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The Effect of Opioid Event Distribution Patterns on Injury Prevention in Fulton County, GA

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2016

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Science in Public Health
in Environmental Health Epidemiology
2018

Abstract

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By Angela Nicole Giaquinto

The opioid epidemic is currently devastating the United States and cases of overdose can be found across all states regardless of race and socioeconomic status. The Centers for Disease Control [CDC] recently released the first government account of nationwide drug deaths and reported 66,324 fatal overdoses in 2016. Accurate surveillance of overdoses, both fatal and non-fatal, could be important to prevention measures. Furthermore, geospatial analysis can be used to understand risk factors and aid in targeted injury prevention to help communities and areas experiencing high rates of overdoses. Accurate surveillance should be a large priority in understanding the opioid epidemic. Current methods of surveillance vary in success with no gold standard and are limited by resources available and information that can be collected. These limitations culminate in case detection error and underreporting. Our study utilizes three created overdose distributions in Fulton County, GA to simulate how various distributions and clustering of events would impact future injury prevention strategies. Distributions are examined in relation to current opioid services such as emergency rooms, rehabilitation centers, and medication-assisted opioid treatment. Our results show that within the historical distribution 73.38% of cases occur within 3 miles of an opioid service. This would influence injury prevention programs to be targeted in areas that already have existing infrastructure and programs. The focus would then be on ensuring these services are reaching out to their communities. The hypothesized distribution resulted in cases moving away from opioid services with 60.39% of cases occurring 3 or more miles away. Injury prevention services and programs would need to be focused in the northern suburbs of Fulton County.

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Acknowledgements

This thesis would not have been possible without the support from my family who acted as my own personal cheer squad throughout this process. Thanks Mom and Dad!

Table of Contents

BACKGROUND

Opioids

The human brain has numerous opioid receptors that when activated by endogenous neurotransmitters such as endorphins, send signals to the brain to block pain, slow breathing, and induce feelings of pleasure. Opioids are a class of drugs whose chemical structure mimics these neurotransmitters and are able to act upon opioid receptors to a much greater extent, producing a physiological response that is greater in magnitude than endogenous endorphins (Kosten & George, 2002). Activation of these receptors by opioids release a flood of dopamine, the neurotransmitter associated with pleasure, creating feelings of euphoria upon taking the drug (NIDA 2007). This feeling of euphoria occurs even in the absence of pain which makes the drug highly addictive. Dopamine has long been associated with compulsive drug use through the feeling of intense pleasure and reward (Berke & Hyman, 2000). Reward and punishment signals are administratively important to learning. Feelings of pleasure rapidly become associated with drug usage which then leads to more frequent use to experience this high (Wise, 1996). Long term elevated levels of dopamine lead to a decrease in dopamine receptors in the brain. This further encourages addiction by increasing impulsive behavior and creating feelings of depression which users may try to revert with higher dosage of drugs (Volkow, Wang, Fowler, Tomasi, & Telang, 2011). Opiates are derived from the plant opium and include morphine, heroin, Vicodin, Percocet, and OxyContin. Opioids are synthetic compounds and include fentanyl and methadone that work similarly to opiates (Katz et al., 2010). Throughout this paper, all opiate and opioid derivatives will be referred to as opioids. Abuse of opioids are well documented as is the addiction that accompanies this abuse (Brown, 2004). Various opioids have been found to be highly addictive within animal models such as rats (Cowan, Zhu, Mosberg, Omnaas, & Porreca, 1988). The Centers for Disease Control and Prevention [CDC] also published data on the highly

addictive characteristics of opioids with 1 out of 5 patients becoming long-term user after exposure to a 10-day supply of prescription (Shah, Hayes, & Martin, 2017).

Opioid Crisis

The United States has a long history of opioid abuse beginning with morphine being heavily utilized during the Civil War and leading to a number of veterans being heavily addicted. The later creation of heroin, an opioid far more potent then morphine, was touted as a 'wonder drug' and sold in common medicines such as cough syrup (Drug-Free World, 2018; Frontline, 2000; Moghe, 2016). Unfortunately, the addictive properties of opium were not fully realized and medicines containing heroin were sold over the counter in the early 20th century. By the 1920s the addictive properties of opioids were known and heroin became illegal in 1924. For decades following, doctors were cautioned against using such powerful painkillers and opioids were saved for the most severe pain, such as end of life care. This continued until a 1980 letter to the editor in the New England journal of medicine stated that of 11,882 patients receiving narcotics, only 4 cases of addiction occurred, arguing that 'despite widespread use of narcotic drugs in hospital[s], the development of addiction is rare in medical patients with no history of addiction'. This conclusion created a revolution of how painkillers were viewed in America leading to the highly cited statistic that 'less than 1%' of opioid users become addicted to the drug (Porter & Jick, 1980). The letter however, was referring to patients in a hospitals on strict, short term regimens of narcotics and were closely monitored by attending physicians. These findings had no information concerning long-term use with chronic pain patients yet has been cited over 600 times as evidence that addiction to narcotics is rare (Leung, Macdonald, Stanbrook, Dhalla, & Juurlink, 2017). The 1996 release of the drug OxyContin, a time-released painkiller, a heavy advertising campaign, and a push for American doctors to treat pain as a 'fifth vital sign' led to millions of opioid prescriptions being authorized. By the early 2000s the signs of opioid addiction were being found across America and the abuse was largely attributed to prescription drugs, such as

OxyContin, with users crushing and injecting the pills. In 2010 the makers of OxyContin reformulated the drug to deter abuse. The drug could no longer be injected as crushing the pills and mixing with water created clumps as oppose to a liquid mixture. The number of people abusing OxyContin dropped dramatically however many of these users turned to illegal street substances, namely heroin, to continue to get their opioid fix (Ingraham, 2017).

Currently, America is facing an opioid epidemic with fatal overdoses being the leading cause of injury deaths for Americans aged 18 to 49 (Katz et al., 2010). Cases of overdose can be found across all states regardless of race and socioeconomic status putting a burden on family's emotions as well as finances (Kandell 2017). Prior studies show the impact of opioid usage on our healthcare system with the mean private insurance of users accruing $14,000 to $24,000 extra costs (Meyer, Patel, Rattana, Quock, & Mody, 2014). The White House recently published a study stating the opioid epidemic cost the United States $500 billion dollars in 2015 alone (The Council of Economic Advisers, 2017). Opioids contribute to over half of drug deaths and are estimated by the CDC to kill on average 115 Americans a day (Centers for Disease Control and Prevention, 2016). The largest proportion of these deaths are within white males whose 2016 rate of overdose death per 100,000 people was approximately 30 (Centers for Disease Control and Prevention [CDC] WONDER 2018). This is a stark contrast compared to previous drug epidemics such as crack-cocaine which devastated low-income, minority communities in the 1980s and 1990s. This shift in opioid of choice and demographics of users is highly evident in areas that had existing heroin addicted populations such as Atlanta, Georgia.

Opioids and Cities

Heroin has long been associated as a drug found within the inner city, associated with low-income and transient populations. Prior to World War II, heroin was primarily confined to a few large cities and the stereotypical user was white or Asian. During World War II a new wave of heroin users grew with the rise of the 'hipster' cultural identity through the Harlem Jazz scene in

the 1930s and 1940s (Frontline, 2000). These populations were made up of young, black jazz musicians whose heroin use inspired not only their music but also fellow aspiring musicians. Charles "Bird" Parker is one of the most famous jazz musicians of the 1930s whose heroin use began at age 15 and led many other jazz artists to believe that to be great, to play the saxophone like the "Bird", you had to be shooting up heroin. This association continued to grow in the 1950s with the 'beatnik' subcultures that developed in cities among downtrodden youth whose rejection of popular western culture led to stereotypes of drug-use inspired by Jazz artists such as Charles Parker (Jonnes, 1996). Heroin acquired a 'powerful, articulated cultural meaning' and soon become an 'essential of the hip life' (Jonnes, 1996).

Opioids Movement into Suburbs

Heroin first started moving into suburbs through white youth that traveled to nearby cities to increase their social standing by copying the 'beatnik' and 'hipster' counter cultures in the late 1960s (Jonnes, 1996). This movement did not grow in popularity and heroin stayed a mostly inner city drug though marijuana spread out into the suburbs. Other drug such as crack-cocaine and methamphetamine gained popularity in cities and were soon the focus of numerous anti-drug messages the most intense being the 1980s 'War on Drugs'. The Reagan administration tackled America's crack-cocaine epidemic with harsh prison sentences that targeted low-income, minority drug users. The AIDS epidemic also began and intravenous drug users were highly stigmatized due to the increased risk associated with injecting drugs and infection of HIV and AIDS (Frontline, 2000). While heroin could be snorted, ingested orally, or smoked the most common and intense high was obtained by injecting the drug. Even with the popularity of crack-cocaine and methamphetamines, heroin was seen as a 'hard drug' within the drug using community as the possibility of overdosing and death was higher. Because of this, rates of heroin use were stable as it was a drug prominent within the older generation that lived through the rise of hipster and beatnik culture (Jonnes, 1996). Opioid medications such as morphine were tightly

controlled by the federal government and only used in extreme cases of pain such as end of life care. Pain was managed multidisciplinary and rarely included medication. American's shifting view on medicated narcotics was due in part to the 1980 Porter & Jick letter reporting less than 1% of users becoming addicted (Porter & Jick, 1980).

The 1990s culminated in pain being seen as a fifth vital sign and the decline of multidisciplinary pain clinics due to several economic factors (Tompkins, Hobelmann, & Compton, 2017). The creation of extended release opioids and vast advertising campaigns led to a large number of opioids prescribed to white, middle class Americans. Although minorities also experience chronic pain, underlying prejudices and racism left over from the crack-cocaine epidemic let to opioids being prescribed at much lower rates within black and Hispanic communities (Singhal, Tien, & Hsia, 2016). Studies reported that 'non-Hispanic blacks [have] significantly lower odds (adjusted OR ranging from 0.51 to 0.67) of receiving opioids during their ED visits for back pain and abdominal pain compared to non-Hispanic whites' (Singhal et al., 2016).

By the new millennia unprecedented amounts of opioids were being prescribed although the chronic pain of Americans was not increasing during this time (Chang, Daubresse, Kruszewski, & Alexander, 2014). By 2007 the amount of prescriptions in the United States was equivalent to 700 mg of morphine per individual, enough for each US citizen to receive a routine 5 mg dose of Vicodin every 4 hours for 3 weeks (Paulozzi et al., 2014) before needing a refill. Thousands of Americans soon became dependent upon prescription drugs and abuse rates of opioids increased dramatically (Paulozzi et al., 2014). The most commonly abused opioid was OxyContin which abusers could crush and precede to chew, snort, or inject (Rookey, 2018). The creators of the drug were found guilty in 2007 of misleading regulators, doctors, and patients about the drug's risk and fined $600 million dollars (Meier, 2007). Following this decision OxyContin was reformulated in 2010 to deter abuse by increasing difficulty to crush or dissolve the pills. This abuse deterrent worked incredibly well and supply and demand of street OxyContin dwindled

(Alpert, Powell, & Pacula, 2017). While individuals could no longer abuse OxyContin, their dependence upon opioids remained and many abusers sought out alternatives to prescription opioids which led to a growing market for heroin (Ingraham, 2017). Working research estimates that 80% of heroin related deaths after 2010 are due to the reformulation of OxyContin (Alpert et al., 2017). The population most heavily prescribed opioids, middle class white Americans, began seeking out heroin (Lighthall, 2017). While in early 2000s suburban users would have to venture into neighboring cities, enterprising drug dealers began to expand into the new market. Heroin was not able to make the journey into suburbs in the 1970s, but riding on the tails of OxyContin heroin began to flow across the country and spread within rural towns and suburb targeting affluent white neighborhoods (T. Cicero, Ellis, Suratt, & Kurtz, 2014; Lighthall, 2017).

Opioids and Atlanta

Historically, if an individual was looking for heroin in metro Atlanta they would need to travel to 'The Bluff' to make their purchases. This section of English Avenue and Vine City neighborhoods in metro Atlanta is a high crime area that was the epicenter of purchasing illegal substances. While the Bluff continues to be an open-market for heroin, the opioid epidemic has spread far outside these areas due to enterprising drug dealers (Baldwin, Speir, Scott, & Norton, 2016). Taking a page out of basic business and economic teachings, dealers have set up shop within the neighborhoods and suburbs where their largest clientele reside, white non-Hispanic Americans (Baldwin et al., 2016; Henry J. Kaiser Family Foundation [KFF], 2017). Some even engage in home deliveries of the drug to their clients similar to getting a pizza delivered (Lighthall, 2017). This ease of access had led to overdoses not just occurring in historical neighborhoods such as 'The Bluff' but also within these suburbs far from addiction and counseling services. CDC latest statistics have Georgia's 2015 age adjusted rate of fatal overdoses to be 12.7 per 100,000 people (CDC 2016). Fulton county, the county containing majority of Atlanta and wealthy suburbs, has seen a significant increase of opioid deaths with 4

overdose deaths occurring in 2010 compared to 82 within 2015 (Miller, 2016). With overdoses now occurring in suburbs, accurate surveillance is needed for targeted responses to this epidemic.

SURVEILLANCE

Surveillance of this epidemic varies state to state with a national surveillance being compromised of state mortality data due to poisonings. Currently, there is no widespread surveillance system though papers have used various databases such as hospital discharge, medical records, causes of death from medical examiners, and electronic prescription monitoring programs (Blanc, Jones, & Olson, 1993; T. J. Cicero et al., 2007; Hughes, Bogdan, & Dart, 2007).

CDC Opioid Surveillance

The CDC compiles drug death data that is sent yearly from all 50 states (Centers for Disease Control and Prevention & National Center for Health Statistics, 2017). While this is the most comprehensive data of opioid deaths, it relies upon the records of states to be accurate. Using mortality data, especially death certificates, is difficult as a number of different causes can be listed and states may have different criteria or practices for how the determine death. Also, while fatal overdoses are one of the most common ways for the opioid epidemic to be reported, the CDC currently does not publish data on non-fatal overdoses which is also important. As of September 2017 the CDC funded 32 states and Washington D.C. as part of their Enhanced State Opioid Overdose Surveillance [ESOOS] program to provide states with the ability to provide more timely and comprehensive data on fatal and nonfatal opioid overdoses.

Poison Control Centers

Fifty-five poison centers are located across the United States and serve all areas of the country including US territories (American Association of Poison Control Centers (AAPC), n.d.). Providing expert advice to both healthcare professionals and patients, the thousands of calls are compiled within the Toxic Exposure Surveillance System [TESS] and reported annually. From

this system poison control centers can release alerts as well as report on poison trends within the United States such as teenagers intentionally exposing themselves to laundry detergent packets to the opioid epidemic (Gummin et al., 2017). This surveillance system depends upon calls to the center and thus does not give an accurate snapshot of ongoing poisonings. Many times, especially with opioid overdoses, emergency room doctors do not need to consult poison centers and treat overdoses with naloxone.

GEO-SPATIAL ANALYSIS

GIS

Geographical Information Systems [GIS] is a mapping technology that allows users to conduct spatial analysis of their data. GIS has been heavily used in the public health field from analyzing infectious disease outbreaks, mapping vector-borne disease trends, to motor vehicle accidents (Kitron, 1998; Shafabakhsh, Famili, & Bahadori, 2017; Vazquez-Prokopec, Spillmann, Zaidenberg, Gürtler, & Kitron, 2012; Zhou et al., 2012).

Opioids and GIS

Very few studies have been published incorporating geospatial analysis in relation to opioid overdoses. One such paper from D. Dworkis used geospatial analysis to identify overdose hotspots within Charlestown, a community north of Boston. These identified hotspots would then help re-distribute existing resources efficiently and address the emergency and long-term health needs of the community (Dworkis, Taylor, Peak, & Bearnot, 2017). The data was collected by identifying hospital discharge data that listed diagnosis as opioid related. The methods of this paper covered numerous codes and text strings to identify this data thus capturing all interested cases. However, using hospital discharge data missed any opioid related EMS calls that did not require hospitalization whether it be outpatient clinic data or overdoses that were fatal on arrival. The research also de-identified addresses for spatial analysis by doing analysis by census tract,

while better than county level still are not refined enough to understand the patterns within neighborhoods. The research met its intended goal of identifying hotspots to focus community resources upon.

Another paper analyzing opioid use disorders and availability of treatment centers related reported use of opioids within counties and availability of opioid services (Abraham, Andrews, Yingling, & Shannon, 2017), Analyzing rates of opioid use disorders and opioid treatment centers that admit Medicaid patients, Abraham noted that several counties in the southern states had areas where low admissions of Medicaid patients, whether due to availability or willingness of the centers to accept Medicaid insurance, corresponds to a high opioid disorder rate (Abraham et al., 2017). Other spatial analysis papers that study opioids include prescription opioid use and fatal motor vehicle accidents (Rookey, 2018). Currently, no papers utilize geospatial analysis to identify risk factors in overdoses nor do they differentiate between fatal and non-fatal overdose differences.

INJURY PREVENTION & OPIOIDS

Injury prevention is the practice of preventing or reducing the consequences of injuries and violence. Prevention can range from interventions at multiple levels such as individual, community, environmental, and socioeconomic. An example would be the United States decreasing the amount of deaths due to motor vehicle accidents. Socioeconomic interventions would be reducing speed limits on roads and requiring passengers to wear seatbelts. Environmental interventions may be put in place such as guardrails or roundabouts. Individuals may attend classes on defensive driving and stay up-to-date on current safety techniques. Opioid overdoses are a form of injury, poisonings, and fall under the concern of state and federal injury prevention centers and services. The CDC lists a variety of ways to prevent opioid use disorder that are in various stages of being followed. Interventions include prescription drug monitoring programs, state prescription drug laws, education of opioid providers on discussing opioid use

disorder with patients and pain treatment options, improve awareness and share resources about opioid risk and management (Centers for Disease Control and Prevention, National Center for Injury Prevention and, & Division of Unintentional Injury Prevention, 2017)

Prevention

Prevention of opioid overdoses requires early interventions to dissuade individuals from getting involved with opioid abuse as they are highly addictive (Darke, 2011). This can be achieved by working at the community level or regulatory levels. Limiting access to prescription opioids that lead to heroin use has been employed by some pharmacies such as CVS which limit amount of opioids per prescription. This has a possibility of preventing future addictions as prescriptions longer than 5 days of opioids can lead to chronic abuse, however it also adversely effects the ability of individuals with severe chronic pain to access their opioid medications (CVS, 2018). The CDC created prescription guidelines for doctors and pharmacists to reduce opioid addiction with a large focus on limiting dosage and duration of opioid medications (Dowell, Haegerich, & Chou, 2016). Education is also a heavily utilized strategy between prescribers and patients as well as across communities. Patients that are well informed of the dangers of opioid abuse may take steps to reduce their chances of future addiction by only taking pills when necessary and disposing of pills properly so they do not end in the hands of children or other family members. Education would also play a role in communities by changing the context of opioid abuse and heroin use ranging from school-based to family-based interventions (Darke, 2011).

Treatment of Overdoses

Nalaxone is currently the only treatment that can reverse an opioid overdose (National Institute of Drug Abuse, 2018). Known also by the brand name Narcan or Evsio, naloxone is an opioid antagonist meaning it attaches to opioid receptors reversing and stopping the effects of other opioids. Nalaxone can either be administered by injection or through a nasal spray. Currently

paramedics within all 50 states, Puerto Rico, and the District of Columbia are allowed to carry and administer naloxone unlike Emergency Medical Technicians or Emergency Medical Responders whose allowance varies by state (Network for Public Health Law Research (NPHL), 2014). Some pharmacies have also began carrying naloxone kits that can be purchased without a prescription. While prescription overdoses may only require 1 dose, overdoses due to more potent drugs such as heroin or fentanyl may need multiple doses of naloxone to reverse the overdose (Centers for Disease Control and Prevention, National Center for Injury Prevention, & Division of Unintentional Injury Prevention, 2018).

Treatment of Opioid Abuse

The major forms of treatment for opioid abuse all begin with detoxification and then opioid maintenance therapies, residential rehabilitation, or outpatient rehabilitation (Darke, 2011). Detoxification is the process of an opioid abuser stopping opioid use causing a period of withdrawal that is can cause discomfort and last for a week. After detoxification, patients are most successful if they engage in a long-term intervention such as rehabilitation or opioid maintenance therapies. Opioid maintenance therapies, also called medication assisted opioid treatments, are usually outpatient therapies under the direction of a doctor. Patients are given a long-lasting opioid that taken orally each day replaces heroin. This is a popular treatment as patients do not have to necessarily stop opioid use cold-turkey and can start prior to detoxification to lessen withdrawal symptoms. Opioids used for these treatments include methadone or buprenorphine which can be packaged into various name brands such as suboxone and subutex. Rehabilitation can be either residential or outpatient and vary in practice depending upon the organization running the program. A common theme across all rehabs however is patient therapy (Darke, 2011). There are additional opioid services such as needle exchanges that lower associated diseases of intravenous drug use but are not the focus of this paper.

METHODS

Study Area

Fulton County is in the northern portion of Georgia and holds 90% of the City of Atlanta. Covering 534 square miles it is one of the Georgia's most populous counties with 1,041,423 inhabitants as of 2017. Overdoses due to heroin have been increasing yearly and their 2015 mortality rate was more than double the national average at 11.7 opioid-related deaths per 100,000 people (CBS 46, 2017). Fulton County has a number of ambulance services with the largest and most pervasive being Grady Emergency Medical Services [EMS], a public ambulance service that delivers to any nearest trauma center. In 2017 Fulton County adopted an opioid misuse and abuse prevention plan with prevention strategies such as launching public awareness campaigns, enhance education and accountability of medical providers, creation of a crisis text assistant line, and increase number of drug drop boxes throughout the County (CBS 46, 2017). The goal of this study was to understand the current spatial trends of opioid overdoses and their associating distances from opioid services. The results will influence future targeting injury prevention

Data Sources

Originally, ambulance records from Grady EMS were to be obtained for all calls involving opioid overdoses for the year 2017. Due to certain constraints, the data was not made available in time for proper analysis. Three artificial data sets were created to simulate various distribution patterns of fatal overdose events in Fulton County. Each data set contained 154 events as Fulton County reported 154 fatal heroin overdoses in 2016 (Kass, 2017). The three distributions created were grid distribution, historical clustering event distribution, and hypothesized clustering event distribution.

Grid Distribution

Events were distributed randomly throughout Fulton County following a grid pattern. A 1x1 square mile grid was projected over Fulton County and any box including a portion of the county was numbered and counted. Using Excel's random number function, each event was randomly assigned a numbered box to occur within. If the county was entirely within the box, the event was placed in the center. If the county was only partially in the box then the event was placed in that area.

Historical Clustering Event Distribution

Events were distributed based upon historical accounts of opioid overdoses within Fulton County from police and news reports. Within 2015, 25% of fatal overdoses occurred within zip codes associated with 'The Bluffs' of Atlanta and 52% of fatal overdoses occurred in Northern Fulton suburbs. Applying this to our 154 fatal overdoses, 39 events were placed at random within 'The Bluff' associated zip codes 30314 and 30318. 80 events were placed within Northern suburbs and the remaining 35 overdoses were placed randomly from remaining zip codes. Placement of events were also influenced by data published from a report released by the Atlanta Judicial System that showed fatal overdoses by zip codes.

Hypothesized Clustering Event Distribution

Events were distributed based upon current literature trends that follow the hypothesis that opioids are moving further from inner city areas and into suburbs. 10% of fatal events were placed at random in 'The Bluffs' of Atlanta situated near down town. 75% of fatal overdoses were distributed in the northern suburbs of Fulton county spreading to the edges of the county into areas now being reported as the 'heroin triangle'. The remaining events were distributed randomly throughout remaining Fulton County. The hypothesized distribution shows events moving away from inner cities and into suburbs, especially the northern suburbs of Atlanta.

Fulton Demographics

A map of Fulton County census tracts and streets was generated using data made available from the Fulton County GIS library (Fulton County Government, 2017). The GIS library is constantly being updated by Fulton County officials and uses multiple data sources such as the 2010 US census. An address locator was created using the street centerlines data set available through the Department of Planning and Community Development (DPCD) GIS library.

Opioid Service Distribution

Opioid Services were identified using searches with keywords ‘in-patient rehab’ ‘opioid clinic’ ‘methadone clinic’ ‘addiction rehabilitation’ ‘Atlanta hospitals’ and ‘Fulton emergency room’. Services were also identified by recommendations from clinicians. Addresses for services were found from their website, by calling the service, or by utilizing google maps.

Services were broken into 3 major categories 1. Clinic 2. Emergency room [ER] and 3. Rehab. Grady EMS headquarters was also chosen as a point of interest for analysis. Clinics included any business, rehab, or organization that offered medication assisted opioid treatment such as methadone, subutex, or bupenephrine under the direction of a licensed doctor. Emergency rooms were hospitals within Fulton County that offered emergency room services and did not exclusively cater to youth or children. Rehab centers were chosen if they focused upon adult drug rehabilitation and had services specifically for opioid addictions, both in-patient and out-patient programs were included as long as licensed therapists were on staff. Any rehabilitation service that also offered medicated assisted rehabilitation was moved to the ‘clinic’ category.

Analysis

Each data set was analyzed individually in relation to opioid services. A buffer analysis was used with center points being opioid services. Buffer distance was decided based upon feasibility of access from walking or driving. Buffers were placed at 1, 3, 5, and 10 miles from the services.

Clustering analysis was conducted using Morans I statistic, a global spatial autocorrelation statistic, for each distribution. The Moran's I assesses the overall pattern and trend of the data to statistically analyze how similar objects are to their surroundings. The tessellation tool was used to create a hexagon grid covering Fulton County. Each cell was given attributes to describe amount of events that occurred within their area. Each cell was then analyzed to themselves and surrounding cells. Hot spot and density analysis was conducted at the census tract level with cases being attributed to the census tract they occurred within. Cluster 'hot spots' were identified using the local spatial statistic Getis G*(d) comparing the historical and hypothesized distributions.

The null hypothesis for the High/Low Clustering (General G) statistic states that there is no spatial clustering of feature values. Statistical significance was determined by using the bonferroni correction (Goldman, n.d.) using an alpha level of 0.05 and the number of observations being 203 (number of fulton census tracts) two sided z score of 3.6661. A kernel density analysis was conducted on the historical and hypothesized data sets as an exploratory look at event clustering. Spatial analysis and exploratory statistics used ARCMap 10.5.1. Maps were also created within ARCMap 10.5.1. Microsoft Excel was used for computational statistics.

RESULTS

Within Fulton County census tracts 22 opioid services were identified made up of Grady EMS headquarters, 8 hospitals, 6 clinics, and 7 rehabs. Figure 1 shows the spatial spread of these services with majority being in and around downtown Atlanta.

Each distribution pattern for overdoses were mapped spatially and grouped by distance from opioid services at 1, 3, 5, and 10 miles. The grid distribution (Figure 2) had 12 cases (7.79%) occur within 1 mile of an opioid service, 35 cases (22.73%) occurred between 1 and 3 miles, 32 cases (20.78%) occurred between 3 and 5 miles, 35 cases (22.72%) occurred between 5 and 10 miles, and 40 (25.97%) cases occurred more than 10 miles away. Descriptive statistics of each

events distance from the nearest service had a minimum of 0.13 miles away and a maximum of 25.21 miles away. The mean distance of opioid overdose and an opioid service was 7.18 miles for the grid distribution.

The historical distribution of opioid cases (Figure 3) had 46 cases (29.87%) occur within 1 mile of an opioid service, 67 cases (43.51%) occurred between 1 and 3 miles, 25 (16.23%) cases occurred between 3 and 5 miles, 15 cases (9.74%) occurred between 5 and 10 miles, and 1 (0.65%) case occurred more than 10 miles away. Descriptive statistics of overdose event and distance to nearest services had a minimum distance of 0.15 miles and a maximum of 11.09 miles. The mean distance was found to be 2.30 miles.

The hypothesized distribution of opioid cases (Figure 4) had 13 cases (8.44%) occur within 1 mile of an opioid service, 48 (31.17%) cases occurred between 1 and 3 miles, 43 cases (27.92%) occurred between 3 and 5 miles, 46 cases (29.87%) occurred between 5 and 10 miles, and 4 (2.60%) cases occurred more than 10 miles away. Descriptive statistics of opioid event distance to an opioid service had a minimum distance of 0.27 miles, a maximum distance of 16.63 miles, and a mean distance of 4.15 miles.

Clusters were statistically analyzed with Moran's I statistic (Figure 5), only the hypothesized distribution (Figure 5C) was statistically significant (p-value < 0.05). A density analysis was done to compare density change from historical distributions to hypothesized distribution of opioid cases. (Figure 6). Lastly, a Getis hot spot analysis was conducted on the historical and hypothesized event distributions (Figure 7). Events were joined to underlying Fulton County census tracts and analysis showed statistically significant hot spots, high prevalence of overdose events, within the northern suburbs of both the historical and hypothesized distribution. The hypothesized distribution (Figure 7B) also had statistically significant cold spots south east of The Bluffs in downtown Atlanta. This is interesting as there are various census tracts, especially in the southern portion of the county, that have little to no prevalence and are not significant cold

spots. A possible explanation of this would be that the map is showing a bias known as a Modifiable Areal Unit Problem [MAUP]. This is a bias that occurs when individual locations are grouped together for ease of understanding analysis, such as the event being grouped to underlying census tracts. This can distort or exaggerate actual data patterns as the census tracts located in downtown Atlanta are much smaller in area then the census tracts located in the north and south suburbs.

DISCUSSION

Fulton County has been experiencing a sharp increase of opioid overdose deaths similar to the rest of the United States. Decreasing overdoses and rates of opioid abuse is becoming the principal goal of existing public health agencies. While rates of abuse and harm are increasing exponentially finite resources must be allocated purposefully to reduce the most harm. Geospatial analysis of overdose trends informs targeted injury prevention methods both short term with nalaxone distributions and long term through rehabs and clinics. Spatial analysis can determine future sites of services to ensure they are located in communities that have the highest prevalence of overdoses and require the most access to care.

Each distribution varied in clustering and distance from opioid services which impacts how injury prevention would be deployed. The grid distribution was created based on the probability that opioid events occur randomly throughout the county independent of any historical trends, population trends, or distance from opioid services. Figure 2B shows this distribution with the 154 fatal events randomly placed across a projected grid of Fulton County. In this distribution, 48.7% of cases occurred 5 or more miles away from any opioid service. This was larger then both the historical, 10.39%, and hypothesized, 32. 47%, frequency of cases at 5 or more miles. A possible explanation for this would be the oblong shape of Fulton County. Northern and Southern portions of the county have the most land mass while the connecting thinner portion of Fulton County stretches across downtown Atlanta where the majority (16/22) of opioid services are

located (Figure 1). With our grid distribution, no clustering of events should have occurred, this was proven in the Moran's I statistic (Figure 5A) no statistical significance of clustered events was found in this distribution. If the grid distribution is similar to the true distribution of opioid overdose events occurring in Fulton County in 2017, then injury prevention services are inadequately located in the county to meet these needs. The mean distance from an overdose event to any opioid service was 7.18 miles. The large urban sprawl and low public transportation within Fulton County means that at this range, opioid services on average are unaccesabile from the location of opioid overdose. With no clustering of events, injury prevention strategies would not be able to conserve resources by targeting specific communities to reduce areas with highest overdose prevalence. Resources instead would need to focused on covering the largest portions of Fulton County to reach the most amount of people. Current services would be encouraged to expand their reach by opening satellite offices throughout the rest of the county to address the far spreading needs.

The historical distribution of cases were based upon police reports, news articles, and local government publications of opioid events in 2015. 73.38% of all opioid overdoses occurred within 3 miles of a clinic, rehab, or emergency room (Figure 3). If fatal opioid event trends of 2017 follow this pattern, then we see that majority of cases are occurring within regions of Fulton County that are on average 2.30 miles from a service and should theoretically have the highest access to services. Cluster and hot spot analysis showed two areas where injury prevention programs would need to be targeting, one in downtown metro Atlanta specifically in and around 'The Bluff' neighborhoods and one within the northern suburbs. The opioid overdoses occurring in the northern Fulton suburbs were still clustered, though not significantly, at opioid service sites (Figure 6). In 'The Bluff' neighborhood, services are located nearby, yet a large amount of fatal opioid overdoses are still occurring.

Next steps would be increasing visibility of injury prevention services and deploying injury prevention programs in these neighborhoods. In this situation, injury prevention messages and programs can build upon the existing infrastructure and partnerships that opioid services have already established in these areas. Further steps would include seeing if there are disparities in the clients that utilized the closest opioid services in these areas compared to the communities that live nearest to these services. 'The Bluff' is a predominately minority, low – income community that would not benefit from services if the closest rehabs and clinics don't accept all forms of insurance. If ambulance records are acquired, it would also be imperative to see if the patients place of residence is similar or close to place of overdose. If majority of overdoses occurring within 'The Bluff' are due to opioid users traveling into this area to purchase and use drugs and not within the members who live in these neighborhoods, then injury prevention programs would need to adjust their strategies. In this historical distribution of opiod events, future injury prevention would need to continue targeting areas where the majority of services are located and ensure outreach is occurring in the areas immediately surrounding them.

The hypothesized distribution shows opioid events moving away from 'The Bluffs' and into the farthest corners of the northern suburbs as well as spreading south away from opioid services (Figure 4). In this distribution pattern, events occur, on average, 4.15 miles from any opioid service, 2 miles further then the average distance of historical cases. This spread of cases from historical to hypothesized distributions is evident by comparing the kernal density of the historical and hypothesized distribution (Figure 6). The hypothesized distribution has 4 clusters of high probability density areas with stasticially significant clusters occuring in northern Fulton suburbs (Figure 5C). The hot spot analysis shows similar statistical trends for the historical and hypothesized distributions (Figure 7). In the hypothesized distribution, there are numerous unexpected statistically significant cold spots southwest of 'The Bluff' area. As described in the results, this could be a result of MAUP and require additional analysis to ensure a bias is not

occurring. A possible explanation would be because this is hypothesized data, the bias could be a result of the random placement of 'elsewhere' overdose events and would not be seen in a true data set.

In this distribution pattern, injury prevention programs need to focus on spreading services into northern suburbs which are not being adequately serviced for their high prevalence of opioid overdoses. Targeted messaging and programs can be directed to these areas through school district education as well as creating community partnerships to decrease opioid abuse and overdoses. The closest available opioid services consist of a clinic and emergency room within this area (Figure 1), we know however that opioid abuse patients have better outcomes when placed in rehabilitations, either in- or out-patient. Therefore, rehabilitation services should be created within these areas with building located within the center of clusters to ensure adequate access. Other prevention measures such as school district education, creation of satellite campuses of services originally located in downtown Atlanta, and greater availability of Nalaxone within these suburbs would also be advised.

From these three distributions we had three separate effects on injury prevention. These effects ranged from canvassing large areas of the county to focusing resources in targeted communities with the highest prevalence of overdoses, whether focusing on existing infrastructure or the creation of new services. The exploratory spatial analysis and surveillance gives a greater understanding of the current trends of opioid overdose cases and how to best reach at-risk populations. These methods would also be valuable as monitoring and evaluation tools to measure if targeted interventions made a difference in opioid overdose frequency and locations. Overdoses from opioids, especially intravenous street drugs such a heroin and fentanyl, are likely to be clustered as the same 'bad batch' or laced drug is responsible for multiple events. While this study used hypothesized and retrospective data, prospective spatial analysis and surveillance in

real time would be able to quickly and efficiently navigate resources such as nalaxone to areas where overdoses occur.

With 115 Americans dying each day due to opioid overdoses, prevention measures and treatment of opioid abuse must be enacted quickly to reduce harm. Using spatial analysis to identify areas of high prevalence can influence allocation of resources and programs to create effective injury prevention. Each of these three distributions of opioid overdose events resulted in different injury prevention needs and would require specialized plans to meet the needs of communities with high prevalence. While the current statistics surrounding the opioid epidemic may be disheartening, it is important to keep in mind that '[opioid] users are not untreatable' (Darke, 2011) and injury prevention is the first step in reducing harm and saving lives of opioid users.

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FIGURES

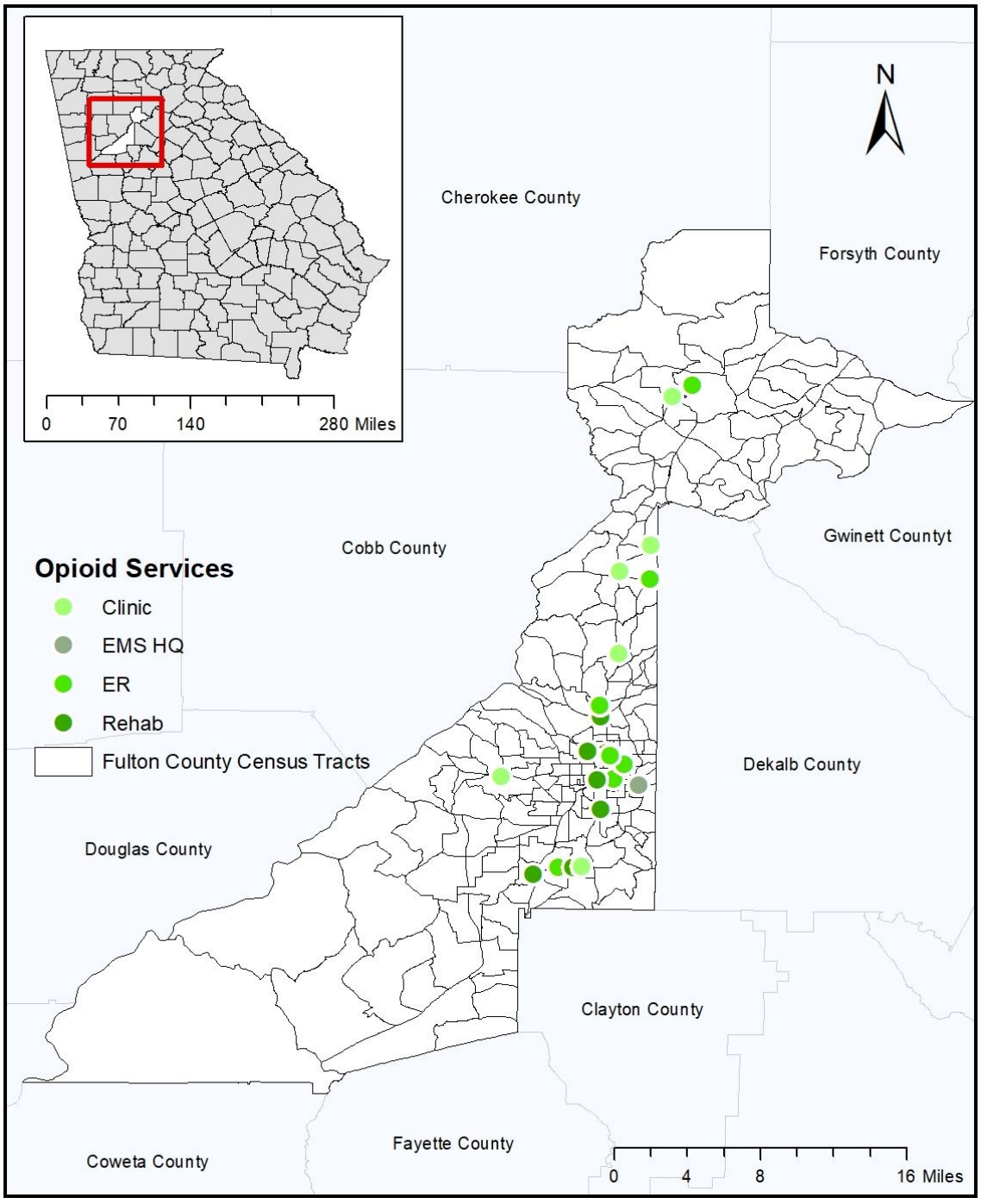

Figure 1. Fulton County, GA Opioid Services as of April 2018. Distribution of opioid services ranging from clinics, hospitals, EMS headquarters, and rehabs. 8 ERs, 6 clinics, and 7 rehabs were included. Insert details relation of Fulton County to the rest of Georgia's counties.

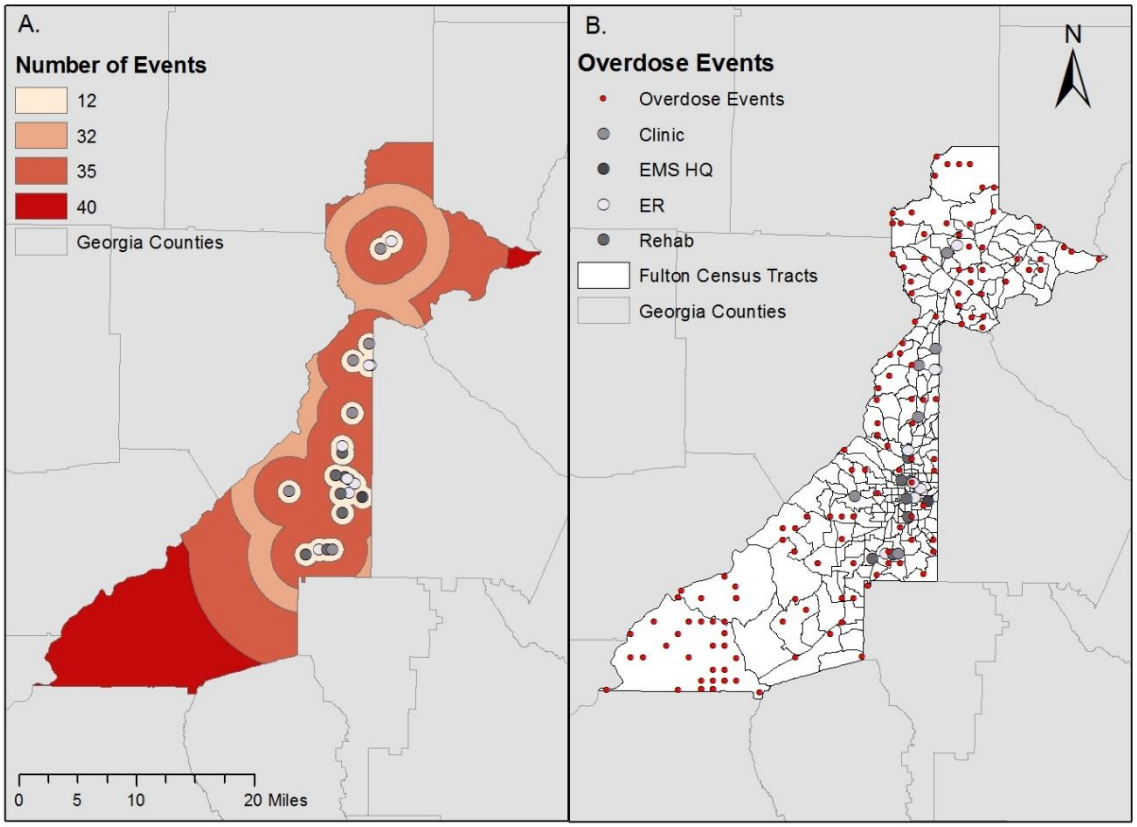

Figure 2. Grid Distribution of Overdose Events, Fulton County GA: Map A shows amount of events that occurred within 1, 3, 5, and 10 miles of any opioid serice. Map B shows specific placement of each fatal event in Fulton County.

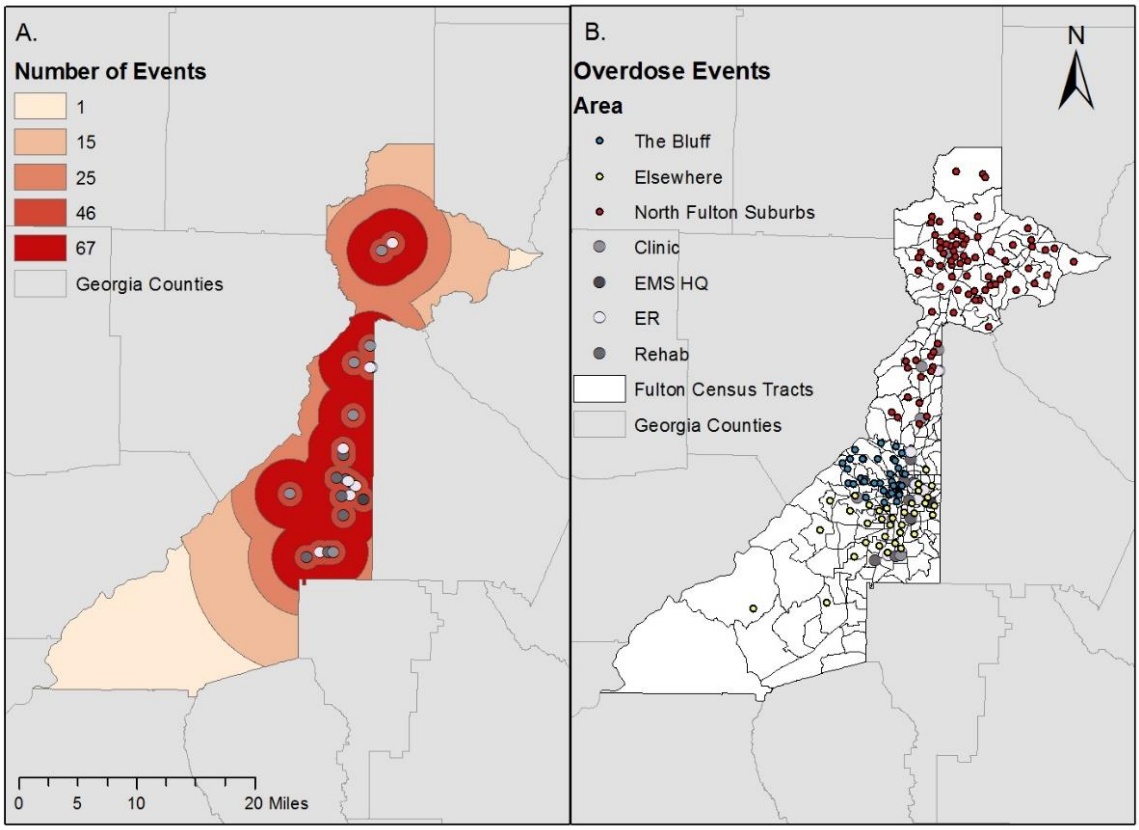

Figure 3. Historical Distribution of Opioid Overdoses, Fulton County GA: Map A shows count of fatal overdoses that occurred at 1, 3, 5, and 10 miles from any opioid service. Map B shows the placement of fatal overdoses within Fulton County. Events are categorized by the specifc spatial area occurring within including ‘the bluff’s zipcodes, North Fulton subrubs, and elswhwere within the county.

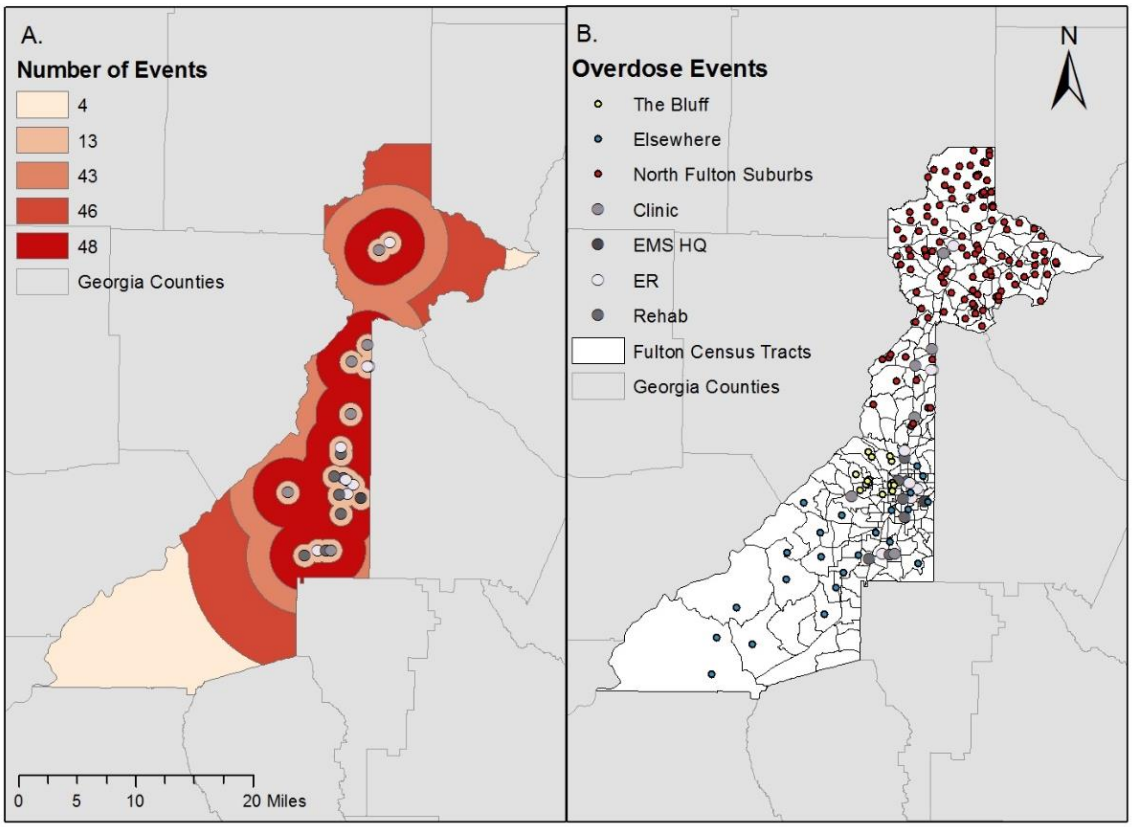

Figure 4. Hypothesizedl Distribution of Opioid Events, Fulton County GA: Map A shows count of fatal overdoses that occurred at 1, 3, 5, and 10 miles from any opioid service. Map B shows the placement of fatal overdoses within Fulton County. Events are categorized by the specifc spatial area occurring within including ‘the bluff’s zipcodes, North Fulton subrubs, and elswhwere within the county.

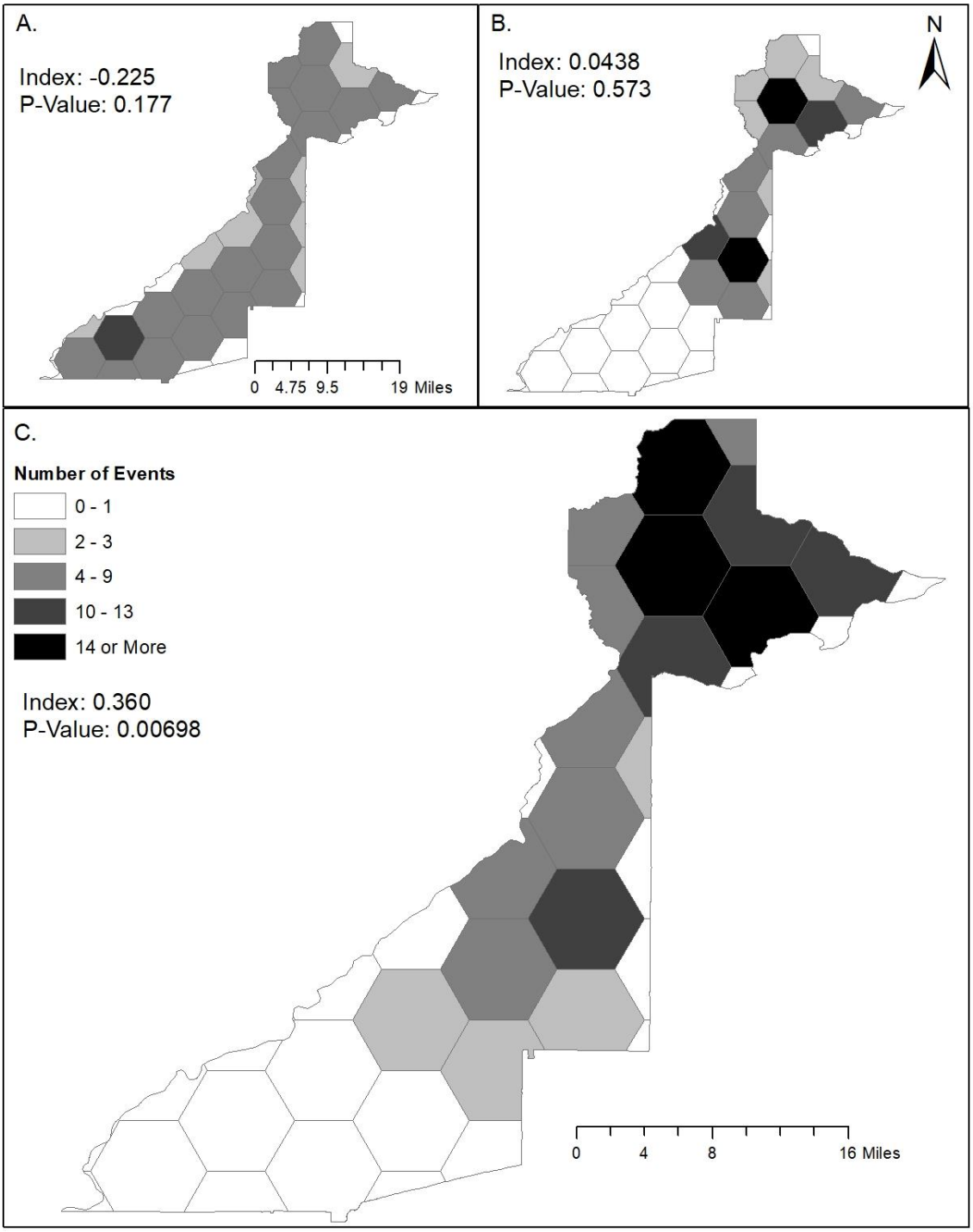

Figure 5. Clusters of Fatal overdose Events for Various Distributions, Fulton County GA: Map A shows clustering patterns for the grid distribution of opioid events, Moran's I statistic had a p-value of 0.177. Map B shows clustering patterns for the historical distribution of opioid events, Moran's I statistic was 0.573. Map C shows clustering patterns for the hypothesized distribution of opioid events, Moran's I statistic was significant at 0.000698.

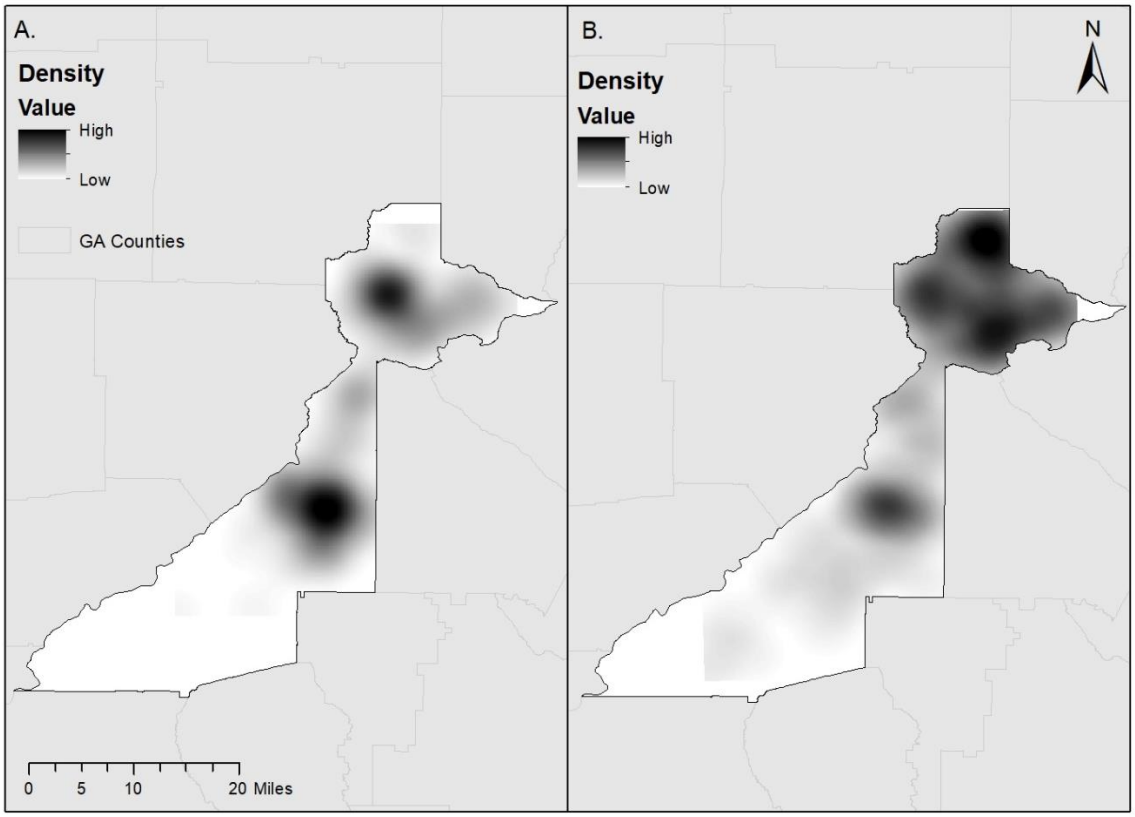

Figure 6. Kernal Density of Historical (A) and Hypothesized (B) Distribution of Opioid Events Fulton County, GA: Comparison of density probability of events occurring within joined census tracts.

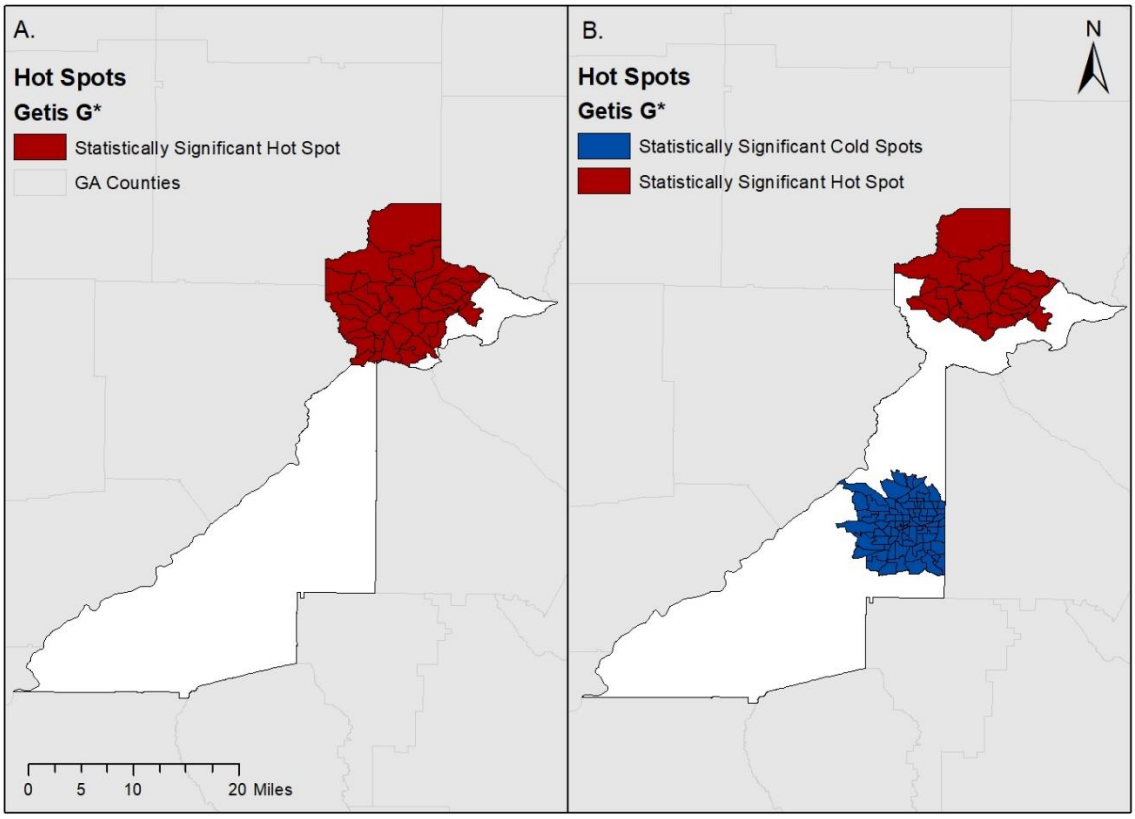

Figure 7. Stastically Significant Hot and Cold Spots of Opioid Overdoses for Historical (A) and Hypothesized (B) Distributions Fulton County, GA