Cities 36 (2014) 41–49

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

A long view of polluting industry and environmental justice in Baltimore

Christopher G. Boone [a,*], Michail Fragkias [b], Geoffrey L. Buckley [c], J. Morgan Grove [d]

[a] School of Sustainability, Arizona State University, PO Box 875502, Tempe, AZ 85287-5502, USA
[b] Department of Economics, Boise State University, 1910 University Drive, Boise, ID 83725, USA
[c] Department of Geography, Ohio University, 122 Clippinger Labs, Athens, OH 45701, USA
[d] Baltimore Field Station and Baltimore Ecosystem Study, US Forest Service Northern Research Station, Suite 350, 5523 Research Park Drive, Baltimore, MD 21228, USA

ARTICLE INFO

Article history:
Received 10 August 2012
Received in revised form 3 September 2013
Accepted 11 September 2013
Available online 5 October 2013

Keywords:
Environmental justice
Baltimore
Longitudinal
Toxics Release Inventory
Hazards Density Index
Sustainability

ABSTRACT

Purpose: This study examines the density of polluting industry by neighborhoods in Baltimore over the long term, from 1950 to 2010, to determine if high pollution burdens correspond spatially with expected demographic and housing variables predicted in the environmental justice literature. For 1960–1980 we use data on heavy industry from Dun and Bradstreet directories and for 1990–2010 the US EPA's Toxics Release Inventory to calculate a Hazards Density Index. Drawing on the decennial censuses for 1960–2010, we populate census tracts from corresponding years with data on race, ethnicity, educational attainment, income, and housing tenure.

Findings: Density of polluting industry is positively correlated with low-income neighborhoods and renter-occupied housing in 1960 and by 2010 with white, Hispanic, and low educational attainment populations. In general, over time density of polluting facilities shifts from an association with wealth to race and ethnicity while educational attainment remains a significant variable throughout. This study confirms earlier analyses on Baltimore that white neighborhoods are more likely than African–American neighborhoods (1990–2010) to contain polluting facilities but reveals for the first time that educational attainment is also significant. The paper concludes with a discussion of the Baltimore Sustainability Plan and its weak efforts to address persistent environmental injustices.

© 2013 Elsevier Ltd. All rights reserved.

Introduction

In a 1958 planning report, the population of Baltimore was projected to steadily increase from 950,000 in 1950 to 1.2 million by 1980 (Baltimore Regional Planning Council., 1958). This projection was based on an assumption that the city would grow uninterrupted along an elegant smooth curve. What the planners did not foresee was the radical transformation of Baltimore's industrial economy; from 1950 to 2000, the city experienced a net loss of more than 100,000 manufacturing jobs. Nor could they predict the full impacts of federally-subsidized suburbanization through the Federal Highway Acts and the guaranteed mortgages for new home construction, the Martin Luther King riots of 1968, the crack cocaine epidemic in the 1980s and rise of violent crime, or the powerful lure of suburban schools, homes, and jobs. Baltimore City's population peaked in 1950 and has been in steady decline ever since.

For the 620,000 residents who remain, what are they left with? Although industries shed thousands of good paying jobs, Baltimoreans have to live with still-functioning and polluting facilities. From 2005 to 2010, nearly 120 million pounds of toxic pollutants were released into the air, water, and land of Baltimore City, far greater than any of the surrounding counties in Maryland. On average, each resident of Baltimore City endures 191 lb of released toxins compared to 47 lb per person for the suburban counties in the metropolitan area.[1]

Baltimore City distinguishes itself from surrounding counties in another way – it is majority (64%) African–American. This corresponding pattern of polluting industry in areas populated by people of color agrees with the vast majority of environmental justice findings (Downey & Hawkins, 2008; Mohai & Saha, 2007). However, when we zoom down to finer spatial scales, an unexpected pattern emerges. Most of the toxic releasing facilities recorded in the US Environmental Protection Agency's Toxics Release Inventory (TRI) are found in or near white rather than black neighborhoods (Boone, 2002; Boone, 2008a; Downey, 2007). This is peculiar given that the majority of environmental justice studies conducted at the census tract or zip code level show that marginalized communities, including persons in poverty and ethnic/racial minorities, are more likely to live near toxic facilities than whites and higher-income residents, and that race and ethnicity are usu-

* Corresponding author.
E-mail addresses: cgboone@asu.edu (C.G. Boone), michailfragkias@boisestate.edu (M. Fragkias), buckleyg@ohio.edu (G.L. Buckley), mgrove@fs.fed.us (J.M. Grove).

[1] Baltimore City is a county equivalent jurisdiction in Maryland. The surrounding suburban counties are Anne Arundel, Baltimore, Carroll, Harford, and Howard.

0264-2751/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cities.2013.09.004

ally stronger predictors than income. Results from Baltimore are more the exception than the rule, although studies from Detroit (Downey, 2005), Buffalo (Krieg, 2005), and Cleveland (Bowen, Salling, Haynes, & Cyran, 1995) show similar findings of African–American neighborhoods not significantly associated with toxic census tracts.

In Baltimore, a variety of historical reasons help to explain why whites are more likely than blacks to live near TRI facilities. One is the changing notion of amenity location combined with community inertia. In the first few decades of the twentieth century, living close to a factory job was a privilege afforded primarily to white Baltimoreans (Olson, 1997). The city has undergone significant demographic shifts but many of these older white communities remain close to what are now designated as toxic releasing facilities. From a distributive justice perspective, the potential for environmental inequities hinges on residential segregation. Baltimore has a long history of residential segregation along racial, ethnic, class, and religious lines. It was the first city in the nation to pass a local ordinance restricting where blacks could live (Power, 1983), setting an example that numerous southern cities would follow before a US Supreme Court ruling in 1917 ended the practice. Wishing to "protect" residents from "negro encroachment" in the wake of the Supreme Court decision, homeowners associations from across the city cooperated with one another to prevent blacks, Jews, and other ethnic whites, particularly those from southern and eastern Europe, from gaining a toehold in their neighborhoods. They also adopted restrictive covenants that forbade homeowners from selling to whomever they wished. While they sought to secure their borders, homeowners lobbied for the provision of a variety of amenities, such as telephone service, paved roads, street trees, and parks (Buckley & Boone, 2011). Federal institutions, including the Home Owners Loan Corporation in the 1930s, helped to reinforce segregation in the city (Lord & Norquist, 2010). The net effect was to keep white neighborhoods occupied by white residents longer than if choice alone dictated. White privilege and accompanying segregation in essence 'backfired' on white residents now living in toxic neighborhoods while black Baltimoreans were subjected to grossly unjust rules and institutions.

Change over time

What has not been adequately explored in the environmental justice literature is how patterns of inequity change over time. In part this is a function of available data. The US Environmental Protection Agency did not begin to collect and publish TRI data until 1987. However, this now amounts to over two decades of information on toxic releases, so longitudinal studies are possible and meaningful using this important data source. A second explanation is the recoil from early "which came first" studies, an approach that has been largely discredited as a means of establishing causation. Minorities moving into a neighborhood after a polluting industry is established can still be an environmental injustice, as institutions, discrimination, and unfair practices might diminish opportunities for minorities to live in neighborhoods without polluting facilities. The causes of where people live and may live are complex, and a simple analysis of which came first – the industry or the population – neglects the myriad array of constraints on the choice of residential or industrial location. A second issue that often arises, as a criticism of environmental justice, is evidence of harm (Bowen, 2002). Making the link between location of a hazardous waste facility, for instance, and the health and well being of nearby residents is a valid and appropriate approach (Brulle, David, & Pellow, 2006; Hynes & Lopez, 2007). Indeed, this is the burden of epidemiologists who have developed painstaking methods to explicate causal pathways of environmental hazards and health outcomes. When this information is available, the environmental justice community has used it (Osiecki, Seijeoung, Ifeanyi, & Calhoun, 2013) but also resisted the argument of evidence of harm for several reasons. First, it could be perilous for residents to wait for the science to demonstrate causal linkages while living with a polluting facility. A second concern is that proof of harm should not rest with victims, as is typically the case, but with the polluters themselves. A third reason that the environmental justice community resists drifting into risk analysis and proof of harm is that it distracts from the processes, rather than the outcomes alone, that may be unjust (Bullard, 1996). Exclusion of citizens from decision-making can be as much of an injustice as living with polluting facilities (Schlosberg, 2007).

In this study, we conduct a longitudinal analysis of polluting industry and demographics not to explore causation but effect. Other analyses and studies have demonstrated that a series of institutions effectively segregated white and black Baltimore and restricted heavy industry through zoning to areas near the harbor (Boone, 2002; Orser, 1994). This paper will examine if those institutions have consistently confined heavy industry to white neighborhoods over time. In other words, we examine if the effect has been consistent over the last 60 years, or if it has shifted in significant ways. To our knowledge, this is the first study to investigate distributive environmental justice over such a long time period. We argue that this long time span allows environmental justice researchers to examine the dynamics of change, persistence, path dependency, and legacies that would otherwise be difficult if not impossible to observe. A site-specific historical approach provides insight into the dynamics of distributive justice, which is a critical starting point for subsequent process justice inquiries.

It is important to note that environmental burdens are more than pollution from heavy industry. Others have studied the location of hazardous waste facilities (Bullard, 1990), recycling sorting centers (Gandy, 2002), housing in flood plains (Maantay & Maroko, 2009), liquor stores (Romley, Cohen, Ringel, & Sturm, 2007) and other unwanted land uses or hazards as environmental justice concerns. Dangerous contaminants such as lead are found in very high concentrations in Baltimore, especially in older housing that is not carefully maintained (Andra, Sarkar, Datta, & Saminathan, 2006; Schwarz et al., 2012). In most cities, lead levels correspond with poverty, which correlates strongly with some ethnic and racial minorities (Zhou, Boone, & Shock, 2012). Traffic and noise pollution, trash, and biohazards (including used syringes) are among many other factors that should be considered environmental burdens (Sobotta, Campbell, & Owens, 2007). Environmental justice is also concerned with the distribution of environmental amenities. Theories of social privilege have been used to show how whites in many US cities enjoy a disproportionate share of environmental amenities, such as access to parks and open space, clean air, and tree canopy cover (Landry & Chakraborty, 2009; Pulido, 2000). In the case of Baltimore, white privilege in the past meant close access to employment in factories. The legacy of that past privilege to an amenity is now a disproportionately high concentration of polluting facilities in white neighborhoods.

Data and methods

The principal objective of this paper is to map the historical distribution of polluting industries in Baltimore and compare those distributions to nearby social and housing characteristics. The purpose for doing so is to examine if the patterns vary or persist over time. To match the decennial census, we analyze the spatial and statistical relationships between polluting industry and social and housing characteristics at 10 year intervals from 1960 to 2010. As with most longitudinal datasets, the categories and

measurement methods of the censuses vary to a degree, but we believe they are reasonably robust for the purposes of the analysis.

The TRI is one of the most commonly used data sources in outcome-equity analysis. Mandated by the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, facilities meeting certain minimum release thresholds and other criteria are required to report to the Environmental Protection Agency releases of chemicals that are toxic to people or the environment. The TRI is used extensively in EJ research because it provides data about actual releases of toxic substances. Since TRI data have been collected only since 1986, we use alternative data sources for 1960, 1970, and 1980. To match the TRI initial screening criteria, we use the Dun & Bradstreet (D&B) Regional Directories to extract location data for heavy manufacturing (SIC divisions 20–29), electric utilities (SIC 4911, 4931, 4939), chemical wholesalers (SIC 5169), and petroleum terminals (SIC 5171). While the presence of such facilities does not necessarily equal the disamenity of present-day TRI sites, for the purposes of this analysis, they are assumed to be sources of pollution and are treated as disamenities. The D&B directories contain street addresses, which we geocoded to approximate location of the facilities. If a D&B facility matched a facility in the TRI, we assigned the location of the D&B facility using the TRI data.

To measure the concentration of polluting industries by neighborhood, we use the Hazards Density Index (HDI) first developed by Bolin et al. (2002). For our analysis, the HDI summarizes the proportion of 800-m (half-mile) buffers from polluting facilities that intersect each census tract. For example, if census tract X contains a TRI site and completely contains the 800 m buffer, it would have a HDI score of 1. If 20% of the area of another 800 m buffer from an adjacent census tract covered census tract X, its HDI score would be 1.2. This method is useful for avoiding a simple container approach to hazards mapping. The 800 m buffer has been used in other EJ analyses, including Baltimore (Boone, 2002), as a measure of potential impact. It is an imperfect measure of risk, but it approximates a measure of living with a disamenity in and around one's neighborhood. Historical census tract boundaries and data (1960–1980) were downloaded from the National Historic GIS (Minnesota Population Center, 2011), while tabular data and boundary files for 1990–2010 were drawn from American Factfinder website (http://www.factfinder2.census.gov) and the TIGER/line shapefiles from the US Census Bureau (http://www.census.gov/geo/www/tiger/).

For each decade, we compare the means (*t*-test) of neighborhood demographics (race/ethnicity, educational attainment, family income) and housing tenure (renters) with zero and nonzero HDI scores for significant ($p < .05$) differences. Spearman's correlations of demographics and housing tenure with HDI are also generated.

We estimate linear relationships between HDI, socioeconomic characteristics, and housing tenure. Land value data, which could potentially strengthen the models, were not available over the study period. However, we believe that family income, which is included in our models, is a reasonable if imperfect proxy for land rent. We use regression analysis and ordinary least squares (OLSs) as our baseline methodology deploying HDI as our dependent variable. Regression analysis allows us to explore the strength of the relationship between the HDI and a variety of socioeconomic variables such as population, income, and race, testing for each variable independently and controlling for the effects of all other variables. We run OLS for both the full sample of observations (the population of all census tracts across the years in our study) and for a sub-sample of observations that only showcase strictly positive values for the HDI dependent variable.

For the case of using the full sample of observations (the population of tracts in the city of Baltimore), the construction of our dependent variable (HDI) gives rise to a large number of zero values; that is, tracts with a zero HDI score constitute a significant majority of our observations while tracts with continuous positive values are a minority. While the zero-inflated continuous dependent variables are not uncommon in social and natural sciences, this feature of our dependent variable leads us to a specific modeling approach for this paper. We hypothesize that the data construction process introduces the property of heteroskedasticity in our regression error term (the unobservables). That is, one of the main assumptions for OLS, the assumption of constant variance for the error term is violated. This can be verified by a look at the plot of standard OLS residuals. Heteroskedasticity leads to the problem of biased standard error estimates for the regression coefficients, but not biased regression coefficients themselves. While the magnitude of a coefficient is not biased, any statistical significance inference is then suspect. We correct for heteroskedasticity by utilizing an OLS estimation method of White's heteroskedasticity consistent standard errors. We also run our OLS regression excluding all tracts that have a zero HDI score.

For our examination of spatial diffusion patterns of hazards across time we use a LISA statistic. A local indicator for spatial association (LISA) is any statistic that gives an indication of the extent of statistically significant spatial clustering of similar values around each observation in the sample (Anselin, 1995). We use a LISA to identify local spatial clusters (hotspots) of HDI and track potential shifts across time. These hotspots are formed by sets of adjacent locations for which our LISA is statistically significant. In order to detect these hotspots and their spatial diffusion over time in clustered, diffused or random patterns we considered both the location of each of our observations and the values of the variable of interest, the HDI in each location and tract in the city of Baltimore.

Results

Hazard density index and bivariate correlations with socioeconomic data, 1960–2010

The Dun and Bradstreet directories for 1960 recorded 63 industries that fell under the SIC codes for likely polluting facilities. For that year, the Hazards Density Index was highest near the core of the city, along the waterfront, and to the east and west of the city (Fig. 1). Census tracts with an HDI score greater than zero tended to have a higher percentage of low income families, "nonwhite" persons, percent renters, and lower percentage of adults with college degrees than census tracts with HDI scores of zero. Bivariate correlations show that race was not significantly correlated with HDI, but income, educational attainment, and persons renting were. Neighborhoods with a higher percentage of families earning less than $1000 and $5000 a year were likely to live in tracts with higher HDI scores, while neighborhoods with a higher proportion of people in the upper income classes were likely to have lower HDI scores. Census tracts with a higher percent of persons with a high school or college degree were negatively correlated with HDI. Percent renters was positively correlated with HDI.

By 1970, the number of likely polluting facilities within city boundaries decreased to 46 although 3 others were within 800 m of the city boundary and thus contributed to the HDI of tracts within the city. Near downtown the HDI continued to be highest as well as to the southwest and in the east end. The HDI was also high along the Jones Falls and railroad corridor to the north of the central city. Census tracts with an HDI score greater than zero tended to have a higher percentage of low income families and percent renters, and a lower percent of high school and college graduates than census tracts with an HDI score of zero. Bivariate correlation shows strong and positive correlations between HDI score and per-

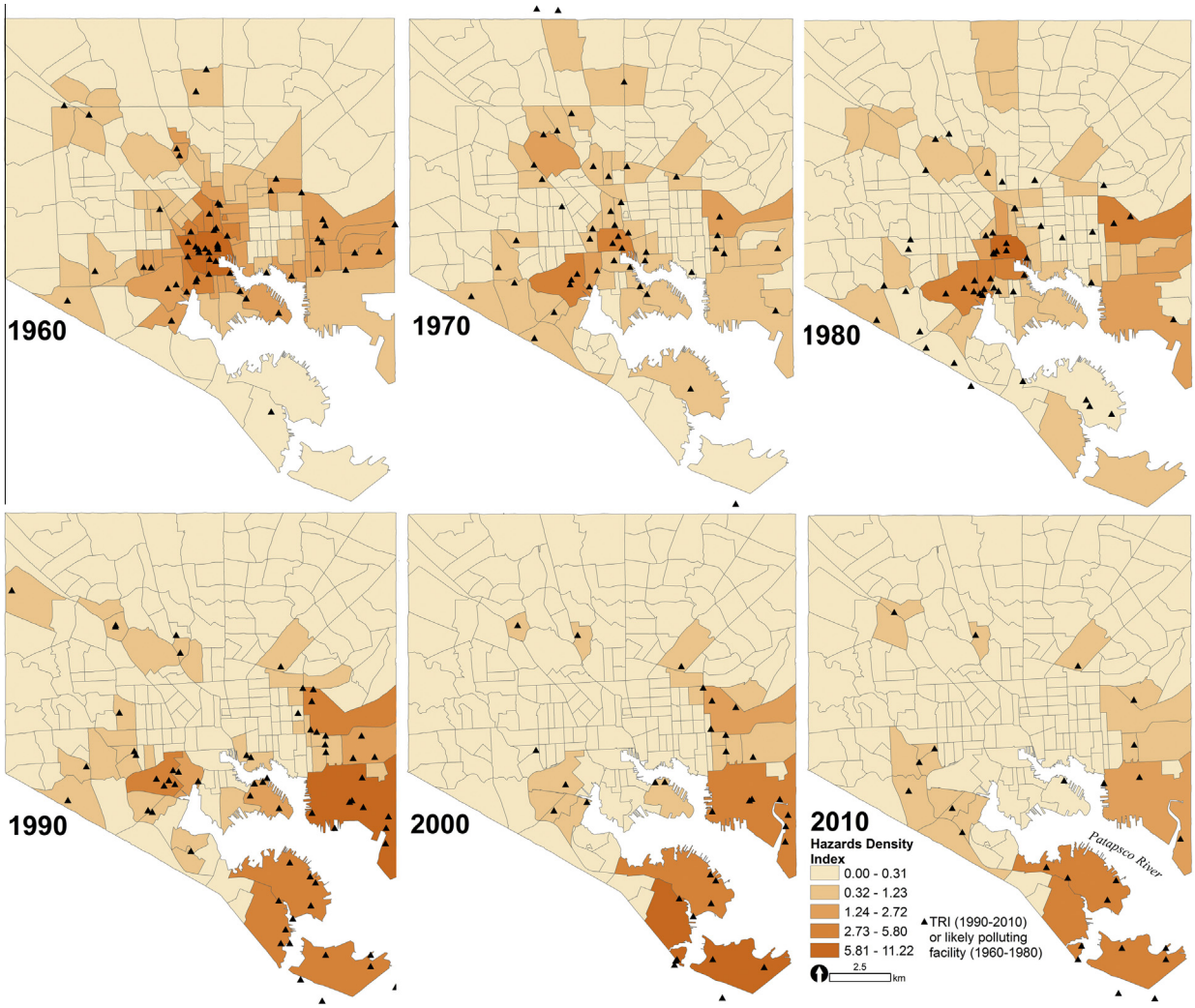

Fig. 1. Hazards Density Index for Baltimore City, 1960–2010.

cent of low income families and percent of adults with 8th grade educational attainment. The relationship is significant and negative with percent of high income families and high school and college educational attainment.

By 1980, the number of likely polluting industries increased to 77, with only 8 matching those from the 1960 directory. This figure is close to the 82 facilities that were recorded in the first TRI in 1987. The match by company names, however, is quite low (5) between the D&B in 1980 and TRI in 1987. Facilities continue to be clustered near downtown and the southwest neighborhoods of Camden, Carroll, and Pigtown, further south in Fairfield and Curtis Bay, and the industrial districts on the eastern edge of the city. Census tracts with an HDI score greater than zero tended to have a lower median family income, a higher percentage of adults with only an 8th grade education, a lower percentage of high school and college educated adults, and a lower percentage of owner occupied houses than census tracts with an HDI score of zero. Bivariate correlations show a positive and significant relationship between HDI score and % with 8th grade educational attainment, % white, and % Hispanic, and a negative and significant relationship between HDI scores and % black and % with a college degree.

For 1990, we switched to using the location of TRI sites and there were 66 within or adjacent to the city boundaries. Notably, TRI facilities were nearly absent in the downtown core or the nearby inner harbor where a decade of redevelopment displaced much of the ageing industry and warehousing (Olson, 1997). Instead, TRI facilities were concentrated in the historic industrial areas of Camden and Carroll to the southwest, Locust Point, Fairfield, and Curtis Bay to the south, and Canton and Pulaski to the east. Census tracts that had HDI scores greater than zero tended to have higher percentages of adults with only an 8th grade education, lower percentages of adults with a college degree, and lower median family incomes than census tracts with an HDI score of zero. Unlike in 1970 or 1980, race variables are significantly different in zero and nonzero HDI census tracts. By 1990, percent white for census tracts with HDI scores greater than zero is significantly higher and percent black is significantly lower than in census tracts with an HDI score of zero. Correlations show % white and % of adults with only an 8th grade education positively and significantly correlated with HDI and % black, % of adults with a college degree, and median family income negatively and significantly correlated with HDI.

In 2000, Baltimore City contained 65 TRI sites. Between 1990 and 2000, the HDI declined in the historic industrial neighborhoods of Camden/Carroll but remained high in the Fairfield, Curtis Bay, and Hawkins Point districts as well as the industrial east end. Census tracts with an HDI score greater than zero tended to have a higher percentage of whites, a higher percentage of adults with only an 8th grade education, and a higher percentage of renters than census tracts with an HDI score of zero. HDI was positively

and significantly correlated with % white, % Hispanic, % 8th grade educational attainment, and % owner-occupied houses, and negatively and significantly correlated with % African American, % with a college degree, and % renters.

In 2010, there were 42 TRI facilities in Baltimore City. By this time, facilities were absent from the downtown commercial core and clustered in the historical industrial zones to the south, east, and west of the city. Census tracts with an HDI score greater than zero tended to have a higher percentage of whites and lower percentage of African Americans and a higher percentage of adults with only an 8th grade education than census tracts with an HDI score of zero. HDI was positively and significantly correlated with % white, % Hispanic, % with 8th grade educational attainment, and negatively and significantly correlated with% African American and percent college educated.

Regressions

We find that our models excluding zero HDI values improve only slightly in terms of the explanatory power of the models across the six time slices in our sample. Excluding zero HDI tracts from the sample also does not lead to substantially different magnitudes of estimated coefficients for the variables included in our specifications. The models also maintain the general patterns of statistical significance of the estimated coefficients. However, other than for 1960 and 2010, the models are relatively weak with *r*-squared values between 0.10 and 0.17. For 2010, which has the highest *r*-squared value (0.45) of all the models, the sign of the coefficients is similar to the bivariate analysis for that year. Percent black, percent with a college degree, and median family income are all negative and significant at $p < 0.01$. For the 1960 model, percent non-white is negatively associated and percent renters are positively associated with HDI and significant at $p < 0.01$. As expected, the percentage of higher income families is negatively associated with HDI ($p < 0.01$). Highly educated neighborhoods are negatively associated with HDI as expected, but the model also returns a negative coefficient for percentage of adults with less than an 8th grade education. Model coefficients for median family income, percent black, percent college educated, and percent renters from 1960 to 2010 are shown in Table 1.

Spatial diffusion

The Moran's I statistic exhibits a declining trend over time. From a high value of 0.66 in 1960 it declines to 0.34 in 1970, increases slightly to 0.38 in 1980, declines again to 0.27 in 1990 and to a low of 0.16 in 2000. Thereafter, we see a rise to 0.29 in 2010. The declining trajectory in the Moran's I statistic suggests that the spatial arrangement of HDI values moves from a more clustered pattern to a less clustered pattern, without ever reaching a dispersed pattern. In the last decade reported, we observe a reversal of this trend. The decline and rise reflects the general shift from a concentration of facilities near the downtown core in 1960 to an eventual re-concentration of facilities in 2010 to the southern and eastern extents of the city. The map Fig. 2 shows locations with significant local Moran statistics across time and classifies those locations by type of spatial association. The spatial autocorrelation at the tract level exhibits an interesting and shifting pattern of spatial diffusion between 1960 and 2010. The bright red and dark blue tracks indicate spatial clusters (respectively, high surrounded by high, and low surrounded by low). In contrast, the light red and light blue tracts indicate spatial outliers (respectively, high surrounded by low, and low surrounded by high). Between 1960 and 1980 there are significant hotspots that are stable across time. The clustered tracks with high HDI associations (hotspots) were found to cover the central census tracts of Baltimore while several clusters of tracts with low HDI exist in the west and the northeast of the city. The figures show a structural break in the pattern in the period of 1990 and a new spatial pattern begins to form in 2000 and 2010. Starting in 1990 the strong high HDI cluster in the center of the city disappears and a low HDI cluster emerges in the north of the city. Several high HDI clusters begin to emerge in the south and east of the city. By 2000, the high HDI clusters have shifted to the south and southeast of the city, and the pattern appears to be stable up to the last year of our observation in 2010.

Discussion

Between 1960 and 2010, the distribution of polluting facilities shifted from the core to the eastern and southern peripheries of the city. This is apparent from visual interpretation of maps showing polluting facilities and from the spatial diffusion analysis. At the same time, overall density of polluting facilities declined. The mean HDI score for census tracts was highest in 1960 (0.96) and lowest in 2010 (0.10), and the number of census tracts without an HDI score increased over time, from 51 (31% of total) in 1960 to 147 (74% of total) in 2010. Similar to other cities, the number of TRI facilities in Baltimore has been in decline since the 1980s. From 82 facilities in 1987, the number declined to 42 in 2010. This may be explained in part by the marked deindustrialization of Baltimore's economy and the draw of suburban locations as centers of employment and industry. Some scholars point to the success of EPCRA for improving transparency of how toxic substances are used and released, providing an incentive for companies to find alternatives or reduce emissions (Fung & O'Rourke, 2000). The right to know about toxic emissions provides data for groups to shame polluting industry, and some companies, especially early in the TRI program, saw their stock prices decline with the publication of information about their toxic releases (Hamilton, 2005).

The news on overall trends of toxic releases in Baltimore is mixed. Despite the decline in number of TRI facilities in Baltimore, reported releases of toxins were greater in the 2000s than the 1990s, increasing from 86 to 222 million pounds. However, when taking into account the toxicity and fate of releases (using the EPA's Risk Screening Environmental Indicators) the trend has been negative, with a high score of 27 million in 1987 to 783,000 in 2007.

As the patterns and magnitude of HDI have shifted over time, who has been burdened most? The results show a general transition

Table 1
Selected regression model coefficients for 1960–2010. Hazards Density Index (HDI) is dependent variable.

	1960	1970	1980	1990	2000	2010
R-squared	0.37	0.10	0.15	0.17	0.13	0.45
% Black	−0.01565**	−0.00224	−0.01195**	−0.01065*	−0.00906*	−0.00521**
% College educated	−0.07650*	0.01327	−0.00203	−0.02201	0.00491	−0.01143**
% Renters	0.02525**	−0.00059	0.01163**	0.00233	0.00111	0.00084
Median family income ($10,000s)			−0.00671**	0.0046	−0.00299	−0.00005**

* $p < 0.05$.
** $p < 0.01$.

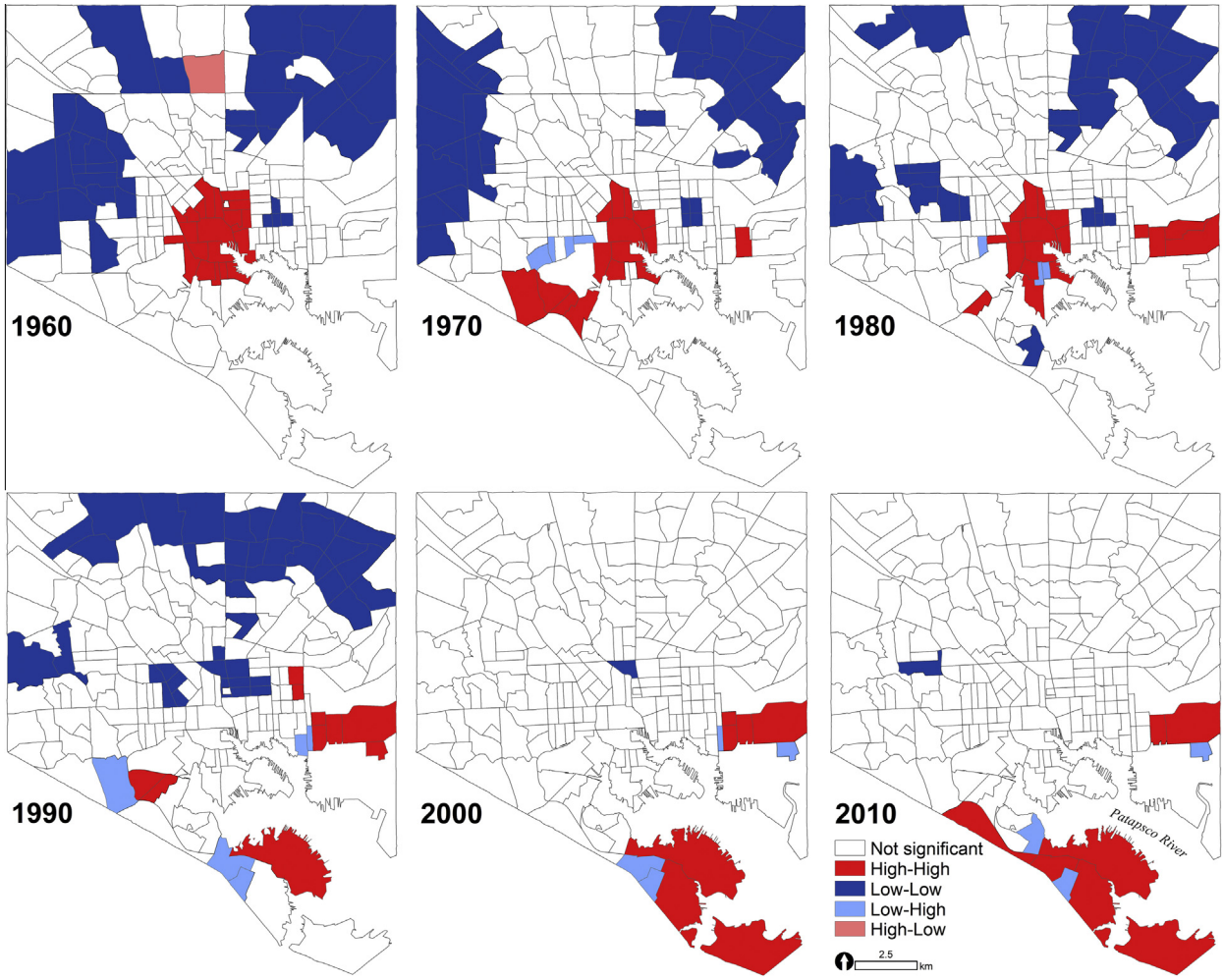

Fig. 2. Significant clusters of spatial autocorrelation in Baltimore, 1960–2010.

from an association between density of polluting facility and wealth to one of race and ethnicity, while educational attainment is significant throughout the 60-year time period. As expected, the HDI is low in high socioeconomic status neighborhoods, but the demographic relationships shift over time. Family income is significantly and negatively correlated with HDI score in 1960 and 1970, and again in 1990. The correlations between race/ethnicity and HDI change in 1970; from 1980 to 2010, % white is positively and significantly correlated with HDI while % black is the opposite. Percent Hispanic joins % white as positively and significantly correlated with HDI in 2000 and 2010, although overall population of Hispanics is only 4% of the total population in Baltimore. Low educational attainment is positively correlated with HDI throughout the 60-year period and significant for the last 50 years while neighborhoods with a high percentage of college graduates enjoyed low HDI scores for the entire period (Fig. 3). Housing tenure is not as strongly associated with HDI as anticipated. However, in 1960 percent renters is a significant predictor of high HDI scores while in 2000 percent owner-occupied homes is unexpectedly a positive predictor of HDI. The two key findings from the bivariate analyses are that (i) neighborhoods with a higher percentage of white residents have had higher HDI scores than African–American neighborhoods for the last 40 years; and that (ii) neighborhoods with low educational attainment have consistently been burdened with a high density of polluting industries over the last 60 years (Table 2).

Associations between socio-economic variables and HDI are not as clear using the regression models compared to the bivariate analyses. Only the 1960 and 2010 models are significantly robust enough for consideration. In 2010, we see an expected negative and significant association between density of polluting facilities and median family income and percent with a college degree. Similar to other findings for Baltimore, we also reveal a negative relationship with percent black or African American and HDI. Some results for the 1960 model, however, are unexpected. Percent non-white (meaning effectively for this period black or African American) is negatively associated with HDI even though the bivariate analysis shows a positive correlation. While the negative association between percent with a college degree and HDI is expected, the model also shows the same sign for percent with a high school diploma and percent with an 8th grade education. Percent of families in the second highest income category ($15–25 K/year) is negatively associated with HDI as one would expect, but the same holds true for the second lowest family income category ($50–10 K/year). Percentage of renters in 1960 is positively associated with the density of polluting facilities, which aligns with some other environmental justice analyses, as renters may possess less political power than homeowners to deflect unwanted land uses (Grineski, Bolin, & Boone, 2007).

The weakness of the models for 1970 through 2000 suggest that other variables are missing that help to explain the density of polluting industries in Baltimore. Indeed, the purpose of this analysis is not to predict land use but to undertake an environmental justice inquiry that asks if some groups are more burdened than others by environmental disamenities. Predictions of land use would

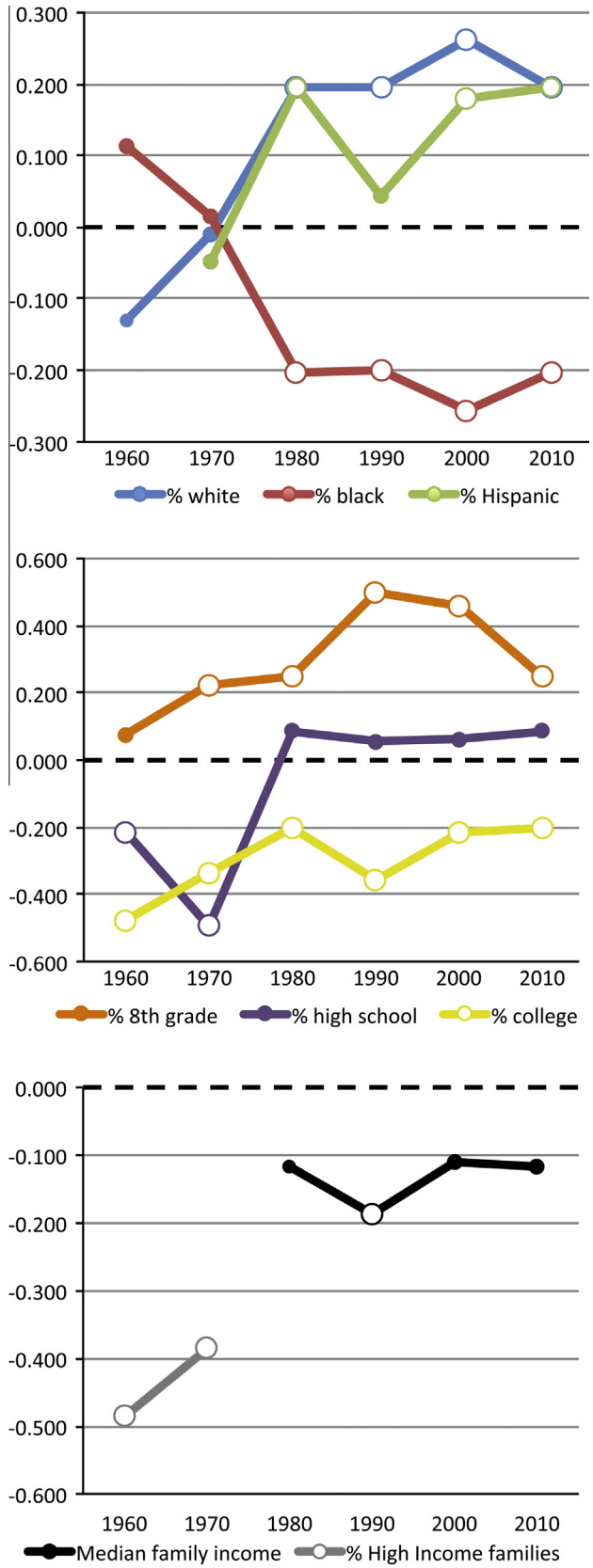

Fig. 3. Correlation coefficients for socioeconomic variables and HDI in Baltimore, 1960–2010. White circles are correlation coefficients that are significant at $p < 0.01$.

take into account many other variables—such as land rents, transportation infrastructure, raw materials costs, market accessibility, zoning and other regulations—that are well established in industrial location theory and regional science as being important determinants. It is possible that more robust land use models that control for industrial location variables might reveal differences in burdens between socioeconomic groups. However, this approach faces some formidable hurdles given that such variables as land rents are imbued with social values, including racism, that drive pricing beyond physical characteristics, scarcity, or location of the land (Pulido, 2000). The same holds true for regulatory structures, such as zoning or transportation planning, that constrain or encourage industrial location (Maantay, 2002). Separating or controlling for social values—including bigotry and prejudice—that are bound up in such seemingly benign things as land rents is a messy business but critically important for exploring causes of environmental injustice.

A second possibility for the weak models is that within the time-series perspective, we are faced with a longer-term structural break period in terms of explanatory power of the standard variables. Clearly the social and built landscape has changed over the 60-year time period. The patterns of polluting industry show significant shifts from the core of Baltimore to the periphery. While the city remained racially segregated throughout the period, in general African–American neighborhoods expanded from smaller concentrations to the east and west of downtown, radiating to the northwest and northeast as well as expanding to the southern fringes of the city. Neighborhoods that remained primarily populated with white residents shrank in number over this period, but included the longstanding industrial districts in Canton to the east and in and around Curtis Bay to the south. During these transitions, and possibility because of the dynamic changes, the models that incorporate race and ethnicity, income, housing tenure, and education proved relatively weak, even though many of the bivariate relationships are quite strong and significant.

Sustainability and environmental justice

This study shows that the burden of pollution has been spread unevenly in Baltimore for a long time. One mechanism for addressing environmental justice concerns is sustainability planning and implementation. Equity is a core principle of sustainability (Vucetich & Nelson, 2010). Although equity for future generations is emphasized more in conceptualizations of sustainability than equity for present populations, environmental justice can and should contribute to sustainability plans and goals (Agyeman, Bullard, & Evans, 2003; Boone, 2010).

In 2009, the Baltimore City Council approved the *Baltimore City Sustainability Plan*. It includes 29 goals within the 7 key themes of cleanliness, pollution prevention, resource conservation, greening, transportation, education & awareness, and green economy. Some of the goals have specific metrics or objectives, such as doubling tree canopy cover by 2037 or reducing the city's energy use by 15% by 2015, while others are aspirational, such as improving public transit services. All of the goals are tied to specific strategies. For instance, one strategy for improving public transit is to implement transit signal priority systems to increase speeds and on-time performance of buses.

Transportation is the only theme in the plan where equity is addressed explicitly. The fourth goal of the transportation theme is to "measure and improve the equity of transportation" (City of Baltimore, 2009, p. 93). Strategies include measuring disparities of transportation costs relative to income by neighborhoods, the current quality of transit service in neighborhoods with low vehicle ownership, and exploring programs to improve car-sharing, walkability, and other transportation alternatives to reduce inequities.

On the issue of pollution prevention, germane to this paper, one of the goals is to "reduce risk from hazardous materials" but there is no mention of the uneven pollution burdens by neighborhood

Table 2
Significant characteristics of census tracts with high and low Hazards Density Index (HDI) scores from 1960 to 2010.

Year	High HDI	Low HDI
1960	Lower income, renters	Higher income, high school and college educated adults
1970	Lower income, 8th grade education	Higher income, high school and college educated adults
1980	Lower income, 8th grade education	Higher income, high school and college educated adults, owner-occupied houses
1990	White, 8th grade education, lower income	African American, college educated, higher income
2000	White, Hispanic, 8th grade education, owner-occupied houses	African American, college educated, renters
2010	White, Hispanic, 8th grade education	African American, college educated

(City of Baltimore, 2009, p. 50). However, the plan does recognize that asthma rates are highest for children in "lower socioeconomic areas" (City of Baltimore, 2009, p. 52). Environmental justice is raised in the section on minimizing production of waste, specifically that landfills are "a serious environmental justice issue because...most are placed in or near lower income communities" (City of Baltimore, 2009, p. 63). However, there are no references to inequities by race or ethnicity even though these are fundamental elements of environmental justice inquiries. Indeed, the plan includes a definition of environmental justice in its glossary that makes reference to "the fair treatment of people of all races, cultures, incomes, and educational levels" and that fairness means "no population should be forced to shoulder a disproportionate share of exposure to the negative effects of pollution due to lack of political or economic strength" (City of Baltimore, 2009, p. 127). Clearly, race and ethnicity can be sensitive subjects, especially in cities like Baltimore that have a long history of racial injustice (McDougall, 1993). Rather than focus on inequities by race or ethnicity, the report focuses on the overall benefit that can accrue from efforts to reduce pollutants. "All who live, work, and visit in Baltimore", the plans states, "would benefit from a concerted effort to reduce the presence of hazardous materials in our environment" (City of Baltimore, 2009, p. 50). Improving lives of all Baltimoreans and visitors is a laudable goal. However, a sustainability plan guided by justice principles would commit to targeting efforts first at populations and neighborhoods that have had to bear the brunt of pollution over the last 60 years, especially vulnerable populations with low educational attainment.

It is important to note that environmental justice is as much about fairness of process as outcome (Boone, 2008a, 2008b; Young, 1990). While Baltimore's plan is not very explicit on environmental justice as an outcome, the process of creating the sustainability plan was inclusive. The Baltimore Office of Sustainability and the Commission on Sustainability developed the plan with an emphasis on public engagement, providing multiple opportunities for community priorities to be heard. In addition to seeking input from city agency personnel and sustainability experts, the public were engaged through community meetings, a youth forum, providing feedback to working groups, and a final sustainability forum.

Conclusion

Environmental inequity is a persistent phenomenon in Baltimore. From 1960 to 2010, the density of polluting facilities has remained high in neighborhoods with low educational attainment. The multivariate regressions for 2010 show a negative relationship between density of polluting industry and the percent of residents with a college degree but the relationship with low educational attainment is not significant. The regression models for 1960 also show a negative and significant relationship between HDI and college education residents but curiously we see the same sign and significant result for all levels of education. In 1960, 1970, and 1990 the density of polluting industry was significantly and negatively correlated with income. The 2010 regression model also shows a negative and significant relationship between income and HDI but the 1960 model shows the same for both a lower and higher income category.

For the last 40 years, the density of polluting facilities has been higher in white than black neighborhoods. The 2010 regression model confirms a strong negative relationship between percent black or African American and HDI. This analysis supports earlier studies on Baltimore that show that percent white is a key variable in explaining the presence of toxic industry (Boone, 2002, 2008a, 2008b; Downey, 2007). However, using the Hazards Density Index, this study reveals that educational attainment is a significant correlate and explanatory variable for the density of polluting facilities in Baltimore neighborhoods. The persistent association of polluting facilities and low educational attainment is troubling given that education is an important resource for comprehending and reacting to risk (Polsky, Neff, & Yarnal, 2007).

Sustainability plans offer an opportunity for municipalities to address inequities in a comprehensive, systematic manner. Baltimore's sustainability plan acknowledges environmental justice as a sustainability concern but does not explicitly address present-day or long standing inequities of environmental burdens by neighborhood or demographics. Creating a sustainable Baltimore has the potential to improve the lives of all Baltimoreans, but ameliorating enduring inequities should be a priority if the justice principles of sustainability are taken seriously. Sustainability is neither credible nor operational without specific attention to justice, including empirical bases of understanding distributive justice such as those offered in this study.

Acknowledgements

Research for this article was supported through awards from the National Science Foundation Long-Term Ecological Research Program (DEB-1027188) and the National Science Foundation Human and Social Dynamics Program (SBE-HSD 0624159).

References

Agyeman, J., Bullard, R. D., & Evans, B. (2003). *Just sustainabilities: Development in an unequal world*. Cambridge: The MIT Press.
Andra, S. S., Sarkar, D., Datta, R., & Saminathan, S. (2006). Lead in soils in paint contaminated residential sites at San Antonio, Texas, and Baltimore, Maryland. *Bulletin of Environmental Contamination and Toxicology, 77*(5), 643–650.
Anselin, L. (1995). Local Indicators of Spatial Association – LISA. *Geographical Analysis, 27*, 93–116.
Baltimore Regional Planning Council. (1958). The Baltimore region: a look at the future–summary of technical reports nos. 1–4. *Maryland State Planning Commission*, Report no. 1.
Bolin, B., Nelson, A., Hackett, E. J., Pijawka, K. D., Scott, C., Sicotte, D., Sadalla, E. K., Matran, E., & O'Donnell, M. (2002). The ecology of technological risk in a Sunbelt city. *Environment and Planning A, 34*(2), 317–339.
Boone, C. G. (2002). An assessment and explanation of environmental inequity in Baltimore. *Urban Geography, 23*(6), 581–595.
Boone, C. G. (2008a). Improving resolution of census data in metropolitan areas using a dasymetric approach: Applications for the Baltimore Ecosystem Study. *Cities and the Environment* 1, 1: article 3. http://digitalcommons.lmu.edu/cate/vol1/iss1/3.
Boone, C. G. (2008b). Environmental justice as process and new avenues for research. *Environmental Justice, 1*(3), 149–154.
Boone, C. G. (2010). Environmental justice, sustainability and vulnerability. *International Journal of Urban Sustainable Development, 2*(1–2), 135–140.
Bowen, W. M. (2002). An analytical review of environmental justice research: What do we really know? *Environmental Management, 29*(1), 3–15.

Bowen, W. M., Salling, M. J., Haynes, K. E., & Cyran, E. J. (1995). Toward environmental justice: Spatial equity in Ohio and Cleveland. *Annals of the Association of American Geographers, 85*(4), 641–663.

Brulle, R. J., David, N., & Pellow, D. N. (2006). Environmental justice: Human health and environmental inequalities. *Annual Review of Public Health, 27*(102), 103–124.

Buckley, G. L., Boone, C. G. (2011). To promote the material and moral welfare of the community: Neighborhood Improvement Associations in Baltimore, Maryland, 1900–1945. In Rodger, R., Massard-Guilbaud, G. (Eds.). *Environmental and Social Justice in the City: Historical Perspectives*. Cambridge: White Horse Press, pp. 43–65.

Bullard, R. D. (1990). *Dumping in dixie: Race, class and environmental quality*. Westview: Boulder.

Bullard, R. D. (1996). Environmental justice: It's more than waste facility siting. *Social Science Quarterly, 77*, 493–499.

City of Baltimore (2005). *The Baltimore Sustainability Plan*. Available online: http://www.baltimorecity.gov/Portals/0/agencies/planning/sustainability/public%20downloads/051509_BCS-001SustainabilityReport.pdf.

Downey, L. (2005). The unintended significance of race: Environmental racial inequality in Detroit. *Social Forces, 83*(3), 971–1007.

Downey, L. (2007). US metropolitan-area variation in environmental inequality outcomes. *Urban Studies, 44*(5), 953–977.

Downey, L., & Hawkins, B. (2008). Race, income, and environmental inequality in the United States. *Sociological Perspectives, 51*(4), 759–781.

Fung, A., & O'Rourke, D. (2000). Reinventing environmental regulation from the grassroots up: Explaining and expanding the success of the toxics release inventory. *Environmental Management, 25*(2), 115–127.

Gandy, M. (2002). *Concrete and clay: Reworking nature in New York City*. Cambridge: MIT Press.

Grineski, S., Bolin, B., & Boone, C. G. (2007). Criteria air pollution and marginalized populations: Environmental inequity in Metropolitan Phoenix, Arizona, USA. *Social Science Quarterly, 88*(2), 535–554.

Hamilton, J. T. (2005). *Regulation through revelation: The origin, politics, and impacts of the Toxics Release Inventory Program*. New York: Cambridge University Press.

Hynes, H. P., & Lopez, R. (2007). Cumulative risk and a call for action in environmental justice communities. *Journal of Health Disparities Research and Practice, 1*(2), 29–57.

Krieg, E. J. (2005). Race and environmental justice in Buffalo, NY: A ZIP code and historical analysis of ecological hazards. *Society & Natural Resources, 18*, 199–213.

Landry, S. M., & Chakraborty, J. (2009). Street trees and equity: Evaluating the spatial distribution of an urban amenity. *Environment and Planning A, 41*, 2651–2670.

Lord, C. L., & Norquist, K. N. (2010). Cities as emergent systems: Race as a rule in organized complexity. *Environmental Law, 40*, 551–597.

Maantay, J. (2002). Zoning law, health, and environmental justice: What's the connection. *Journal of Law Medicine & Ethics, 30*, 572–593.

Maantay, J., & Maroko, M. (2009). Mapping urban risk: Flood hazards, race, and environmental justice in New York. *Applied Geography, 29*(1), 111–124.

McDougall, H. A. (1993). *Black Baltimore: A new theory of community*. Philadelphia: Temple University Press.

Minnesota Population Center (2011). *National Historical Geographic Information System*: Version 2.0. Minneapolis, MN: University of Minnesota. <http://www.nhgis.org>.

Mohai, P., & Saha, R. (2007). Racial inequality in the distribution of hazardous waste: A national-level reassessment. *Social Problems, 54*(3), 343–370.

Olson, S. H. (1997). *Baltimore: The building of an American city*. Baltimore: The Johns Hopkins University Press.

Orser, W. E. (1994). *Blockbusting in Baltimore: The Edmondson village story*. Lexington: University of Kentucky Press.

Osiecki, K. M., Seijeoung, K., Ifeanyi, B. C., & Calhoun, E. A. (2013). Utilizing exploratory spatial data analysis to examine health and environmental disparities in disadvantaged neighborhoods. *Environmental Justice, 6*(3), 81–87.

Polsky, C., Neff, R., & Yarnal, B. (2007). Building comparable global change vulnerability assessments: The vulnerability scoping diagram. *Global Environmental Change, 17*(3–4), 472–485.

Power, G. (1983). Apartheid Baltimore style: The residential segregation ordinances of 1910–1913. *Maryland Law Review, 42*, 289–328.

Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographers, 90*(1), 12–40.

Romley, J. A., Cohen, D., Ringel, J., & Sturm, R. (2007). Alcohol and environmental justice: The density of liquor stores and bars in urban neighborhoods in the United States. *Journal of Studies on Alcohol, 68*(1), 48–55.

Schlosberg, D. (2007). *Defining environmental justice: Theories, movements, and nature*. Oxford: Oxford University Press.

Schwarz, K., Pickett, S. T. A., Lathrop, R. G., Weathers, K. C., Pouyat, R. V., & Cadenasso, M. L. (2012). The effects of the urban built environment on the spatial distribution of lead in residential soils. *Environmental Pollution, 163*, 32–39.

Sobotta, R. R., Campbell, H. E., & Owens, B. J. (2007). Aviation noise and environmental justice: The barrio barrier. *Journal of Regional Science, 47*(1), 125–154.

Vucetich, J. A., & Nelson, M. P. (2010). Sustainability: Virtuous or Vulgar? *BioScience, 60*(7), 539–544.

Young, I. M. (1990). *Justice and the politics of difference*. Princeton, NJ: Princeton University Press.

Zhou, X., Boone, C. G., Shock, E. (2012). Soil lead distribution and environmental justice in the Phoenix metropolitan region. *Environmental Justice*.