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Application of Space-Time Scan Statistics to Describe Geographic and Temporal Clustering of Visible Drug Activity

Sabriya L. Linton, Jacky M. Jennings, Carl A. Latkin, Marisela B. Gomez, and Shruti H. Mehta

ABSTRACT *Knowledge of the geographic and temporal clustering of drug activity can inform where health and social services are needed and can provide insight on the potential impact of local policies on drug activity. This ecologic study assessed the spatial and temporal distribution of drug activity in Baltimore, Maryland, prior to and following the implementation of a large urban redevelopment project in East Baltimore, which began in 2003. Drug activity was measured by narcotic calls for service at the neighborhood level. A space-time scan statistic approach was used to identify statistically significant clusters of narcotic calls for service across space and time, using a discrete Poisson model. After adjusting for economic deprivation and housing vacancy, clusters of narcotic calls for service were identified among neighborhoods located in Southeast, Northeast, Northwest, and West Baltimore from 2001 to 2010. Clusters of narcotic calls for service were identified among neighborhoods located in East Baltimore from 2001 to 2003, indicating a decrease in narcotic calls thereafter. A large proportion of clusters occurred among neighborhoods located in North and Northeast Baltimore after 2003, which indicated a potential spike during this time frame. These findings suggest potential displacement of drug activity coinciding with the initiation of urban redevelopment in East Baltimore. Space-time scan statistics should be used in future research to describe the potential implications of local policies on drug activity.*

KEYWORDS *Drug activity, Space-time scan statistics, GIS, Urban redevelopment*

INTRODUCTION

Illicit drug activity, including the sale and use of illicit drugs, has been deemed a significant marker of social disorder, as evidenced by the unprecedented amount of investment in drug-related law enforcement in the United States (US) since the 1970s.[1] Drug-related law enforcement has been associated with negative health outcomes[2,3,4] and has been scrutinized for being disproportionately targeted in low-income minority communities.[1] Inequities in the targeting of drug-related law enforcement have partly been attributed to the extent to which drug market activity is visible.[1]

Linton is with the Department of Behavioral Sciences and Health Education, Rollins School of Public Health at Emory University, 1518 Clifton Road NE, GCR 527, Atlanta, GA 30322, USA; Linton, Jennings, and Mehta are with the Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA; Jennings is with the Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, MD, USA; Latkin is with the Department of Health, Behavior and Society, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA; Gomez is with the Social Health Concepts and Practice, Baltimore, MD, USA.

Correspondence: Sabriya L. Linton, Department of Behavioral Sciences and Health Education, Rollins School of Public Health at Emory University, 1518 Clifton Road NE, GCR 527, Atlanta, GA 30322, USA. (E-mail: sabriya.linton@emory.edu)

In contrast to person-specific drug markets that are largely sustained through social networks, hidden, and may not be geographically bounded,[5] visible drug markets are characterized by place, facilitating accessibility, drug tourism (e.g., traffic of non-residents to a given neighborhood to purchase drugs), and profit.[5–7] Visible drug market activity bears negative implications upon residents living in proximity by glorifying risk behaviors to youth, stigmatizing and marginalizing communities,[5] and serving as a potential determinant of violence,[8] sexually transmitted diseases,[9] and drug abuse.[10,11]

Baltimore City is among several US cities where visible drug market activity occurs in some communities and has been associated with economic deprivation, poor housing stock, and social disorder.[12–14] Visible drug market activity has been reported as being concentrated in East and West Baltimore,[15] but these regions greatly influence illicit drug use beyond their borders. Heroin and cocaine are the primary drugs of abuse and account for the largest percentage of intoxication-related deaths in Baltimore City and adjacent counties.[16]

Visible drug markets where cocaine and heroin are largely sold, as in Baltimore City, have been reported to exist in communities where a large proportion of people with a history of drug addiction reside.[17] Additionally, due to the concentration of poor housing stock in visible drug market areas, drug use and discarded paraphernalia may be visible in these areas.[18,19]

Visible drug markets are also likely to be operated by multiple drug dealers who provide small quantities of drugs at low cost within close proximity of each other,[7,17] and illicit drug users have been reported to serve many roles in visible drug markets including touting drugs, providing street security, guarding drug stashes, and dealing drugs.[19,20] These circumstances coupled with an increased likelihood that residents will be offered illicit drugs in visible drug market areas, regardless of whether they solicit drugs or not,[21] facilitates drug availability among inner city drug users.

Drug availability has important implications for cessation and recovery, especially among low-income residents who lack mobility, as research has suggested that residing in an area with high drug activity is associated with a lower likelihood of cessation among people who abuse drugs.[10] Perceived opportunities to use illicit drugs have been associated with urges to use illicit drugs[22] and social norms supportive of use.[23] Through such pathways, visible drug activity may encourage illicit drug use. Additionally, the purveyance of social disorder, physical disorder, economic deprivation, and increased likelihood of incarceration in areas with high visible drug activity may further lead to poor drug-related sequelae.[24–27]

Several Baltimore City neighborhoods have been targeted for urban redevelopment in an effort to ameliorate the physical conditions that support visible drug activity. The largest urban redevelopment project in Baltimore since development of the Baltimore Harbor,[28] the East Baltimore Development Initiative, is currently underway in an 88-acre section of East Baltimore. Spearheaded by a non-profit, East Baltimore Development Inc. (EBDI), the project footprint encompasses an area that was considered to be blighted and economically deprived prior to redevelopment.[29, 30] Since the EBDI project was announced in 2003, extensive demolition and construction have occurred, and approximately 750 households were relocated during 2004–2006 and 2007–2009.[29,30] The majority of households were relocated to other areas of East Baltimore and Northeast Baltimore during the first phase of the project.[31]

Local officials have reported that the EBDI project has partly led to a reduction of crime in East Baltimore as the foothold of a major gang involved in drug trafficking was eliminated.[32] However, a spike in violent crime in Northeast Baltimore within the same time frame[33] suggests that crime may have been displaced as a result.[32]

The displacement of crime due to urban redevelopment has been suggested in prior research. For example, an evaluation of public housing demolitions in Atlanta, Georgia, as part of the Housing Opportunities for People Everywhere initiative, demonstrated that while public housing demolition was associated with overall crime reductions in the city, the decline was greater in areas where public housing was demolished and lower in areas where public housing residents relocated.[34] Additionally, our prior qualitative research,[35] and ethnographic studies conducted in Brooklyn, New York City,[36] and Denver, Colorado,[6] have reported an association between urban redevelopment and the displacement of drug activity.

Such findings provide impetus for exploring whether the geographies of concentrated visible drug activity in Baltimore may have changed following the implementation of the EBDI redevelopment project. We used space-time scan statistics to assess geographic and temporal clusters of visible drug activity and determined the extent to which housing vacancy and economic deprivation were associated with the spatial distribution of visible drug activity over time.

METHODS

Data Collection

Visible drug activity was measured using data on emergency and non-emergency narcotic calls for service reported to the Baltimore City Police Department via 911 and 311 dispatch centers by an on-duty police officer or resident. Annual data on narcotic calls for service were compiled by the Baltimore Neighborhoods Indicator Alliance (BNIA) and made available to the authors from 2000 to 2010. Narcotic calls for service can reflect a wide range of offenses related to narcotics, including but not limited to the sale and possession of illicit drugs, discarded paraphernalia, and drug-related overdose. Narcotic calls for service have been used to measure drug activity in prior research.[11]

Narcotic calls for service were aggregated to neighborhood statistical areas (NSAs) due to the interpretability of NSAs and relevance to policy. The Baltimore City Department of Planning defined NSA boundaries in the 1970s using census data and resident input. The boundaries have since been updated with each decennial census. NSA boundaries are generally larger than census block groups and smaller than census tracts. They may reflect natural boundaries (e.g., lakes, parks) and other non-residential areas (e.g., cemeteries, stadiums). The 2000 boundaries are used in this study, and residential NSAs, which account for 88 % (239/271) of all neighborhoods, were considered in the analysis given that calls for services would systematically be null or few in non-residential areas.

Economic deprivation and percentage of housing vacancy at the NSA level were included as covariates in this analysis due to their relationships with drug activity. Neighborhood economic deprivation was measured by an index of the following items from the 2000 US census: percent of individuals employed in professional occupations (reverse coded), percent of crowded households, percent of households in poverty, percent of female-headed households with dependent children <18 years old, percent of households on public assistance, percent of households earning low income, percent of individuals ≥ 25 years old with less than a high school education, and percent of unemployed individuals ≥ 16 years old. These items have been included in other indices used and validated in Baltimore.[27,37] The items were standardized by z-score according to the distribution of narcotic calls for service across Baltimore City neighborhoods, weighted by factor loadings, and summed to create an index. Economic deprivation was categorized into quartiles based on the distribution of the economic deprivation index across Baltimore City neighborhoods.

Annual data on housing vacancy, defined as the percentage of abandoned homes out of all residential properties in a given year, is measured by the Baltimore City Department of Housing. A linear relationship between housing vacancy and narcotic calls for service was observed. Therefore, housing vacancy was analyzed as a continuous variable.

ANALYSIS

Descriptive Analysis

The geographic distribution of narcotic calls for service, economic deprivation in 2000, and housing vacancy in 2001 were mapped using ArcMap version 10 (ESRI, Redlands, CA) to describe and compare the geographic distribution of these attributes during the first year of follow-up.

Space-Time Cluster Detection

SaTScan cluster detection software was used to identify where and when narcotic calls for service occurred at higher levels than expected by chance (i.e., space-time clusters) using a discrete Poisson model.[38] SaTScan cluster detection has been published widely in public health literature, but, the utilization of space-time scan statistics in epidemiologic research on drug abuse has been limited.[39–41] SaTScan has been reported to demonstrate more precision in identifying outliers (e.g., local clusters that have small geographic or population sizes) as compared to other methods.[42] Briefly, the SaTScan statistical technique detects spatial clusters of areal units by imposing an infinite number of overlapping circular (or elliptical) scanning windows of various sizes across a defined geographic area.[43] Temporal clusters can simultaneously be evaluated using a space-time scan statistic, which includes an infinite number of overlapping cylindrical windows that are defined by a base that includes a spatial scan statistic and height that corresponds to a temporal scan statistic.[38] The size of the spatial and temporal windows vary up to a maximum, with the defaults respectively set at 50 % of the total population at risk and 50 % of the period of follow-up. The presence of spatial and temporal clusters of elevated risk is evaluated using a likelihood ratio test that determines whether the observed number of cases exceeds the expected number of cases in each scanning window, based on the total number of cases and population size observed in the entire geographic area over a particular time period. The ratio of observed to expected denotes the risk within the window, and the relative risk compares the risk within the window to the risk outside the window. In the discrete Poisson model, the likelihood ratio test is performed under the null hypothesis of complete spatial and temporal randomness (i.e., the risk inside the window is equal to that outside the window). The window with the maximum likelihood ratio is denoted the "most likely cluster", and secondary clusters are identified and ranked according to their likelihood ratios. The statistical significance of identified clusters is determined using a Monte Carlo approach.

In this study, a retrospective space-time scan statistic was used to identify clusters of narcotic calls across space and time in Baltimore, Maryland. Two analyses were conducted, with the first modeling the geographic and temporal variation in narcotic calls from 2000 to 2010, without adjusting for covariates. The second adjusted for housing vacancy and economic deprivation to determine whether the geographic and temporal variation in narcotic calls was associated with these factors. Because housing vacancy was made available beginning in 2001, adjusted analysis was performed from 2001 to 2010. Adjusted analysis was conducted by first calculating the covariate-adjusted expected number of narcotic calls for service using STATA version 12 (STATACorp., College Station, TX), which were then entered into SaTScan, as similarly performed in prior research.[44]

The maximum size of the scanning spatial window was restricted to 30 % of the total population at risk to better detect outliers[42] and to detect clusters that included neighborhoods with a greater number of observed versus expected cases. Increasing the spatial window to the default maximum size (50 %) resulted in less specificity in identifying such clusters. The spatial window was set to a circular shape, which has been suggested to be optimal when using aggregate data.[45] The size of the temporal window was set to the default (50 %), and purely spatial clusters that occurred during the entire follow-up period were considered, as suggested in prior research.[38]

Statistically significant space-time clusters of narcotic calls for service with $p < 0.05$ were mapped using ArcMap version 10 (ESRI, Redlands, CA).

RESULTS

Descriptive Analysis

In 2000, narcotic calls for service were in the highest quartile in East, Northwest, and West Baltimore (Fig. 1); these areas also experienced the highest economic deprivation and housing vacancy in 2000 and 2001 (Figs. 2 and 3).

Space-Time Cluster Detection

Unadjusted Analysis The space-time scan statistic identified five statistically significant clusters of narcotic calls that occurred during 2000–2010 (Fig. 4 and Table 1). Four of these clusters occurred in areas where economic deprivation and housing vacancy were high at first year of follow-up. The most likely cluster occurred in West Baltimore during 2000–2010 (relative risk (RR) = 3.91, $p < 0.001$). The second cluster occurred in East Baltimore during 2000–2004 (RR = 3.40, $p < 0.001$), which suggests that narcotic calls for service declined in subsequent years. The third cluster occurred in Northwest Baltimore during 2000–2010 (RR = 4.33, $p < 0.001$). Two small clusters located in the Northeast and North Baltimore were identified during 2009 and 2002 (RR = 3.07 ($p < 0.001$); RR = 1.54 ($p < 0.001$)), suggesting that higher narcotic calls for service occurred during these years as compared to other years.

Adjusted Analysis The size, location, and number of statistically significant clusters of narcotic calls changed after adjusting for neighborhood economic deprivation and housing vacancy (Fig. 5 and Table 2). Three statistically significant clusters were found in West Baltimore from 2001 to 2010. Two of these overlapped with the cluster identified in unadjusted analysis and included the most likely cluster that

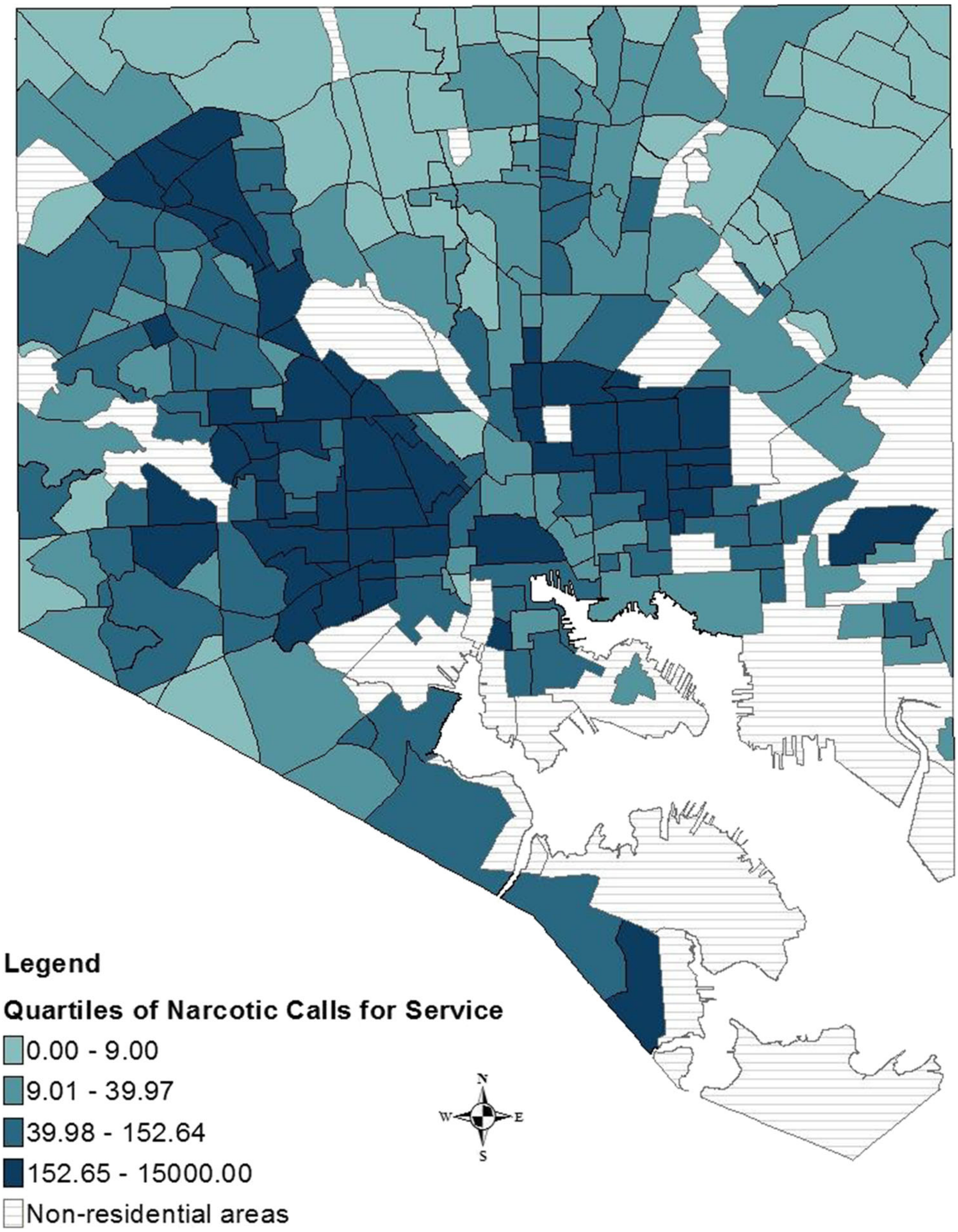

FIG. 1 Spatial distribution of narcotic calls per 1,000 residents across neighborhoods in Baltimore, MD, in 2000.

occurred during 2005–2009 (RR=10.33, $p<0.001$) and a cluster that occurred during 2001–2010 (RR=1.32, $p<0.001$). The third cluster did not overlap with the previous cluster identified in unadjusted analysis and occurred during 2001–2010 (RR=2.13, $p<0.001$).

Similar to unadjusted analysis, a statistically significant cluster of narcotic calls was identified in Northwest Baltimore during 2001–2010 (RR=2.34, $p<0.001$) in adjusted analysis. However, the cluster was larger and included areas that were not included in the cluster identified in unadjusted analysis.

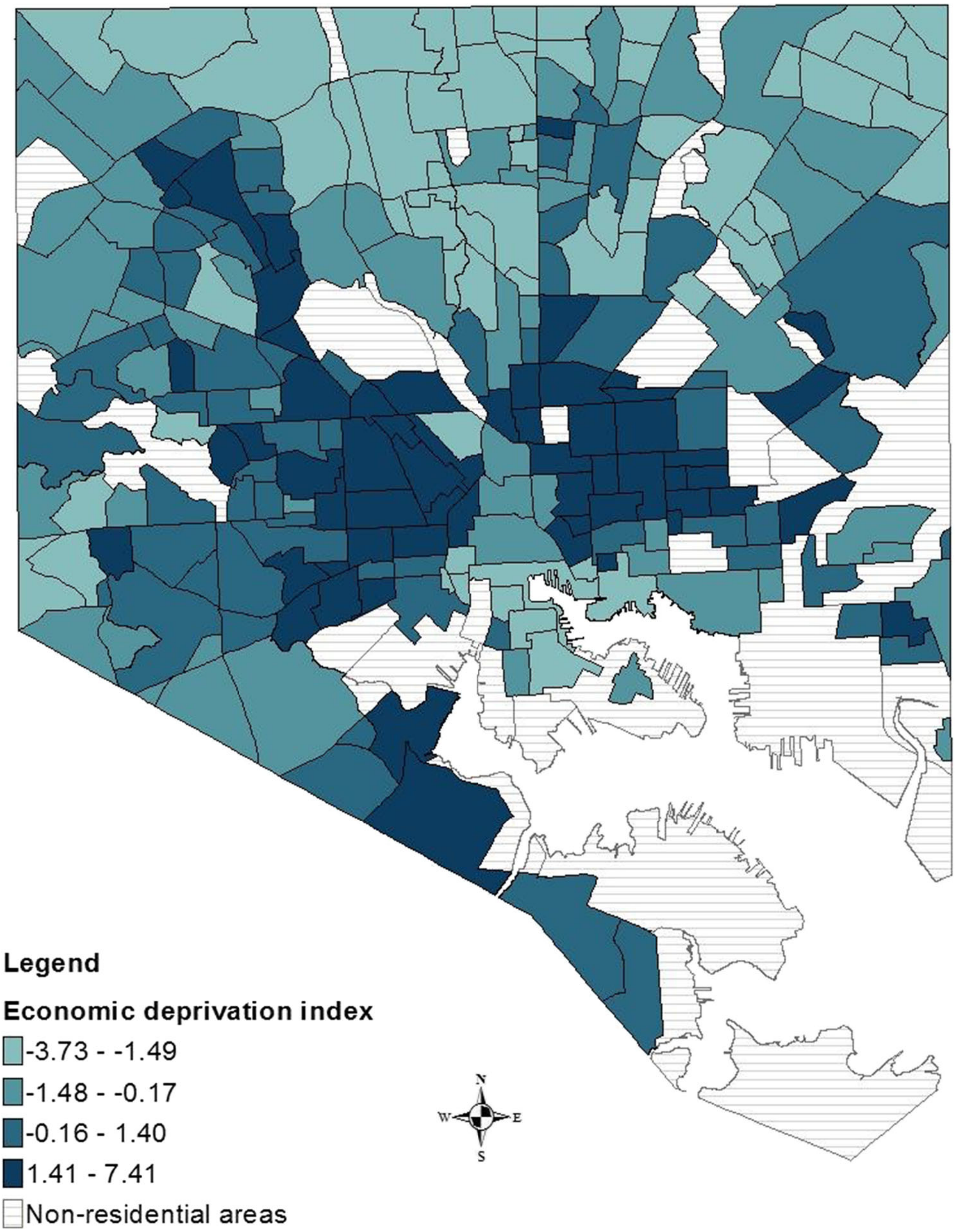

FIG. 2 Spatial distribution of economic deprivation across neighborhoods in Baltimore, MD, in 2000. Economic deprivation was measured by an index constructed using the following eight items from the 2000 US census: percent of individuals employed in professional/managerial occupations (reverse coded), percent of households with crowding, percent of households living in poverty, percent of female-headed households with dependent children <18 years old, percent of households on public assistance, percent of households earning low income, percent of individuals ≥25 years old with less than a high school education, percent of unemployed individuals >16 years old. The map reflects quartiles of economic deprivation based on its distribution across Baltimore City neighborhoods.

Three statistically significant clusters were identified in East Baltimore between 2001 and 2003 that overlapped with the cluster identified in East Baltimore in unadjusted analysis and similarly suggested a potential reduction in narcotic calls for

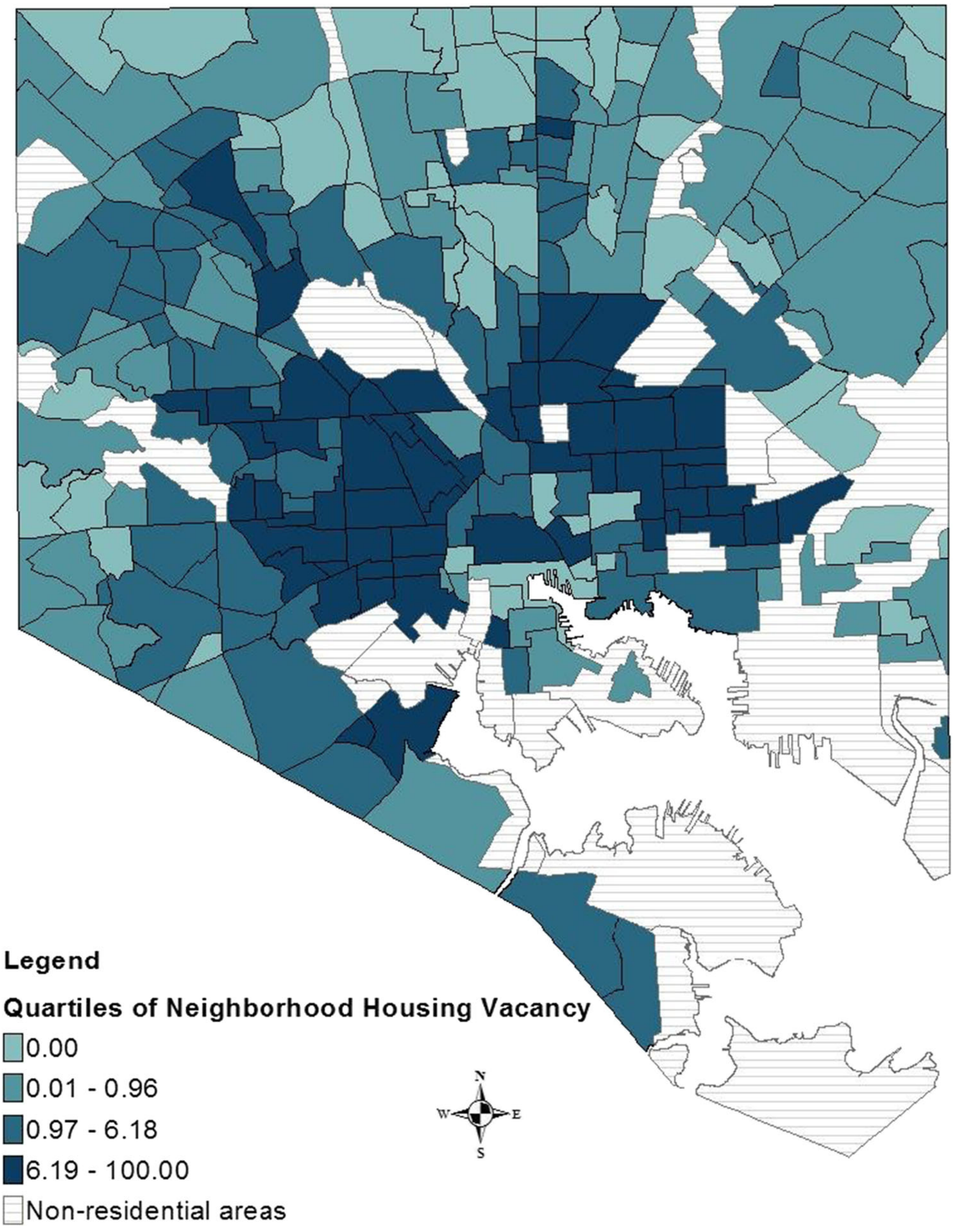

FIG. 3 Spatial distribution of vacant houses per 100 residences across neighborhoods in Baltimore, MD, in 2001. Housing vacancy is measured by the Baltimore City Department of Housing and is defined as the percentage of vacant and abandoned homes out of all residential properties in a given year.

service following 2003. The relative risk of these clusters ranged from 1.33 to 1.59 ($p<0.001$ for all). Eight of the neighborhoods that were included in the cluster identified in unadjusted analysis were not included in the clusters identified in adjusted analysis. Additionally, a statistically significant cluster was identified in Southeast Baltimore during 2001–2010 that was not statistically significant in unadjusted analysis (RR=6.23, $p<0.001$).

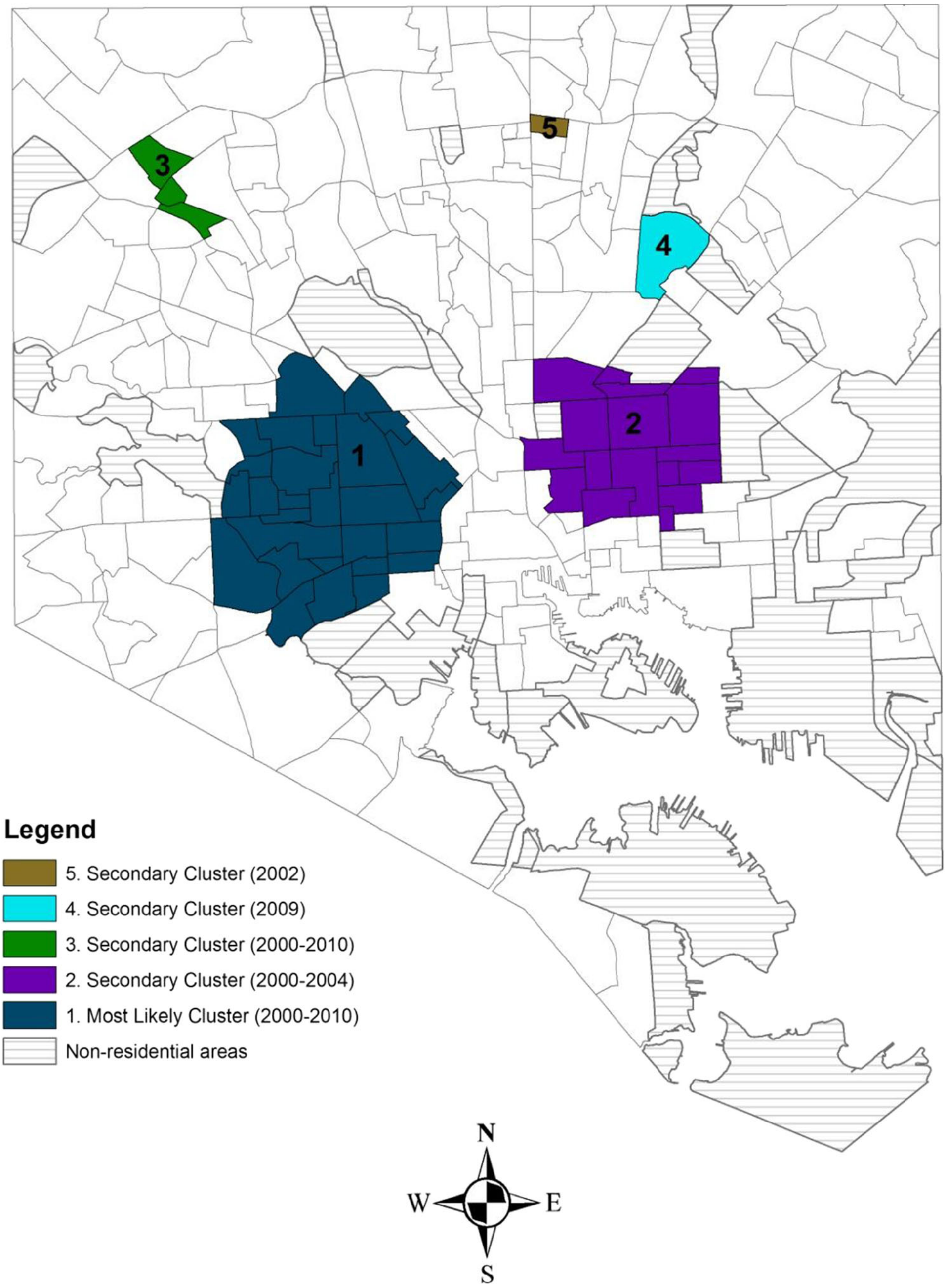

FIG. 4 SaTScan detection of space-time clusters of narcotic calls in Baltimore, MD, 2000 to 2010. Significant clusters are shown. Most likely cluster defines the cluster with the highest maximum likelihood ratio. Secondary clusters are listed in order from highest to lowest maximum likelihood ratio.

The cluster identified in Northeast Baltimore during 2009 in unadjusted analysis remained statistically significant in adjusted analysis (RR=3.80, $p<0.001$); the cluster previously identified in North Baltimore in unadjusted analysis was no longer statistically significant. Ten additional statistically significant clusters were identified

TABLE 1 Analysis of narcotic calls for service in Baltimore, MD, from 2000 to 2010, using space-time statistics

Cluster (region)	Years	No. of neighborhoods in cluster	No. of observed narcotic calls for service	No. of expected narcotic calls for service	Risk[a]	Relative risk[b]	*P* value[c]
1. Most likely cluster (West)	2000–2010	28	102,926.0	35,299.21	2.92	3.91	<0.001
2. Secondary cluster (East)	2000–2004	17	30,723.0	9,745.06	3.15	3.40	<0.001
3. Secondary cluster (Northwest)	2000–2010	3	15,714.0	3,782.06	4.15	4.33	<0.001
4. Secondary cluster (Northeast)	2009	1	351.0	114.52	3.06	3.07	<0.001
5. Secondary cluster (North)	2002	1	176.0	114.52	1.54	1.54	0.007

Most likely cluster defines the cluster with the highest maximum likelihood ratio

[a]Risk is the number of observed narcotic calls for service / number of expected narcotic calls for service in the cluster

[b]Relative risk is the ratio of risk inside cluster compared to risk outside cluster

[c]Significance determined by Monte Carlo simulations

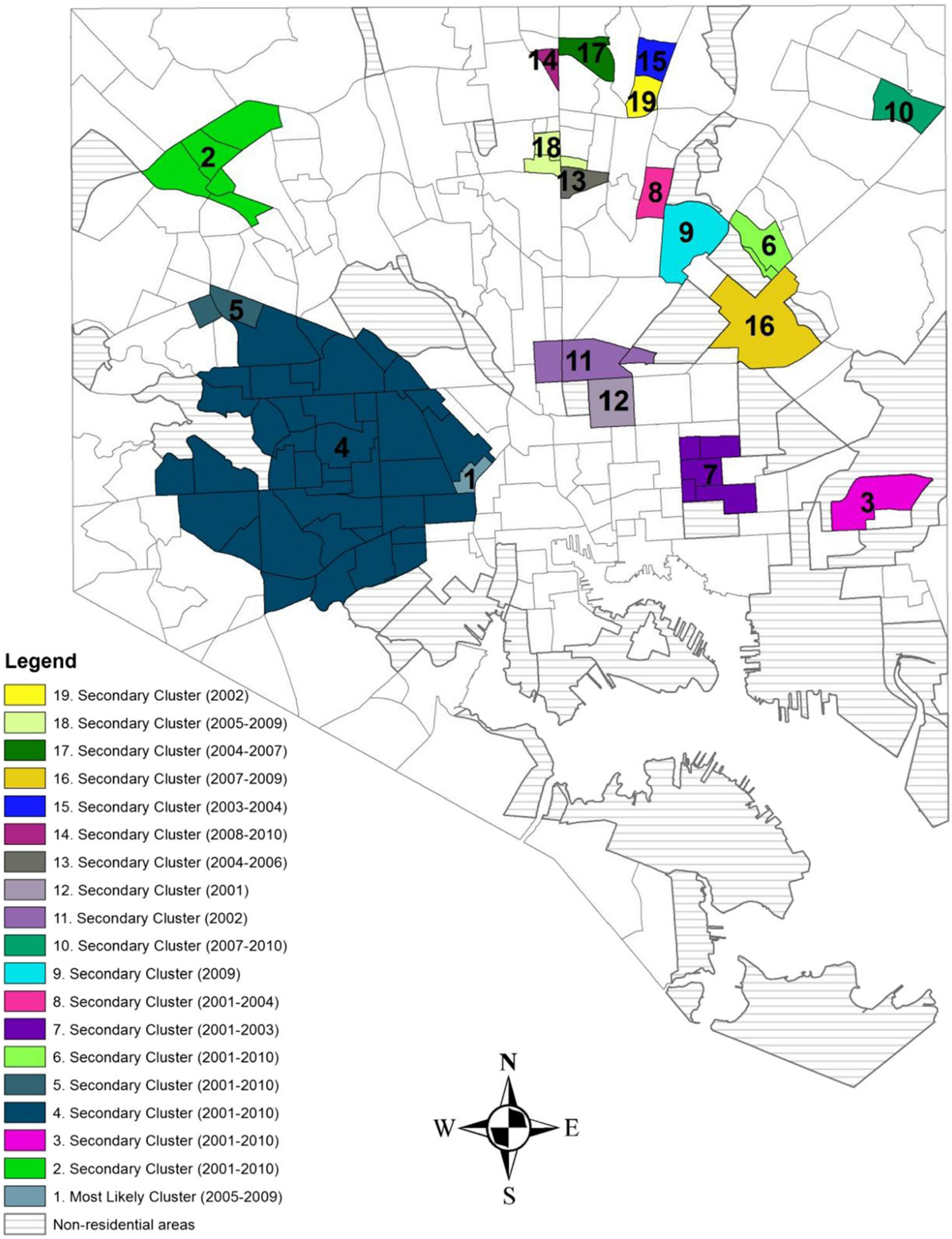

FIG. 5 SaTScan detection of space-time clusters of narcotic calls in Baltimore, MD, 2001 to 2010, adjusted for economic deprivation and housing vacancy. Significant clusters are shown. Most likely cluster defines the cluster with the highest maximum likelihood ratio. Secondary clusters are listed in order from highest to lowest maximum likelihood ratio.

in North and Northeast Baltimore during 2001–2010, which were not statistically significant in unadjusted analysis. The majority of these clusters ($n=7$) occurred intermittently between 2003 and 2010, which suggests a rise in narcotic calls during this time frame. The relative risk of these clusters ranged from 1.27 to 4.25 ($p<0.05$ for all), and several of these clusters occurred in areas where economic deprivation and housing vacancy were low to moderate at the first year of follow-up.

TABLE 2 Analysis of narcotic calls for service in Baltimore, MD, from 2001 to 2010, using space-time statistics and adjusting for neighborhood economic deprivation and housing vacancy

Cluster (region)	Years	No. of neighborhoods in cluster	No. of observed narcotic calls for service	No. of expected narcotic calls for service	Risk[a]	Relative risk[b]	*P* value[c]
1. Most likely cluster (West)	2005–2009	1	8,589	856.12	10.03	10.33	<0.001
2. Secondary cluster (Northwest)	2001–2010	5	18,038	8,009.17	2.25	2.34	<0.001
3. Secondary cluster (Southeast)	2001–2010	1	2,591	418.98	6.18	6.23	<0.001
4. Secondary cluster: (West)	2001–2010	39	93,677	77,622.42	1.21	1.32	<0.001
5. Secondary cluster (West)	2001–2010	2	4,333	2,056.38	2.11	2.13	<0.001
6. Secondary cluster (Northeast)	2001–2010	2	1,808	586.75	3.08	3.10	<0.001
7. Secondary cluster (East)	2001–2003	5	8,322	5,292.71	1.57	1.59	<0.001
8. Secondary cluster (Northeast)	2001–2004	1	292	41.58	7.02	7.03	<0.001
9. Secondary cluster (Northeast)	2009	1	351	92.54	3.79	3.80	<0.001
10. Secondary cluster (Northeast)	2007–2010	1	285	67.19	4.24	4.25	<0.001
11. Secondary cluster (East)	2002	3	1,550	1,168.35	1.33	1.33	<0.001
12. Secondary cluster (East)	2001	1	581	388.81	1.49	1.50	<0.001
13. Secondary cluster (Northeast)	2004–2006	1	334	204.47	1.63	1.63	<0.001
14. Secondary cluster (North)	2008–2010	1	105	50.49	2.08	2.08	<0.001
15. Secondary cluster (Northeast)	2003–2004	1	57	21.27	2.68	2.68	<0.001
16. Secondary cluster (Northeast)	2007–2009	1	214	133.56	1.60	1.60	<0.001
17. Secondary cluster (North)	2004–2007	1	104	52.89	1.97	1.97	<0.001
18. Secondary cluster (North)	2005–2009	3	715	563.56	1.27	1.27	<0.001
19. Secondary cluster (Northeast)	2002	1	63	31.25	2.02	2.02	0.022

Neighborhood economic deprivation was measured by an index constructed using the following eight items from the 2000 US census: percent of individuals employed in professional/managerial occupations (reverse coded), percent of households with crowding, percent of households living in poverty, percent of female-headed households with dependent children <18 years old, per households on public assistance, percent of households earning low income, percent of individuals with less than a high school education, percent of unemployed individuals >16 years old. Most likely, cluster defines the cluster with the highest maximum likelihood ratio

[a]Risk is the number of observed narcotic calls for service / number of expected narcotic calls for service in the cluster

[b]Relative risk is the ratio of risk inside cluster compared to risk outside cluster

[c]Significance determined by Monte Carlo simulations

DISCUSSION

This study describes the geographic and temporal distribution of visible drug activity, as measured by narcotic calls for service, across Baltimore City neighborhoods over the past decade. Visible drug activity was observed at higher levels than expected by chance, and above and beyond the influence of housing and economic conditions among neighborhoods located in Southeast Baltimore, Northeast Baltimore, Northwest Baltimore, and West Baltimore from 2001 to 2010. Following 2003, drug activity appeared to decrease in East Baltimore and increase among several neighborhoods in North and Northeast Baltimore.

The reduction in drug activity in East Baltimore that was observed in this study occurred during a time when initial phases of urban redevelopment were being implemented in East Baltimore, suggesting that revitalization of the area may have played a role. Indeed, prior literature evaluating Crime Prevention Through Environmental Design (CPTED) approaches that incorporate physical revitalization have demonstrated that these approaches can reduce crime.[46,47] Other areas in Baltimore have undergone redevelopment; however, the expansiveness of the EBDI project in East Baltimore and the extent of residential relocation may have altered the context of East Baltimore more than other areas where smaller redevelopment projects have been targeted.

The apparent spike in drug activity among several neighborhoods in North and Northeast Baltimore corresponds with the reduction in East Baltimore, and these trends suggest that drug activity may have been displaced north of East Baltimore due to the EBDI project. The plausibility of this is supported by prior studies, including our prior qualitative research conducted in Baltimore, which have linked drug activity displacement to urban redevelopment,[6,35,36] local media reports,[32] and the geography of residential relocation due to EBDI, which resembles the clustering of drug activity in North and Northeast Baltimore.[31]

The potential for drug activity to be displaced as a result of urban redevelopment suggests that spatial inequities in drug activity may not be resolved entirely by such efforts. In Baltimore, it has been reported that employment opportunities for local residents have not materialized from the EBDI redevelopment project as intended,[35,48] and this may have been a missed opportunity through which redevelopment could reduce drug-related crime overall. Indeed, substance users followed in prior research have reported a willingness to forgo illegal income generation activities if provided with alternative employment.[49] Similarly, greater provision or referral to drug treatment and harm reduction services during the relocation process may be needed, given that residents may continue their use of drugs following relocation.[35,36]

Also important, the potential displacement of visible drug activity may coincide with the displacement of drug-related sequelae, such as HIV and other sexually transmitted infections. For instance, Wallace et al. in prior research demonstrated correlations among planned housing demolition in Bronx, New York City, changes in the geography of people who inject drugs, and the subsequent rise in HIV transmission in other neighborhoods in the borough.[50]

This study, however, does not provide evidence of a causal relationship between the EBDI urban redevelopment project and drug activity displacement. Alternative explanations for the rise of drug activity in North and Northeast Baltimore are lacking. However, causes beyond urban redevelopment may contribute to the reduction of visible drug activity in East Baltimore. For instance, crime reductions in Baltimore, and nationally, have been attributed to stringent law enforcement and incarceration policies.[32,51] However, it would be expected that these circumstances would lead to similar reductions across the entire city of Baltimore. Longitudinal and quasi-experimental studies are needed to assess the potential association between urban redevelopment and displacement of drug activity.

The findings from this study should be interpreted in light of other limitations. There is no gold standard for measuring drug activity. Previous measures of drug activity have relied on self-reported data, systematic observations, and administrative data on drug related arrests and narcotic calls for service. Each has strengths and limitations. Self-reported information can capture residents' experiences with drug activity, but perceptions of neighborhood conditions may vary based on individual characteristics.[52] Additionally, if self-reported data is aggregated, this can establish unreliable estimates, particularly when a small number of residents are sampled.[53] Systematic observation of drug activity is an objective alternative, but it lacks resident insight and is resource intensive.[54]

Administrative data on arrests and calls for service are objective measures of drug activity. We used narcotic calls for service because they have been reported to better reflect where drug-related crimes occur and to be less biased by policing strategies as compared to arrest data.[11] However, narcotic calls for service may be influenced by the level of collective efficacy and social cohesion amongst residents, residents' perceptions of police, and how visible and normative drug activity is perceived to be. We lacked aggregate measures of these social and psychological factors and thus did not consider them in analysis. However, by adjusting for economic deprivation and housing vacancy we may have partly accounted for differences in the number of calls made by residents living in areas of varying levels of socioeconomic status and abandonment.

Additionally, the modifiable area unit problem may have been an issue.[55,56] However, we believe that the findings from this study were minimally impacted by this, as the results from a spatial scan of clusters of narcotic calls across NSAs for each year of follow-up did not vary substantially from the findings observed when analysis was performed among census block groups.

Lastly, the final year of follow-up in this analysis was restricted to 2010 given that neighborhood-level data beyond that time was not made available to the authors. Therefore, an understanding of whether the geography of neighborhood-level drug activity has changed to date cannot be inferred from the data here.

However, despite these limitations, this study demonstrates the utility of using space-time scan statistics to identify persistent clusters of drug activity, and generates hypotheses on the association between targeted local policies and drug activity. Understanding the spatial and temporal distribution of drug activity has relevance to the design and implementation of place-based drug abuse interventions. The location of drug treatment, harm reduction programs, and other prevention services including outreach for STI, HIV/AIDS, and drug overdose can be targeted to areas where the geographic distribution of drug activity is highest. Additionally, the distribution of drug activity can be used to advocate for more equitable placement of drug treatment and homeless centers, which are overwhelmingly concentrated in distressed areas where high visible drug activity may occur, and to ensure that sufficient support systems are available to assist coping when visible drug activity is located near these facilities. This information can also inform where employment opportunities and affordable and quality housing stock, and problem oriented policing strategies, which attempt to strengthen informal social control, reduce supportive norms around drug activity, and increase social service outreach, can be implemented. Future research and prevention programs should consider using space-time scanning methods to assess drug activity for the aforementioned reasons. Furthermore, use of space-time analytic methods to evaluate drug activity over shorter durations of time (e.g., monthly) could enable timely and rapid responses by prevention and drug treatment programs.

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