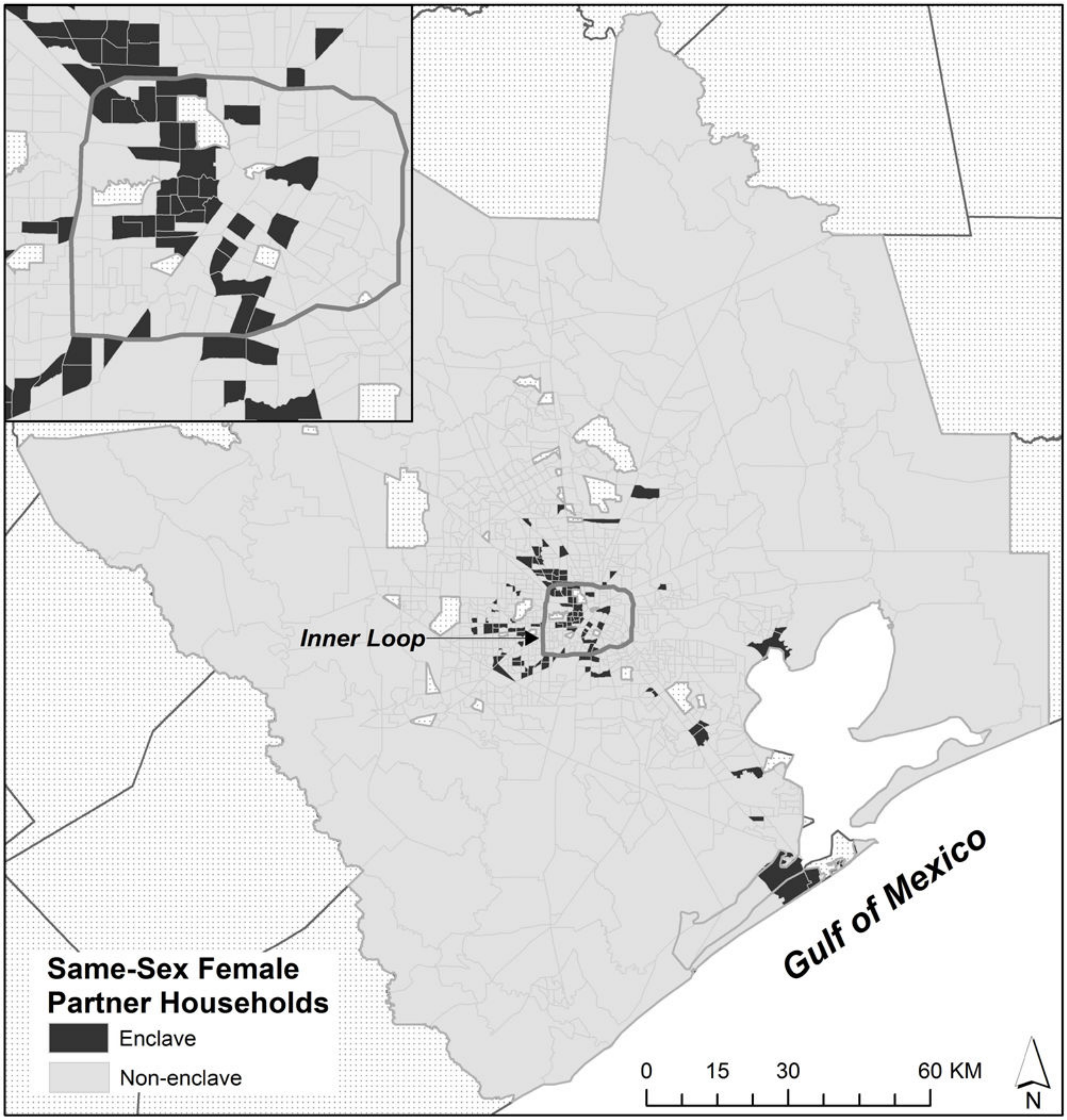

Figure 5.
Distribution of same-sex female partner household enclaves, Greater Houston.

Table 1

Summary statistics for variables analyzed, Greater Houston (*n*=1,023 census tracts).

Continuous Variables	Mean	Std. Dev.	Min.	Max.
Dependent variable:				
NATA cumulative cancer risk (persons per million)	43.829	7.360	20.765	87.023
Control variables:				
Population density (per square km)	1573.50	1249.00	3.73	8850.72
Proportion non-Hispanic Black	0.178	0.207	0.001	0.941
Proportion Hispanic	0.362	0.241	0.035	0.972
Median household income ($)	60,262	31,603	9,605	217,176
Income inequality (Gini index)	0.413	0.064	0.240	0.664
Proportion renter-occupied homes	0.385	0.235	0.019	0.982
Dichotomous Variables	**Yes**	**No**		
Explanatory variables:				
Same-sex partner household enclave	41	982		
Same-sex male partner household enclave	35	988		
Same-sex female partner household enclave	108	915		

Table 2

Bivariate correlation of hazardous air pollutant cancer risk with census tract level characteristics, Greater Houston (*n*=1,023).

	NATA cumulative cancer risk
Variable	**Spearman's rank correlation coefficient (rho)**
Same-sex partner enclave	0.207***
Same-sex male partner enclave	0.201***
Same-sex female partner enclave	0.114***
Population density	0.365***
Proportion non-Hispanic Black	−0.083***
Proportion Hispanic	0.344***
Median household income ($)	−0.261***
Income inequality (Gini index)	0.114***
Proportion renter-occupied homes	0.377***

* $p<.10$;

** $p<.05$;

*** $p<.01$

Table 3

Generalized estimating equation[1] predicting hazardous air pollutant cancer risk, with composite same-sex partner enclave variable, Greater Houston (*n*=1,023).

Variable	Beta Estimate	SE	95% CI
(Intercept)	3.668	0.016	(3.636, 3.701) ***
Same-sex partner enclave	0.105	0.014	(0.078, 0.131) ***
Population density	0.010	0.007	(−0.004, 0.025)
Proportion non-Hispanic Black	0.024	0.010	(0.005, 0.044) **
Proportion Hispanic	0.075	0.010	(0.056, 0.095) ***
Median household income ($)	0.107	0.037	(0.034, 0.180) ***
Median household income ($) squared	−0.045	0.025	(−0.093, 0.004) *
Income inequality (Gini index)	0.006	0.006	(−0.005, 0.017)
Proportion renter-occupied homes	0.050	0.006	(0.038, 0.061) ***
(Scale)	0.001		

* $p<0.10$;

** $p<0.05$;

*** $p<0.01$

[1] Exchangeable correlation matrix; number of clusters=27; number of measurements per cluster=2 (min) to 94 (max).

Table 4

Generalized estimating equation[1] predicting hazardous air pollutant cancer risk, with male and female same-sex partner enclave variables, Greater Houston (n=1,023).

Variable	Beta Estimate	SE	95% CI
(Intercept)	3.691	0.016	(3.660, 3.721) ***
Same-sex male partner enclave	0.114	0.023	(0.070, 0.159) ***
Same-sex female partner enclave	−0.028	0.020	(−0.068, 0.012)
Population density	0.011	0.007	(−0.003, 0.025)
Proportion non-Hispanic Black	0.025	0.010	(0.005, 0.045) **
Proportion Hispanic	0.074	0.010	(0.055, 0.093) ***
Median household income ($)	0.108	0.037	(0.035, 0.180) ***
Median household income ($) squared	−0.046	0.025	(−0.095, 0.002) *
Income inequality (Gini index)	0.006	0.006	(−0.006, 0.017)
Proportion renter-occupied homes	0.052	0.007	(0.039, 0.064) ***
(Scale)	0.001		

* p<0.10;

** p<0.05;

*** p<0.01

[1] Exchangeable correlation matrix; number of clusters=27; number of measurements per cluster=2 (min) to 94 (max).