January 2013

Assessing the Relationship Between Hotspots of Lead and Hotspots of Crime

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By

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
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Date of Approval:
April 5, 2013

Keywords: environmental justice, green criminology, political ecology, behavioral toxicology, social disorganization theory

Dedication

This dissertation is dedicated to my family, especially Barbara Ann, Thomas Charles, Karen Elizabeth, my grandparents, and Henry. There will never be enough words to express my gratitude for the unconditional love and support you have provided me throughout this experience, and all other endeavors. Thank you for everything you have given me. I love you, always.

Acknowledgments

This work was made possible through the generous support I have received from my mentors, colleagues, and friends. I would like to recognize Dr. Richard Dembo and the staff at the Truancy Intake Center for introducing me to public health research in the field, and affording me the privilege of working with children and families in Tampa. Dr. Dembo, I am one of many who admire your passion for helping young people. Thank you for an unforgettable experience.

This study was enriched by the expertise of Dr. Lyndsay Boggess and Dr. Paul Stretesky. Thank you both for your commitment to guiding me through this project, and your support over the past year especially. I would also like to thank Dr. Michael Long for his assistance and advisement on the analytic approach, and the Research and Development staff at the Chicago Police Department for their cooperation.

I continue to be humbled by the work of my fellow graduate students, and I thank them for their camaraderie. Thank you also to Dr. Liz Cass, Lisa Landis, Elisa Horton, Dr. Larry Siegel, and Dr. Mary Carney for believing in me. And thank you to Keri Hovey, Lisa McCaffrey, Jessi Krezmien, and Ali Eagen for years of friendship from near and far. I look forward to years more.

This study, and my graduate career, were both profoundly shaped by the research and mentorship of my major professor. So lastly, I would like to thank Dr. Michael J. Lynch- you are a brilliant scholar, role model, advocate, and friend. I hope I have made you proud.

Table of Contents

List of Tables

List of Figures

Abstract

Numerous medical and environmental toxicology studies have established a link between lead (Pb) exposure, crime, and delinquency. In human environments, lead pollution- like crime- is unequally distributed, creating lead hot spots. In spite of this, studies of crime hotspots have routinely focused on traditional sociological predictors of crime, leaving environmental predictors of crime like lead and other neurotoxins relatively unaddressed. This study attends to this gap in the literature by asking a very straightforward research question: Is there a relationship between hotspots of lead and hotspots of crime? Furthermore, what is the nature and extent of this relationship? Lastly, is the distribution of lead across communities relative to race, class, and/or ethnicity?

To explore these issues, a series of thirteen research hypotheses are derived based on findings from previous lead and crime studies. To test these research hypotheses, data was collected from the city of Chicago's Community Areas (n = 77) in Cook County, Illinois. Information from a range of secondary sources including the U.S. Census, Environmental Protection Agency, Chicago Police Department, and City of Chicago are merged and analyzed. Cross sectional and longitudinal assessments are conducted, and results from a series of negative binomial regressions, fixed effects negative binomial regressions, and correlations are presented. Findings suggest the association between lead and crime appeared particularly robust with respect to rates of violent index crime, but less so for rates of property index crime. Contrary to what prior research suggests,

the association between lead and crime appears stronger for rates of arrests for adult index crimes than rates of arrests for juvenile index crime arrests. This study concludes by discussing theory and policy implications alongside recommendations for future study.

Chapter One:

Introduction

Hotspots, Lead, and Crime

The spatial context of crime has been a topic of criminological inquiry for over 180 years (Quetelet, 1968). Few observations about crime and offending are supported as consistently in the literature as the non-random distribution of index crime across space. Findings repeatedly indicate over representation of index crime in areas of concentrated urban disadvantage. In efforts to explain this phenomenon, criminologists have found street crime occurs frequently in areas high in poverty, increased racial and ethnic heterogeneity, and high residential turnover (Lowenkamp, Cullen, & Pratt, 2003; Park & Burgess, 1925; Sampson & Groves, 1989; Shaw & McKay, 1942). Other explanations include subculture of violence theses, intimating the derivation of counter-cultural norms that cultivate in areas of disadvantage (Anderson, 1999; Wolfgang & Ferracuti, 1982). Leading mainstream macro-level theories of crime charge that these socio-structural and/or cultural variables reduce informal social control, increase disorganization, create criminal opportunities and, in turn, concentrate crime.

Recently, crime and place experts have turned their attention to these theoretical frameworks to inform work on crime hotspots (Weisburd, 2012). While the precise

definition of hotspot may vary subtly, the general understanding of a crime hotspot is, “an area that has a greater than average number of criminal or disorder events, or an area where people have a higher than average risk of victimization,” (Eck et al., 2005, pg. 2). An NIJ special report on understanding crime hot spots regards neighborhood area hot spots as informed by disorganization, ecological, and opportunity theories (Eck et al., 2005). The same report attributes likely causes to neighborhood hot spots as: “low collective efficacy, social fragmentation, concentrations of youth, economic disinvestments, and concentrations of crime targets,” (Eck et al., 2005, pg.5).

However, a growing literature is elucidating other factors that may explain the unequal distribution of index crime. Environmental justice studies have found evidence of disproportionate siting of environmental harms proximal to low income minority neighborhoods[1] (Bullard, 1994, 1996; Checker 2007; Hipp & Lakon, 2010; Krieg, 1995; Opp, 2012; Stretesky & Hogan, 1998). As such, it appears many of the same areas carrying the burden of above average levels of index crime also carry the burden of increased exposure to environmental contaminants that pose threats to human health and behavior. In turn, as researchers observe crime hot spots, they can also observe pollution hot spots (Oyana & Margai, 2010; Pastor, Morello-Frosch, & Sadd, 2006).

Pollution hot spots may be important causes of crime. Prior research has shown that exposure to various environmental toxins possesses the ability to alter behavior. Based on prior research, it is plausible that environmental hazard sites may emit toxins

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[1] Green criminology encompasses the study of environmental justice and argues pollution as criminal, likening the harms associated with environmental degradation to criminal behaviors prohibited by law (assault, battery). For further information see: Lynch & Michalowski, 2006; Lynch & Stretesky, 2003; White, 2003

into nearby communities threatening the neurological functioning and cognition of people residing in those neighborhoods (Carpenter & Nevin, 2010). Some of these chemicals, particularly heavy metals and dioxins, have the capacity to compromise the central nervous system. The link between neurological deficiencies and exposure to numerous types of environmental toxins is well documented (Colburn, Dumanoski, & Myers, 1998; Kampa & Castanas, 2008; Miranda, Kim, Reiter, Galeano, & Maxson, 2009; Nevin, 2000), with perhaps the most prominent environmental neurotoxin being lead (Pb) (Rodricks, 2007).

The research on the spatial distribution of crime and distribution of neurotoxins converged in 2001 when Stretesky and Lynch assessed the relations between air lead (Pb) levels[2] and homicide rates across the United States. Lead (Pb) presented as a toxic agent of interest because numerous extant studies demonstrated lead's relationship with variables established as correlates of crime and delinquency in individuals. For example, individuals with elevated blood lead levels have been found to be more aggressive and have lower IQ levels than individuals who do not have elevated blood lead levels. Stretesky and Lynch found that counties with higher quantities of air lead also experienced higher rates of homicide. Air lead level explained unique variance in homicide rates even while controlling for the sociological predictors of crime widely tested in the criminology literature, including: classification of area as urban, number of persons, area in square miles, number of adults without a high school education, number

[2] Empirical evidence has established there is a positive relationship between air lead level and blood lead level. This will be discussed in further detail in subsequent chapters, but see also: Stretesky & Lynch, 2001; 2004

of young persons, number of persons living below the poverty line, number of black residents, and classification of county as part of the South.

Following this study, criminology was posed with a new variable with important implications related to place and crime. Subsequent studies went on to find relationships between lead and violent crime and property crime at the county level across the United States (Stretesky & Lynch, 2004). Other studies found relationships between lead and juvenile delinquency assessing bone and teeth lead levels (Olympio et al., 2010; Needleman et al., 2002). Another study assessed childhood blood lead level and crime rates internationally across countries (Nevin, 2007). These studies support the notion that lead is related to crime at the individual, county, and country levels.

Yet, as criminologists continue to study crime hotspots, the majority of studies consistently employ theoretical frameworks oriented towards traditional predictors of crime. Left unaddressed, it is reasonable to question whether hotspots of crime may be indicative of hotspots of lead. Ambiguity in this area is problematic, as even the most promising of policy initiatives may be of limited utility if other sociological and individual level correlates of crime are addressed while ignoring environmental threats to pro social human behavior. This gap in the literature is acknowledged by both environmental crime scholars (Narag, Pizarro, & Gibbs, 2009) and crime hotspot experts (Lersch & Hart, 2011). However, with the exception of one unpublished study assessing lead and homicide across census tracts (Lynch, McGurrin, & Stretesky, 2001), the relationship between crime and lead hotspots at the community level of analysis has yet to be subjected to empirical assessment. This study proposes to fill this gap.

The Present Study

This study addresses a very straightforward research question: Is there a relationship between hotspots of lead and hotspots of crime? Subsequently, what is the nature and extent of lead's impact on crime? This study explores these issues using the city of Chicago's Community Areas (n=77). In doing so, this study makes at least three contributions to the literature. First, this study examines lead across community rates of violent and nonviolent (property) index crimes to compare the predictive power of lead exposure across types of offenses. Extant studies suggest lead exposure is a stronger predictor of violent crime than non-violent crime (Pihl & Ervin, 1990). Second, this study examines lead's impact on adult and juvenile arrest rates to compare the predictive power of lead relative to rates of juvenile and adult crime. Prior work has suggested that youth are more vulnerable to the adverse impacts of lead and other pollutants than adults (Landrigan, Rauh, & Galvez, 2010; Moore, 2003; Nevin, 2007). Finally, the study conducts an exploratory assessment of the socio-demographics of community areas relative to their lead exposure. Prior environmental justice studies have found that minorities and populations at risk are disproportionately exposed to environmental hazards (Bullard, 1994; Landrigan et al., 2010; Opp, 2012).

Overview of Chapters

This study is organized into seven chapters. Chapter two introduces lead, and chronicles its various industrial uses from past to present. Literature exploring the relationship between lead and emotional behavioral disorders, including ADHD,

impulsivity, learning disabilities, and IQ reduction is reviewed. Also reviewed are studies that have documented a link between lead and delinquency and antisocial behavior in youth, as well as lead and criminal offending in adults, at both micro and macro levels. Lastly, chapter two discusses the spatial distribution of lead and introduces to the discussion the concept of lead hotspots.

Chapter three serves to define, describe, and review literature on crime hotspots. This chapter discusses the empirical standing of crime hotspot studies. Focus is given to predicting variables used in crime hotspot studies, as well as the policy initiatives inspired by such studies. In this chapter, the issues associated with the omission of lead from community and crime studies will be demonstrated. Taken together with chapter two, an argument will be made that the exclusion of lead in crime hotspot studies is an important issue in need of resolve.

Data for this study was obtained for the city of Chicago in Cook County, Illinois. Chapter four justifies Chicago as an ideal location for this research, due to the Chicago area's documented struggle with the presence of both lead and crime. This chapter provides background on the Chicago area, and explains rates of lead exposure and crime as they pertain to the region.

Following the review of relevant literatures and background information on this study's setting, chapter five presents the research hypotheses, methods, and measures. Hypotheses are expressly stated, and information on the data collection procedure and sample is provided. Measurement and the conceptualization of variables employed in this study are also presented.

Chapter six presents the analytic procedures for the data and results from the hypothesis tests. Descriptive information and bivariate relationships are provided. Results from a series of negative binomial regressions, fixed effects negative binomial regressions, and correlations are presented and interpreted. Finally, chapter seven discusses results from the study relative to previous findings, as well as theory and policy implications. Limitations of the study are discussed, and suggestions for future research are provided.

Chapter Two:

Lead

Lead is classified as a heavy metal, akin to Mercury (Hg), Cadmium (Cd) Chromium (Cd), and Manganese (Mn). It is connoted as Pb on the periodic table of elements and belongs to the transition metals family. Lead is a soft, malleable substance, and its ability to resist corrosion has made it appealing for numerous commercial and industrial purposes. Lead can be present in the air, water, and soil, and once absorbed in the human bloodstream, lead has a half-life of approximately thirty days. However, lead (like other heavy metals) can bio-accumulate in bones and teeth (Kampa & Castanas, 2008) where it has a half-life of twenty-seven years (Needleman, 2009). Lead has such a long half life in the environment that it is considered a stable element. This is problematic since the extraction and processing of lead ores into lead products can create lead pollution which is relatively stable once emitted into the environment. This chapter is concerned with presenting an overview of lead as well as reviewing literature relevant to lead's industrial uses, lead's impact on behavior, and the distribution of lead across place.

Industrial History & Uses of Lead

It has been estimated that lead was discovered in Turkey in 6500 B.C., and thus has been mined and in use for thousands of years. Records indicate the Romans were

routinely mining and smelting lead from 500 BC to 300 BC (Gilbert & Weiss, 2006), and that they had used it in the construction of pipes (Kinder, 2012), and even to flavor wine. While steel and iron required painting to resist corrosion, lead naturally resisted deterioration. This made lead desirable for a number of uses, and through the middle ages, lead was used for roofing, coffins, tanks and gutters. Lead was also used at this time in producing artworks in the form of ink, statues, ornaments, and for making strips that joined together pieces of stained glass for church windows (Kinder, 2012). In later years, lead's malleability and resistance to erosion made it an appealing material to use to protect electrical wires, and was continually used in the construction of pipes and plumbing systems. It was not until the early 20th century that lead was assigned the two industrial purposes that make lead most ubiquitous today: inclusion in paint and inclusion in gasoline[3] (Reyes, 2007).

Lead in paint. Because of lead's resilience, when lead is added to paint, it increases paints ability to remain intact and become resistant to chipping or peeling. Lead has been used to give paint color or tint, and common forms of lead used for this purpose are white lead ($PbCO_3$) and vivid yellow lead chromate ($PbCrO_4$) (Crow, 2007). Leaded paint is also waterproof and opaque, making a small amount of lead paint able to cover relatively large surfaces. Lead paint has been used to coat furniture and toys, and

[3] While the Environmental Protection Agency claims that the greatest exposure to lead is caused by swallowing lead-based paint chips or breathing in lead contaminated dust, the EPA also recognizes lead is present today in drinking water. Lead is said to be rarely found in source water, although it has been (and continues to be) detected in tap water. Lead may enter tap water through the corrosion of metal pipes and plumbing materials. The EPA advises that homes built prior to 1986 are more likely to have lead pipes and fixtures. However, the EPA also states that newer homes are also at risk for lead contaminated drinking water, because, "even legally 'lead-free' plumbing may contain up to 8 percent lead," (Environmental Protection Agency, 2012). Industrial sites and hazardous waste sites (e.g.) Superfund sites, also act as contemporary sources of lead.

used for interior and exterior purposes on houses. While alternative chemicals shared these properties with lead, and were available as early as 1914 (e.g.- zinc based and titanium based paints), lead remained highly prevalent in paint for several years. The leaded paint industry was very profitable for manufacturers: in 1948 alone, Dutch Boy leaded paint had grossed $320 million (Markowitz & Rosner, 2000).

The use of lead paint for indoor purposes was banned overseas as early as 1909 (Moore, 2003); however it was not until 1970 that the United States passed the Lead Paint Poisoning Prevention Act marking the beginning of the phasing out of lead based paint. In 1978 the use of lead in paint was drastically reduced in the United States by the federal government. Following this legislation, lead was largely replaced with titanium dioxide (Crow, 2007). Regardless, smaller levels of lead are still used in paint today. The federal government currently permits up to 600 parts per million (ppm) of lead in household paint (California Department of Education, 2012). The use of paint with higher concentrations of lead is also lawful in the United States at certain industrial settings (Crow, 2007).

Lead in gasoline. In 1921 researchers employed by the automobile industry found that adding tetraethyl lead $[(CH_3CH_2)_4Pb]$ to gasoline curbed engine "knock"; a loud noise resulting from an explosion of unburned fuel inside the engine(Davis, 2002). Engine knock causes reduced fuel economy for the vehicle as well as wear on the engine. Prior to tetraethyl lead's discovery as an antiknock gas additive, General Motors had been reliant on ethanol, which not only served as an antiknock additive to gasoline, but burned "clean" (no carbon emissions), and increased horsepower. However, the automotive

industry could neither patent ethanol nor prevent consumers from producing it on their own. Because of its patenting potential, tetraethyl lead presented the auto industry with a more lucrative solution to engine knock. In 1923 DuPont, Standard Oil (later the Exxon Corporation) and General Motors patented tetraethyl lead, and co-founded the Ethyl Corporation for the purpose of producing tetraethyl lead (Davis, 2002). Within ten years of its inception, leaded gasoline dominated 80% of the U.S. gasoline market, grossing an annual profit of $300 million for General Motors and its shareholders (including DuPont, who simultaneously profited from Dutch Boy leaded paint) (Kitman, 2000) (Markowitz & Rosner, 2000).

Tetraethyl lead continued to be the most prominent antiknock agent used in gasoline in the United States through the 1960s, and remained unregulated even after the passage of the Clean Air Act in 1970 (Moore, 2003). In 1973 the Environmental Protection Agency passed the first laws regulating lead in gasoline, marking the beginning of a phase out of leaded gas. Amendments to the Clean Air Act in 1990 mandated the elimination of lead from all U.S. motor fuel by 1996. Ethanol, and other compounds, would slowly be reintroduced as antiknock agents. In the U.S., tetraethyl lead continues to lawfully be added to aviation fuel, and it is estimated that approximately 200,000 airplanes and helicopters in the United States are powered by leaded fuel (Peeples, 2012). The U.S. government also currently allows .05 grams of lead or less per gallon to lawfully be defined as “unleaded gasoline,” (Protection of Environment, 40 C.F.R. § 80.2). Thus, today, a car with a twelve-gallon tank may contain fuel with up to .6 grams of lead.

Lead and Neurotoxicity

For nearly as long as lead has been used for commercial and industrial purposes, it has been recognized that lead exposure poses serious threats to the healthy functioning of the human brain[4]. Greek physicists as early as the second century BC described lead as "deadly," with one physicist stating, "Lead makes the mind give way," (Needleman, 2009, p.245). In 1786, Benjamin Franklin wrote a letter discussing his observation of lead poisoning among printers in London, and emphasized that lead has been known to threaten public health for at least sixty years. In 1892, Dr. J. Lockhart Gibson treated a number of children with "severe neurological disease," (Needleman, 2009, p.245) at Brisbane Hospital in Australia. He determined the cause of the disease to be the lead in the white paint that was being used to paint railings and porches in the region.

In the United States, as early as 1910, experts with clinical and research experience with lead's neurotoxicity publicized findings and urged representatives from industry and government to ban lead (Markowitz & Rosner, 2000; Moore, 2003; Needleman, 1997; Rosner & Markowitz, 1985). Doctors treating Ethyl factory employees who exhibited violent insanity told the press their conditions were directly linked to lead exposure. Employees at the Ethyl Corporation referred to tetraethyl lead as, "looney gas," and the plant as "the House of Butterflies," because of hallucinations brought on by lead exposure (Needleman, 1997). In 1924, Dr. Yendell Henderson, a biochemist at Yale University (who formerly guided U.S. chemical warfare research

[4] One study theorizes the high consumption of wine by Ancient Roman aristocracy caused lead-induced psychosis, which contributed to the fall of the Roman empire (Gilfillan, 1965).

during World War I), wrote to the head of the U.S. Bureau of Mines[5] that leaded gas indicated, "General Motors is now deeply committed financially in reckless disregard of the possible and even probable industrial and public health hazard," (Henderson, 1924 in Needleman, 1997, p.97). One year later, Dr. Alice Hamilton, an occupational health expert at Harvard who had treated lead workers with brain damage, testified before the U.S. Surgeon general and lead industry representatives that, "lead is a slow and cumulative poison." Also presented to the Surgeon General and industry representatives[6] was data from Columbia University's Dr. Frederick Flinn, demonstrating death and toxicity in animals exposed to lead[7]. Markowitz and Rosner (2000) identified at least thirteen scholarly publications documenting the relationship between lead exposure and

[5] In the 1920s, the U.S. Bureau of Mines began conducting research on the safety of lead on grant funding from General Motors. One stipulation of this funding was that the Ethyl Corporation would be granted permission to screen all manuscripts prior to publication of findings, and no manuscript may be submitted for publication without joint consent from the Ethyl Corporation and the Department of Interior. In the same letter, Henderson addressed this, stating: "It seems to me extremely unfortunate that the experts of the United States Government should be carrying out this investigation on a grant from the General Motors. I feel very strongly that there is the most urgent need for an absolutely unbiased investigation," (Needleman, 1997). On this point, Needleman (1997) himself comments this correspondence reveals, "the Bureau of Mines, a government agency acting in a regulatory capacity, complicit with the industry. In straining to protect the corporation and its product, the Bureau agreed to act as a shield against the press, to camouflage the nature of the toxin, and to cede to the company control of the publication of any results," (p.97). This illustrates the early roots of lead's relationship with political-economy.

[6] In the face of testimony from experts, the U.S. government continually failed to implement policy regulating lead. In 1966, Dr. Clair Patterson (geochemist at California Institute of Technology) testified at U.S. Senate Hearings on the first Clean Air Act (attended also by industry representatives) that the presence of background lead levels in the U.S. were not healthy or natural. For further discussion and additional examples of this, see: Moore, 2003; Davis, 2002; Needleman, 1997; Markowitz & Rosner, 2000; 2003; Rosner & Markowitz, 1985). This is consistent with the notion that political-economic institutions- not human health and safety- give rise to law and public policy (Lynch & Michalowski, 2006; Marx, 1859; Quinney, 1970; Reiman, 2003). It is also consistent with critiques of the free market theory's argument that an unregulated economy has natural mechanisms to protect the environment (Burns, Stretesky, & Lynch, 2008)

[7] Lead exposure has since been linked to neurotoxicity using samples of rats, fruit flies, and monkeys

adverse impacts on the nervous system published prior to 1928, inclusive of studies documenting lead paint ingestion and effects on children.

While these early studies were very important, they generally understood neurological damage from lead exposure as having one of two outcomes in humans: (1) death, or (2) full recovery. The idea that someone could fully recover from lead poisoning was first challenged in an analysis by Byers and Lord in 1943. Their study examined twenty patients with elevated blood lead levels in infancy that were treated and thought to have recovered. The patients were subsequently administered neurological tests as children, where all but one demonstrated decreased IQ, learning problems, and behavioral disorders. As children, all patients appeared healthy in terms of acute lead exposure effects (e.g.) none reported/demonstrated nausea, dizziness, fever, headaches. Byers and Lord's study introduced the notion that neurological damage caused by lead exposure may not only be physically asymptomatic, but also persistent and irredeemable[8].

Following Byers and Lord, researchers published correlations between subclinical blood lead levels and neuropsychological impairments (de la Burdé & Choate, 1975; Kotok, 1972; Landrigan et al., 1975). In a landmark study published in the *New England Journal of Medicine*, pediatrician Herbert Needleman and colleagues studied subclinical lead levels and neurotoxicity using a sample of first and second grade children from Boston. Needleman et al. (1979) tested subjects' cognition as well as dentine lead levels, and interviewed childrens' parents and teachers (Needleman et al., 1979). Compared to

children with low dentine lead levels, teachers were found to rate children with high dentine lead levels as significantly more: distractible (36% vs. 14%), hyperactive (16% vs. 6%) and impulsive (25% vs. 9%). Children with high dentine lead levels had a mean IQ score significantly lower than children with low dentine lead levels (102.1 vs. 106.6). Importantly, these relationships held net of thirty nine control variables, including: social class, age, sex, race, weight, history of pica, level of parental education, parental occupation, and parental age at subject's birth—overcoming a limitation of prior studies. Since this study, Needleman and colleagues repeatedly found relationships between subclinical bone and blood lead levels among these and other emotional behavioral impairments (Needleman & Gatsonis, 1990; Needleman et al., 1990; Bellinger et al., 1987; Bellinger, Stiles, & Needleman, 1992), and the study of lead's neurotoxicity has grown exponentially.

Lead and emotional behavioral disorders. A subset of lead and neurotoxicity studies that continues to captivate scientists is lead exposure's relationship with emotional behavioral disorders. An emotional behavioral disorder can be described as a persistent condition in which abnormal emotions or behaviors impede an individual's ability to: build relationships, learn, and/or self-regulate mood or actions. These impairments may also manifest in the form of phobias and/or physical pain, and can include both externalizing (anger, aggression) and internalizing (anxiety, depression) symptoms. Cecil et al. (2008) found subjects who had increased blood lead levels as children demonstrated significantly decreased development of gray brain matter

[8] Even when individuals who have been exposed to lead have been properly screened and identified, the effectiveness of interventions, medicines, and therapies remains topic of contemporary debate among

(specifically in the prefrontal cortex and anterior cingulate cortex) as adults; these regions of the brain are responsible for regulating emotions, mood, executive functioning, and decision making. Lead exposure has demonstrated relationships with depression, anxiety, schizophrenia, conduct disorders, and inattention (Bouchard et al., 2009; Braun et al., 2008; Opler et al., 2008; Roddicks, 2007; Roy et al., 2009; White et al., 1993).

Using the Bayley Scales of Infant Development, Mendelsohn et al. (1998) found that children with blood lead levels between 10μg/dL and 24.9μg/dL reported significantly greater levels of fear, withdrawal, and disinterest, differing from children with decreased blood lead levels by a mean score of 14.2 points. Using the Achenbach Child Behavior Checklist, Burns et al. (1999) found increases in cumulative blood lead level among adolescent girls to be associated with corresponding increases in levels of anxiety, depression, aggression, withdrawal, thought problems, and attention problems. The same study found increases in cumulative blood lead level among adolescent boys to be associated with increased aggression and attention problems (Burns et al., 1999). Chiodo, Jacobson, and Jacobson (2004) also used the Achenbach Child Behavior Checklist, and found children to exhibit significantly increased withdrawn and inattentive behaviors at blood lead levels at as low as under 3 μg/dL.

Lead & ADHD. A growing literature has also documented lead's relationship with an especially prevalent emotional behavioral condition: attention deficit hyperactivity disorder (ADHD) (Braun et al., 2006; Chiodo et al., 2007; Nigg et al., 2010; Nigg et al., 2008; Roy et al., 2009; Wang et al., 2008). The *DSM-IV* describes ADHD as

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scientists (Moore, 2003; Rogan et al., 2001; Taylor et al., 2011)

difficulty maintaining attention and focus, hyperactivity, and difficulty controlling behavior. Nigg et al. (2010) found significant associations between childhood blood lead level and parent reports of their children's impulsivity and hyperactivity on the Connors Rating Scale. Braun et al. (2006) assessed 4,704 respondents in the NHANES and found parents of children with blood lead levels between 2 and 5 μg/dL were over four times more likely to also report that their child has an ADHD diagnosis than parents of children with blood lead levels less than .7 μg/dL. A case-control study of 1,260 subjects found nearly 76% of respondents diagnosed with ADHD to have blood lead levels greater than 5 μg/dL- a significant difference from participants not diagnosed with ADHD (where nearly 50% reported blood lead levels greater than 5 μg/dL) (Wang et al., 2008).

ADHD & crime. The link between ADHD and lead is relevant to criminology because studies have linked ADHD to criminal[9] and delinquent behavior (Dembo et al., 2011; Pratt et al., 2002; Sibley et al., 2011; Teplin et al., 2006; Winters et al., 2008). In a meta analysis, Pratt and colleagues (2002) found ADHD to carry a strong association to crime and delinquency. Of particular interest to criminologists has been the impulsivity component of ADHD, as it has been empirically linked to increased risk behavior (Winters et al, 2008), delinquency (White et al., 1994), crime (Jones & Lynam, 2009; Lynam et al., 2000; Yarbrough et al., 2011) and is theoretically argued to be an important dimension of low self control (Gottfredson & Hirschi, 1990). A meta-analysis of twenty one studies testing Gottfredson and Hirschi's General Theory of Crime finds self control

[9] Index and "street crimes"- this trend has not been observed among white collar or corporate criminals

a robust predictor of crime and analogous behavior[10] (Pratt & Cullen, 2000). In a sample of adult inmates, Cahill et al. (2009) find more than one in ten inmates with ADHD, while Eme (2009) estimates one in four adults in the U.S. correction system has ADHD. McCabe et al. (2002) find among 625 adjudicated youth, 15% of males and 21% of females had ADHD. When these rates are compared to the rates of ADHD in the general public- 3-7% of children and 4% of adults- ADHD appears overrepresented among offending populations. This is consistent with the overrepresentation of all emotional behavioral disorders among incarcerated populations, and associations between ADHD and offending do not appear exclusive to violent offending.

Lead & intellectual functioning. ADHD maintains high co morbidity with one of the earliest established neurological problems associated with lead exposure- learning problems. Furthermore, lead exposure has been linked to decreases in IQ points and intellectual functioning, even at very low exposure levels (Fulton et al, 1987; Canfield et al., 2003; Chiodo et al., 2004; Landrigan, 2000; Lanphear et al., 2000; Lanphear et al, 2005; Miranda et al., 2007; Schwartz, 1994; Wasserman et al., 2000). In a meta-analysis of lead exposure and childhood IQ, Schwartz (1994) finds across eight studies an overall increase in blood lead level from 10 to 20 μg/dL resulted in a corresponding decrease of 2.6 IQ points. Gilbert and Weiss (2006) report that for every 1 μg/dL increase in blood lead, a decrease of .87 IQ points can be anticipated. In an analysis of academic

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[10] Pratt & Cullen (2000) also find social learning theory variables (differential association, delinquent definitions) a robust predictor of criminal behavior (Akers & Sellers, 2009; but see also Pratt et al., 2010). Relatedly, parents of children with ADHD report that their children have peer problems at a rate almost three times higher than parents of children without ADHD (Strine et al. 2006). The same study finds that parents of children with ADHD report that their children have difficulties that interfere with friendships at a rate almost ten times higher than parents of children without ADHD (Strine et al., 2006).

achievement and neurotoxicity, Zahran et al. (2009) found children with elevated blood lead levels underperformed significantly on standardized tests, and Miranda et al. (2007) found fourth grade students with increased blood lead levels significantly underperformed on end of grade math and reading tests. Studies have demonstrated that lead exposure in early years (including infancy and exposure in utero) have long lasting impairments on intelligence which were detectable in childhood (Bellinger et al., 1987; Bellinger, et al., 1992; Wasserman et al., 2000) and again in young adulthood (Needleman et al., 1990). Muldoon et al. (1996) state that while that the developing nervous systems of children are more sensitive to lead exposure than adults, adult populations remain at risk for damage associated with lead exposure. They observed decreased performance on neuropsychological tests in a sample of elderly women at blood lead levels as low as 8 μg/dL (Muldoon et al., 1996).

Intellectual functioning & crime. The link between lead exposures and diminished intellectual functioning is relevant to criminology because a relationship between diminished intellectual functioning and criminal behavior has been observed[11] (Bellair & McNulty, 2010; Diamond, Morris, & Barnes, 2012; Hirschi & Hindelang, 1977; Lynam, Moffitt, & Stouthamer-Loeber, 1993; McGloin & Pratt, 2003). Lynam et al. (1993) studied participants from the Pittsburg Youth Study and found on average juvenile delinquents score eight IQ points lower than non-delinquents on standardized IQ tests. Lynam et al. (1993) also found IQ to be a significant predictor of subsequent self-reported delinquency. Mainstream theories of criminology also argue associations

[11] This does not apply to white collar and corporate criminals, where associations between offending and intellect have been found to be positively correlated (Friedrichs, 2009)

between intellect and all crime. In their *General Theory of Crime,* Gottfredson and Hirschi (1990) regard individuals with low self control to be “short-sighted” (p.90) and describe crimes as “[requiring] little skill.” Gottfredson and Hirschi (1990) go on to specify that they intend for their general theory of crime to, “explain all crime, at all times,” (p. 117). Among a sample of prison inmates, Diamond et al. (2012) report a mean IQ of 90, ten points below the mean score among the general population, and associate this IQ reduction with inmate violence. A meta analysis finds that juveniles with reduced academic performance offend more frequently, commit more serious offenses, and are more likely to persist in offending (Maguin & Loeber, 1996).

In sum, lead has a lengthy history of widespread industrial use and established neurotoxicity. Lead’s ability to cause long-term, asymptomatic effects on the human brain were demonstrated empirically in the 1940s, and have since been replicated numerous times over. Studies supporting these relationships find the association tenable using a variety of subjects (human, non-human, children, adults), and employing a range of study designs (cross sectional, longitudinal). Pertinent to a discussion of crime is lead’s relationship with well-established crime correlates, especially emotional behavioral disorders, impulsivity, ADHD, and intelligence. Taken together, it is reasonable to suspect lead exposure may set into motion neurological conditions (mood, emotions, behavior) conducive to criminal activity.

Lead and Crime

Given the well-established relationship between lead exposure and widely studied causes and correlates of crime (impaired cognition, emotional behavioral disorders, ADHD, impulsivity, learning problems, diminished IQ), a number of causal pathways linking lead to crime may be explicated (Narag, Pizarro, & Gibbs, 2009). In the 1990s, researchers became interested in assessing the dynamic between lead and criminal behaviors directly, and empirical tests of this association began to emerge. Research has supported associations between lead and property offenses (Nevin, 2007; Stretesky & Lynch, 2004), and violent offenses (Lynch, McGurrin, & Stretesky, 2001; Nevin, 2000; Reyes, 2007; Stretesky & Lynch, 2001). As of current, studies have tested and found support for the relationship between lead and criminal behavior at both micro and macro levels of analysis.

Micro level findings. Individual level studies have evinced a relationship between lead exposure and adult criminal behavior. For example, Pihl and Ervin (1990) measured lead levels in a sample of male adult inmates. They found that inmates convicted of violent offenses had mean hair lead concentrations significantly higher than inmates convicted of non-violent offenses (10.57ppm vs. 4.58ppm). Fergusson, Boden, & Horwood (2008) studied dentine lead levels and crime among a birth cohort of 1265 participants. Results indicated that dentine lead level at age 6-9 was significantly related to criminal convictions and self-reported criminal behavior at ages 14-21 (Fergusson et al., 2008). Controlling for confounders, participants with childhood dentine lead levels over 15 µg/g self-reported an average of about 13 criminal offenses as opposed to

participants with childhood dentine lead levels between 0-2 µg/g, who self-reported an average of about 6 criminal offenses (Fergusson et al, 2008). Fergusson and colleagues (2008) observed significant associations between lead and both property and violent crime combined. Wright et al. (2008) and Denno (1990) have also found an association between prenatal and childhood blood lead level and criminal arrests for violent crimes in young adulthood.

Macro level findings. These associations have persisted in macro level studies using aggregate measures of crime and lead at the international and national levels. Nevin (2007) employed time series analyses and found associations between preschool blood lead levels and index crime arrest rates across eight developed nations. Nevin (2007) detects an 18 year lag impact of preschool lead exposure on burglary rates in eight developed nations, five of which retain the significant association even when controlling for unemployment. In the U.S., Nevin (2000) measured gasoline lead exposure with annual U.S. gasoline consumption between 1941-1987 as reported by the U.S. Geological Survey. Nevin (2000) found gasoline lead level to explain unique variance in the U.S. violent crime rate from 1960-1998 while controlling for teenage pregnancy, unemployment, maternal education level, and age. In 2007, Reyes also uses aggregate crime and lead exposure rates in the U.S. to study the predictive power of childhood lead exposure relative to the oft studied 1990s crime drop. Controlling for income, employment, poverty, welfare dispersion, prison population, size of police force, beer consumption, age, and teen pregnancy rates, Reyes (2007) found 56% of the drop in violent crime in the 1990s is attributable to the reduction of lead in gasoline. Unlike

Nevin (2007), however, Reyes (2007) did not detect a significant relationship between lead and property crime.

Macro level studies have also demonstrated an association between lead and crime at the county level (Stretesky & Lynch, 2001; 2004). In their 2001 study, Stretesky and Lynch test the relationship between air lead level and homicide across 3,111 U.S. counties, controlling for nine other air pollutants and eight other relevant sociological variables (race, population, area, poverty, education, age, urban area, and region of U.S.). Findings revealed the relationship between lead and homicide to be significant, with results of a negative binomial regression indicating an incident rate ratio of 4.12. This suggests that homicide is over four times more likely in counties with the highest level of air lead as opposed to counties without air lead, net of confounders. None of the other air pollutants controlled for emerged as significant predictors of homicide. These findings demonstrated not only that the relationship between lead crime was tenable at the county level, but also, they suggest lead is a relevant characteristic of place for criminologists to consider in ecological studies of crime.

This suggestion was bolstered in 2004, when Stretesky and Lynch demonstrated that county air lead levels were significantly related to both county violent and property crime rates. Inclusion of lead and other sociologically relevant variables in regression models explained 44% the variance in violent crime and and 34% of the variance in property crime. The same study also found air lead level and resource deprivation to have an interactive effect on violent and property crime rates, suggesting the impact of lead on crime is exacerbated in resource deprived areas.

A recent study uses aggregate statistics and finds a relationship between lead and crime across six U.S. cities: Chicago, Minneapolis, Indianapolis, Atlanta, New Orleans, and San Diego (Mielke & Zahran, 2012). Mielke and Zahran (2012) examine the relationship between air lead (measured by calculating annual city estimates of air lead from vehicle traffic from 1950-1985) and number of aggravated assaults reported to police from 1972-2007, employing lags theoretically informed by the age-crime curve. Mielke and Zahran (2012) control for income per capita as well as percent of population between 15 and 24 years of age. Their findings suggest that for every 1% increase in lead air a corresponding .46% increase in aggravated assault rate can be anticipated 22 years following that increase. Mielke and Zahran (2012) stated that their full model explained 90% of the variance in reported aggravated assault rate across all of the cities in their analysis.

Lead and Delinquency

In addition to associations found between lead and adult crime (Denno, 1990; Wright et al., 2008), associations have also been found between lead and juvenile delinquency (Needleman et al., 1996; Olympio et al., 2010).

The relationship between lead and juvenile offending at the individual level has garnered particular interest among researchers (Denno, 1990; Dietrich et al, 2001; Needleman et al., 2002; Olympio et al., 2010). This is reflective of trends in lead and neurotoxicity in general, and is likely related to the fact that children are especially vulnerable to environmental toxins (Landrigan & Carlson, 1995; Landrigan, Kimmel, Correa, & Eskenazi, 2004; Moore, 2003; Reyes, 2007). In 1993, a report by the National

Research Council established that children are especially vulnerable to environmental toxicity for four reasons. Landrigan et al (2004) describe these four reasons as (1) children have a comparatively higher exposure to environmental agents, (2) children's metabolisms are under-developed, (3) developmental processes are susceptible to disruption during phases of rapid growth, and (4) exposure early in the life course leads to longer time frames for diseases to develop. What this implies is a differential age effect for the association between lead exposure and human behavior. As such, one consequence of this may be increased rates of juvenile delinquency.

Findings from the empirical literature document associations between lead exposure and juvenile delinquency. For instance, Denno (1990) found childhood lead poisoning to significantly predict juvenile delinquency among black men, following a sample of black children through young adulthood. Needleman et al. (1996) found increased bone lead burdens among participants in the Pittsburgh Youth Study to be significantly related to self-reports of delinquency at age 11 (log transformed scores on the SRD indicated 1.51 for a low lead group compared to 2.39 for a high lead group, p=.04). The same study also found teachers and parents were more likely to indicate higher rates of aggressive and delinquent behavior on the Child Behavior Checklist for children with high bone lead burdens. These findings were replicated recently implementing the same delinquency measures but using dentine lead level on a sample of adolescents from Brazil (Olympio et al., 2010). A case control study of adjudicated juvenile delinquents (compared to non-adjudicated youth) found after controlling for confounders, adjudicated youth were four times more likely to have increased bone lead

burdens (greater than 25 ppm) than controls (Needleman et al., 2002). Dietrich et al. (2001) studied this relationship prospectively, and found prenatal and postnatal blood lead levels to significantly predict frequency of self-reported teenage delinquency. Dietrich and colleagues (2001) used responses on the Self-Report of Delinquent Behavior to measure delinquency, which includes items capturing both violent and non-violent offenses.

In sum, lead appears to consistently relate to crime across several units of analysis: individuals, cities, counties, and countries. Further, these studies have employed a wide range of methodologies, and have documented a link between lead and crime prospectively in longitudinal designs, utilizing birth cohorts, panel studies, and time series techniques. By design, these studies illustrate the hypothesized temporal ordering of lead as a causal mechanism in explaining crime. Lead and crime relationships have also been observed in cross sectional studies using case control designs. Taken together, these findings suggest that lead should not be discounted as a factor in explaining crime. A study of lead and crime at the community level, however, is further justified by reviewing literature discussing the factors that connect lead exposure to place.

The Spatial Distribution of Lead

According to the EPA's Toxic Release Inventory (TRI) database, in 2010 alone, industries across the United States reported disposing, transporting, or releasing over 570 million pounds of lead and lead compounds. The EPA also states that over 300 Superfund sites on the National Priorities List indicate lead presence (suggesting the

presence of lead at over 25% of Superfund sites). In 2011, Mielke, Laidlaw, and Gonzales analyzed soil lead levels across 90 U.S. urban areas and found anthropogenic lead deposited from leaded gasoline sold between 1950 and 1982, demonstrating lead's ability to accumulate and persist in surface materials. According to the 2000 Census, there are 17.4 million housing structures in the United States built before 1940 (a risk factor for lead paint exposure), with other accounts estimating up to 38 million U.S. housing units containing lead-based paint (Jacobs et al., 2002).

These sources of lead, however, are not randomly distributed. For example, using TRI data, Masters, Hone, and Doshi (1998) find the distribution of lead to be highly skewed, with over 80% of all U.S. counties reporting no release of lead or lead compounds in 1991. For that same year (1991), TRI reports indicate industries reported disposing of or releasing 40,311,787 pounds of lead or lead compounds. Thus, the dispersion of over 40 million pounds of lead appears restricted to approximately 451 (out of 3,111) U.S. counties. Similarly, Stretesky and Lynch (2001; 2004) found presence of air lead across U.S. counties using the Cumulative Exposure Project (CEP) to range from 0 $\mu g/m^3$ to .172 $\mu g/m^3$, with a mean and median of .001, also indicative of skewness. In a study assessing lead poisoning in North Carolina, Hanchette (2008) analyzes North Carolina's Childhood Lead Poisoning Prevention Program and finds positive spatial autocorrelation among county lead poisoning prevalence rates each year from the years 1994 to 2005. In 2008, the EPA identified 21 areas in 22 counties where air lead levels exceeded national ambient air quality standards. This observed disproportionality in the

distribution of lead, has resulted in what this study will refer to as lead hotspots- areas with disproportionately high concentrations of lead.

Explaining the lead hotspot phenomenon. Explaining this phenomenon of lead hotspots requires recognition that the spatial distribution of lead is inextricably wedded to historical, political, economic, and social forces (Hanchette, 2008; Kitman, 2000; Lynch, 2004; Moore, 2003; Davis, 2002; Markowitz & Rosner, 2000; 2003; Needleman, 1997; Rosner & Markowitz, 1985; Stretesky, 2003; Stretesky & Lynch, 2004). Consider that lead's neurotixicity was known by manufactuers and the U.S. government for over sixty years before the first act of legislation was passed regulating lead presence in products. Further, when policies were eventually implemented, they were not retroactive in nature, in spite of lead's bioaccumulative properties. As such, facilities built prior to lead paint regulation carry higher concentrations of lead than newer structures (Jacobs et al., 2002; Lanphear et al., 1998). Further, areas proximal to freeways, roadways, and heavy traffic patterns carry higher lead concentrations, as new lead gasoline deposits commingle with anthropogenic deposits (Needleman & Bellinger, 1991). Because the use of lead is still permissible in some industries, and present at a number of Superfund sites, centers of industry and smelteries also typify lead hotspots. Taken together: lead hotspots tend to be urban areas (Mielke, 2005).

Urban ecology and community composition are also linked to historical, political, economic and social factors (Lynch, 2004; Lynch & Michalowski, 2006). Housing choices increase with income, and urban ecologists have illustrated a tendency of income to increase as distance from industrial zones (Park & Burgess, 1924) and environmental

hazards also increase. Public policy has shaped community composition through history, and housing practices such as redlining, regulation on interest rates and subprime mortgage lending, as well as bussing and school segregation have left legacies in American communities and shaped the composition of place (Wacquaint & Wilson, 1989).

The consequence of these relationships is observed differences in community composition relative to race, class, and ethnicity (Park & Burgess, 1924). For example, institutionalized racism and classism (zoning, covenants, redlining, subprime lending) have tempered educational, occupational, and housing choices for individuals, resulting cumulatively in the overrepresentation of minorities in poor, urban communities (Massey & Denton, 1993). Comparisons of black and white communities reveal disparate income levels, with black neighborhoods earning less overall than similarly situated white neighborhoods (Pattillo, 1998). These segregation practices organize the sociological composition of space in a way that makes race and class power lines visible; with ecological goods (employment opportunities, cleaner environments) farther in distance, and ecological bads (pollution, decay) increasingly proximal to minority groups most marginalized by political-economic practices.

Lead's distribution and urban ecology's shared underlying relationship to these factors force lead and communities to converge in time and space in such a way that is reflective of overarching power dynamics in the United States (Lynch, 2004; Stretesky, 2003). In turn, the nonrandom distribution of lead parallels the nonrandom distribution of income, race, and ethnic minority communities. Ecological studies observe sociological

differences between communities with and without increased lead presence (Hanchette, 2008; Stretesky, 2003). Because income precludes access to newer schools and housing units, individuals of lower socioeconomic status become disproportionately restricted to older buildings (increased lead paint and lead plumbing presence). Historically, communities lacking the social capital and resources to organize and resist interstate and expressway construction were disproportionately targeted by builders (increased leaded gasoline presence). This same logic can be extended to environmental hazards and waste sites, which since the 1970s, have tended to follow a path of least resistance (Burns et al., 2008). These historical, political, economic, and social factors act in concert, and generate observable, consistent characteristics of lead hotspots.

Correlates of lead hotspots. Racial disparities have been observed across lead hot spots. In an assessment of lead exposure across U.S. counties, Stretesky (2003) found counties with the largest proportions of black youth contained 7.9% more air lead than counties with no black youth. Further, the same study found that counties with the largest presence of white youth have nearly 10% less air lead than counties with the smallest proportion of white youth. Stretesky (2003) found these compositional changes were observable even while controlling for urbanization, income, location of manufacturing sites, age of house, and housing values. Mielke et al. (1999) studied soil lead levels across census tracts in New Orleans and found 60% of New Orleans black population resided in tracts with high levels of lead in soil. By comparison, the same study found 37% of New Orleans' white population to be residing in tracts with high levels of lead in soil. Lanphear, Weitzman, and Eberly (1996) found black children

significantly more likely than white children to be exposed to lead dust and to be residing in houses with poor interior paint conditions.

Income disparities are also observable across lead hot spots. Lanphear and Roghmann (1997) found income to have a significant, inverse relationship with level of lead dust found in home. Diawara et al. (2006) studied levels of lead in topsoil in Pueblo, Colorado and find higher proportions of low-income communities situated closer to lead-contaminated areas. Jacobs et al. (2002) collected a nationally representative sample of 831 housing units between 1998 and 2000 and found 35% of households with incomes less than $30K a year resided in housing units with lead hazards, and 38% of households living in poverty resided in housing units with lead hazards. By comparison, the same study found 19% of households earning equal to or greater than $30K a year to live in units with lead hazards, and 22% of households not in poverty to live in units with lead hazards.

Differences in ethnicity are visible across lead hotspots. In addition to observed income disparities, Jacobs et al. (2002) find differences in rates of Hispanic residents occupying housing units with lead hazards: 32% of Hispanic or Latino residents reside in units with lead hazards present as opposed to 24% of non-Hispanic or Latino residents. Diawara et al. (2006) observe that populations in census tracts with lowest lead soil levels are nearly 80% non-Hispanic white. They also observe that as soil lead level increases within census tract, there is a corresponding significant, positive increase in the percentage of Hispanic residents (Diawara et al., 2006). In Sargent et al.'s (1997) multivariate analysis of predictors of elevated childhood blood lead levels ($\geq$10 µg/dL),

as percentage of recent immigrants increased among census tracts, a corresponding increase of .56 was observed in percentage of children with elevated blood lead levels. This relationship held even while controlling for other significant socio-demographic variables.

In the same study, researchers found a relationship between residential mobility and lead hot spots. Sargent et al. (1997) analyze census tracts in Providence, Rhode Island, examining socio-demographic predictors of childhood blood lead levels. Sargent et al. (1997) found the percentage of owner occupied houses and the percentage of stand-alone vacant homes to be associated with more than 60% of the variation in elevated childhood blood lead. In addition to the above referenced association between percent of recent immigrants ($b=.56$, $p = .003$) and elevated childhood blood lead level, this study found a significant relationship between percentage of vacant houses ($b= 5.18$, $p = <.0001$) and elevated childhood blood lead level. Sargent et al. (1997) found these predictors significant while simultaneously controlling for eleven other socio-demographic variables. Their final parsimonious model, which included percent screened, households on public assistance, percent homes built prior to 1950, houses vacant, and percent of recent immigrants was associated with 83% of the variance in elevated childhood blood lead.

Connecting lead hotspots to exposure patterns. Disparate distributions of lead have been linked to disparate exposure patterns. Studies evincing this link demonstrate an important relationship between environmental lead and human body lead burden (Brunkenreff, 1984; Hayes et al., 1994; Lanphear et al., 1996; Lanphear et al., 1998;

Pirkle et al, 1994; Reyes, 2007; Schwartz & Pitcher, 1989; Stretesky & Lynch, 2001). For example, Hayes et al. (1994) finds a strong correlation ($r=.8$, $p<.001$) between air lead level and blood lead level, with a regression model finding each decrease in .1 µg/m^3 in mean air lead level (when air lead was around 1 µg/m^3) to be associated with a corresponding .56 µg/dL decrease in median blood lead level. When federal policy initiatives called for a reduction of lead in gasoline, an analysis of the National Health and Nutrition Surveys (NHANES) revealed the average blood lead level for Americans aged 1 to 74 decreased from 12.8 µg/dL at NHANES II (1976-1980) to 2.8 µg/dL at NHANES III (1988-1991) (Pirkle et al., 1994). This marked an overall decrease in national blood lead level by 78%. Associations between air lead, soil lead, and blood lead levels have also been observed (Laidlaw et al., 2012; Zahran et al., 2011). Aschengrau et al. (1994) report every 1000-ppm decrease in soil lead level corresponded with a 1.12-1.35 µg/dL decrease in blood lead level. Thus, prior studies demonstrate that the presence of environmental lead implies a presence of lead in the human body, and vice versa.

As anticipated, it logically follows that groups disproportionately exposed to environmental lead sources are more likely to carry higher body lead burdens (Bernard & McGeehin, 2003; Brody et al., 1994; Scinicariello, Abadin, & Murray, 2011; Lanphear et al., 1998; Pirkle et al., 1994). Bernard and McGeehin (2003) assess the NHANES III from 1988-1994 and found percentage of non-Hispanic blacks with blood lead burdens between 5-10 µg/dL to be twice the rate of non-Hispanic whites with the same blood lead levels (32% vs 15%). When blood lead level increased from 10-20 µg/dL, non-Hispanic

blacks reported these levels at three times the rate of non-Hispanic whites (12% vs 4%). Further, individuals living at or below the poverty level were more than twice as likely to report a blood lead level of 5-10 µg/dL as those living above poverty (30% vs 14%). According to Brody et al.'s (1994) findings, when income and location of residence were considered, race effects became exacerbated: blacks who lived in cities or reported low income were more than twice as likely as whites to report elevated blood lead levels. Lanphear et al. (1996) reach similar conclusions on a smaller sample of residents of Rochester, New York, finding race and income to be significantly related to blood lead level and lead dust exposure.

Socio-demographic relationships with lead distribution and exposure patterns are consistent with broader findings in environmental justice research: race, class, and ethnicity are significantly related to environmental hazards. Specifically, environmental hazards, like lead, appear to be disproportionately close in proximity to communities with high percentages of racial and ethnic minorities, and high rates of poverty (Lerner, 2005; Brulle & Pellow, 2006; Bullard 1994; 1996; Checker, 2007; Hipp & Lakon, 2010; Opp, 2012; Pastor, Morello-Frosch, & Sadd, 2006; Stretesky & Lynch, 2002). A meta-analysis of 49 environmental equity studies finds racial inequity consistently emerged as a significant variable relating to environmental hazards, regardless of level of analysis or type of hazard examined (Ringquist, 2005). In a study assessing school segregation and proxy to EPA identified environmental hazard sites (including Superfund sites), Stretesky & Lynch (2002) find schools with high rates of racial and ethnic minority student enrollment and high rates of students participating in free or reduced lunch programs are

closer in distance to hazard sites. Environmental justice studies have grown exponentially over the past twenty years; however, environmental studies remain underrepresented (constitute less than 4%) of the criminology literature (Burns et al., 2008; Lynch, McGurrin, & Fenwick, 2004).

In sum, the spatial distribution of lead appears as nonrandom. Data indicates that lead highly concentrates in some areas over others, resulting in lead hotspots. Studies suggest lead hotspots tend to be urban areas, have high rates of racial and ethnic minority populations, have high rates of poverty, and evince trends of residential mobility. This, in turn, has resulted in disproportionately high exposure patterns for minority groups, particularly African Americans, Hispanics, city residents, and low income individuals.

Combined with the adverse behavioral outcomes associated with lead, it is suggested lead exposure could contribute to disproportionate rates of crime and delinquency in: urban areas, areas with high rates of poverty, areas with high percentage of racial and ethnic minorities, and residential mobility. A consequence of this would be disproportionate rates of racial and ethnic minorities, urban residents, and low income individuals involved in the criminal justice system. In spite of criminology acknowledging race, ethnicity, and urban disadvantage as correlates of community crime rates, lead exposure's relationship with crime has yet to be tested at the community level. Further, lead exposure has yet to be integrated into community level crime theories.

Chapter Three:

Mainstream Interpretations of Crime and Place

In the previous chapter, it was suggested that the distribution of lead and crime are related, and that as a result, the distribution of lead may play a role in explaining the geographical distribution of crime. However, lead represents a variable that has *yet to be included* in mainstream criminology theory and community-level empirical assessments of crime. What remains to be discussed in this study are the explanatory variables that *have been included* in mainstream criminology theory and community-level empirical assessments of crime. The aim of chapter three is to review literature that documents what mainstream criminologists have established about the spatial distribution of crime. Also presented are the community level policy initiatives that have been informed by mainstream criminology theory and research. Chapter three concludes by arguing why these theories and policies are limited with regard to lead hotspots.

The Spatial Distribution of Crime

According to FBI's Uniform Crime Report, in the year 2010, there were approximately 10,329,135 index crimes reported in the United States. Of these crimes, 1,246,248 (12%) were violent crimes and 9,082,887 (88%) were property crimes. Estimates for violent crime were obtained by adding the totals of reported murders (14,748), rapes (84,767), robberies (367,832), and aggravated assaults (778,901).

Estimates for property crime were obtained by adding the totals of reported burglaries (2,159,878), larceny-thefts (6,185,867), and motor vehicle thefts (737,142). Alternatively phrased, the sum of index crimes can be broken down as: 59.8% larceny-theft, 20.9% burglary, 7.5% aggravated assault, 7.1% motor vehicle theft, 3.6% robbery, .8% rape, and .1% murder.

The distribution of index crime, however, is not random. For example, when index offenses are broken down by region, differences between the Western, Southern, Northeastern, and Midwestern United States can be observed. The UCR indicates the property crime rate (per 1,000 inhabitants) in the South (34.39) is 1.19 times higher than the property crime rate in the West (28.87), 1.21 times higher than the Midwest (28.34), and 1.63 times higher than the Northeast (21.16). A similar pattern emerges across regions for violent offenses.

Crime also is distributed differentially across states. Table 1 uses UCR data to display the top and bottom five states with respect to rate of index offending. Each state's overall crime rate was calculated using the number of index offenses committed in each state and each state's population. The national index crime rate in 2010 was approximately 33.46 offenses per 1,000 U.S. residents. The state with the highest index crime rate was South Carolina, with 44.98 index offenses per 1,000 inhabitants. According to this data, offenses in South Carolina occurred twice as frequently as offenses in North Dakota, South Dakota, or Idaho (the bottom three states for index offending rates, respectively). Offenses in South Carolina, Tennessee, Texas, Louisiana,

and Florida occurred at a rate that is more than twice as frequent as offenses in North Dakota. The disproportionality of crime has also been evinced at the county level (Baller

Table 1. *Top and Bottom Five States for Rate of Index Crimes, per Uniform Crime Report, 2010*

Top 5			Bottom 5		
Name	Rate*	# Offenses	Name	Rate*	# Offenses
South Carolina	44.98	208,055	North Dakota	19.93	13,408
Tennessee	42.71	271,053	South Dakota	21.21	17,268
Texas†	42.33	1,064,477	Idaho	22.17	34,751
Louisiana	41.97	190,243	New York	23.33	452,138
Florida	41.01	771,004	New Hampshire	23.53	30,980

* Per 1,000 inhabitants

†Texas alone accounted for approximately 10.31% of all index crime in the U.S. in 2010

Table 2. *Annual Rates and Counts of Index Crimes by Community Type, per Uniform Crime Report, 2010-2008*

		2010		2009		2008	
Community Type	Crime Type	Rate*	Count	Rate*	Count	Rate*	Count
Metropolitan Statistical Area	Violent	4.28	1,107,026	4.59	1,177,758	4.89	1,242,047
	Non-Violent	30.47	7,874,193	31.60	8,113,233	33.52	8,514,199
	Total	34.75	8,981,219	36.19	9,290,991	38.41	9,756,246
Cities Outside Metropolitan Statistical Area	Violent	4.00	80,340	3.96	79,446	3.92	78,232
	Non-Violent	36.00	724,070	36.58	733,161	37.46	747,713
	Total	40.00	804,410	40.55	812,607	41.38	825,945
Non-Metropolitan Counties	Violent	1.95	58,882	2.02	61,194	2.05	61,733
	Non-Violent	16.06	484,624	15.70	474,577	16.81	506,003
	Total	18.00	543,506	17.72	535,771	18.86	567,736

* Per 1,000 inhabitants

et al., 2001; Beaver & Wright, 2011; Kposowa, Breault, & Harrison, 1995; Phillips, 2006).

Crime rates also vary by community type or with respect to the designation of communities on a continuum from metropolitan to nonmetropolitan areas. Table 2 presents UCR data from the years 2008, 2009, and 2010, classified by community type. The UCR rates and counts are categorized by area of occurrence, specifically, metropolitan statistical area, cities outside metropolitan areas, or nonmetropolitan counties. According to these figures, approximately 87% of all index offending in 2010 occurred in metropolitan statistical areas.

In 2010, rates of violent index offending were highest in metropolitan statistical areas, with violent offenses being more than twice as frequent in these areas than non-metropolitan counties. Metropolitan statistical areas accounted for 89% of all violent index offenses in 2010, and 87% of non-violent (property) crimes. Further, these observations appear stable across each year. These data are consistent with research that finds index crime, like lead, concentrates in cities and urban areas (Bursik, 1984; Cullen & Levitt, 1999; Venkatesh, 2000; Massey, 1990; Massey & Denton, 1993). This appears particularly true of violent crime (see also Krivo & Peterson, 1996).

Crime is also found to be distributed non-normally within community areas, including across census tracts (Kubrin, Squires, Graves, & Ousey, 2011; Krivo & Peterson, 1996; Garcia, Taylor, & Lawton, 2007; Griffiths & Chavez, 2004; Mears &

Bhati, 2006; Morenoff, Sampson, & Raudenbush, 2001; Sampson & Wilson, 1995; Logan & Stults, 1999). For example, Krivo and Peterson (1996) examine index crime using 1990 census data from 177 tracts in Columbus, Ohio. They find a strong, positive correlation between violent crime and extreme disadvantage (r=.717), and find rates of both property and violent crimes to be significantly higher in extremely economically disadvantaged tracts (Krivo & Peterson, 1996). Mears and Bhati (2006) study neighborhoods in Chicago and find that a one standard deviation increase in neighborhood resource deprivation is associated with a corresponding 60% increase in homicides.

More recently, criminologists have taken up the study of crime across micro-geographical areas (addresses, streets, blocks), where they have continued to find evidence of non-random distributions of crime (Braga, Papachristos, & Hureau, 2010; Braga & Weisburd, 2010; Eck, Clarke, & Guerette, 2007; Sherman, Gartin, Buerger, 1989; Weisburd, Morris, & Goff, 2009). In a widely-cited study, Sherman et al. (1989) analyze 323,979 police calls for service over the course of one year, across 115,000 addresses and intersections in Minneapolis. Their findings revealed that 50% of all calls originated at 3% of all places (Sherman et al. 1989). Alternatively stated, approximately 161,990 calls came from 3,450 areas, meaning that each of these areas where calls for service are concentrated generate approximately 47 annual calls for service.

In their study, Weisburd et al. (2009) examined juvenile crime on street segments in Seattle across a fourteen year time frame (1989-2002). Their findings indicate that across all years studied, 100% of juvenile arrests occurred within 2-5% (less than 1,400)

of all street segments (n=29,849) in Seattle. The same study found over the same time frame that 50% of all juvenile arrests occurred within less than 1% (less than 299) of all of Seattle's street segments (Weisburd et al., 2009). Further, Weisburd and colleagues (2009) state that the locations of these delinquency concentration areas appeared relatively stable over the course of fourteen years.

Taken together, areas with high concentrations of crime in space have been defined by criminologists as crime hotspots (Eck et al., 2005; Paulsen & Robinson, 2009). On the issue of defining what is meant by crime hot spot, Eck and colleagues (2005) state, "Though no common definition of the term hot spot of crime exists, the common understanding is that a hot spot is an area that has a greater than average number of criminal or disorder events, or an area where people have a higher than average risk of victimization" (p.2). This study draws on Eck and colleagues (2005) understanding of crime hotspots to facilitate an analysis of the relationship between lead and crime hotspots at the community level. For purposes of this research the term "area" is conceptualized as community area as defined by the U.S. Census Bureau and the University of Chicago (Chicago Police Department, 2008).

Explaining Crime Hotspots

While the study of crime hotspots has yielded a great deal of attention from criminologists in recent years (Lersch & Hart, 2011), researchers have been observing the existence of crime hotspots for over a century. In doing so, scholars have documented a number of community-level attributes that correlate with crime hotspots. Further, researchers have incorporated these covariates into theories that attempt to explain why it

is that crime is concentrated in some areas over others. The observation of crime hotspots, correlates of crime hotspots, and explanations of crime hotspots are all rooted in the work of nineteenth century statisticians and sociologists (Levin & Lindesmith,1937).

The cartographic school of criminology. Levin and Lindesmith (1937) attribute the earliest systematic studies on the ecology of crime to the work of attorney and cartographer Andre-Michel Guerry and astronomer and statistician Adolph Quetelet. Guerry used cartography to map occurrences of crime in France. As part of his method, Guerry divided France into five sections (north, west, south, east, and centre), and mapped data on rates of crime by type from the years 1825 to 1830. Guerry also employed maps to study co-occurance of crime and gender, age, climate, education, illegitimacy, and philanthropy (Paulsen & Robinson, 2009). Among his findings were the observations of higher rates of property crime than violent crime in Northern France, while the opposite appeared true in Southern France. From his maps, it became Guerry's speculation that poverty, lack of education, and population density acted as causes of crime[12].

Quetelet earned his doctorate in mathematics from the University of Ghent. He subsequently became interested in whether laws of regularity found in the physical sciences applied to human behavior. Quetelet, like Guerry, was among the first to employ probability and statistics to assess demographic data (Beirne, 1987). In doing so, he was able to quantitatively

[12] Guerry's data and corresponding maps are discussed and presented by Friendly (2007), and at Friendly's corresponding website: http://www.datavis.ca/gallery/guerry/guerrymap.html.

assess patterns and consistencies in human behavior, including crime and place[13]. In, "A Treatise on Man: and the Development of his Faculties," Quetelet (1842), analyzes data on the distribution of crime across France and across countries. Congruent with Guerry, Quetelet found that property crime in France occurred with a greater frequency than violent crime (approximately 3:1). He also observed fluctuation in crime rates across departments of France, by dividing departments into three classes: (1) departments where rates of violent and property crime were above average (e.g. Corse, Landes), (2) departments where rates of violent and property crime were below average (e.g. Creuse, Indre), and (3) departments where either rates of violent or rates of nonviolent crime were below average (e.g. Var, Hautes-Alpes). Quetelet observed that departments that had more industrial establishments, greater inequity between "riches and wants," greater influxes of people, and greater heterogeneous racial and ethnic populations also displayed evidence of higher crime rates. On this matter, Quetelet concludes:

> "The countries where frequent mixture of the people takes place; those in which industry and trade collect many persons and things together, and possess the greatest activity; finally, those where the inequality of fortune is most felt, all things being equal, are those which give rise to the greatest number of crimes," (1842, p.95).

The work of both Guerry and Quetelet inspired English scholars, where after studies on the ecology of crime continued to emerge in the nineteenth century. For example, Levin and Lindesmith (1937) describe the work of Henry Mayhew, who used

[13] In addition to Quetelet's observations on crime and place, Quetelet also wrote about relationships between crime and gender as well as crime and age. For more detail on Quetelet's contibutions to positivist

official statistics to map juvenile delinquency, female criminality, recidivism, and other types of crime across London, as well as across counties in England and Wales from 1841 to 1850. Much like contemporary UCR data reveals, Mayhew found counties that had large cities in them had higher rates of juvenile delinquency. Much like contemporary hot spot research, Mayhew broke down the county containing London and found 41% of all juvenile offenders were concentrated into one of seven police districts, with another 24% concentrated to another. These studies by Guerry, Quetelet, Mayhew, and others concerning the distribution of crime from 1830 to 1880, comprise what has been referred to as the cartographic school of criminology (Paulsen & Robinson, 2009).

The contributions of the cartographic school of criminology, especially the work of Quetelet, would go on to influence the research of French sociologist Emile Durkheim. In the late 1800s, Durkheim studied the sociological changes associated with the emerging shift from agrarian-based economies to industrialized economies, or what he described as the transition from mechanical to organic societies. Durkheim (1892) theorized that these shifts resulted in a phenomenon that he termed anomie—which translates literally into "normlessness." Anomie is described by Durkheim as being present when fast-paced societal changes take place, producing a state of normlessness for individuals in which individuals become unclear concerning the content of the collective conscience. Durkheim argued that these rapid structural changes disrupt the collective conscience, or a society's uniform sense of behaviors that are right or wrong (Lersch & Hart, 2011). Durkheim went on to explain that when individuals cannot rely

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criminology, see Beirne (1987).

on the collective conscience to regulate their behavior, they rely only on their own hedonistic tendencies, and their wants and desires become unchecked. This observation has been interpreted as a society losing its ability to control the behavior of its people (Kornhauser, 1978). Durkheim (1897) also pointed out that as wants and desires grew, and there was also a failure in the structure of society increase the means to meet these wants and desires, feelings of despair and frustration emerge, a position linked to social strain (Agnew, 1992; 2001; 2005).

Durkheim examined the effect of anomie in a study of suicide rates across Europe. Durkheim, like Guerry, Quetelet, and Mayhew, used quantitative data and cartography to study human behavior. When he mapped suicide rates across gender, region, ethnicity, and religion, he observed different rates of these behaviors across the subgroups under examination. Among his findings were that in times of economic transition (anomic conditions), suicide rates increased (Durkheim, 1897). Durkheim (1897) also describes the "world of trade and industry" as inherently anomic, and finds higher suicide rates among professionals employed by trade and industrial sectors. Durkheim (1897) coined the phrase anomic suicide, which he described as depending, "not on the way in which individuals are attached to the society but on the way in which it controls them," (p. 283). While Durkheim never wrote about crime or delinquency explicitly in *Suicide*, his work is often regarded as the cornerstone for many contemporary criminological theories (Vold & Bernard, 1979).

In sum, the existence of crime hotspots has been demonstrated by researchers since the nineteenth century. The earliest studies of crime and place appeared from 1830-

1880, and are referred to as the cartographic school of crime. The earliest observed correlates of concentrated crime were reported by Guerry, Quetelet, and Mayhew as poverty, education, industry, population density, race, ethnicity, and mobility. Explanations as to why human behavior differs across place are elaborated upon by Durkheim in the 1890s, when he introduces the concept of anomie. It is noteworthy that the correlates of crime hotspots established by the Cartographic School of Crime would later come to be established as correlates of lead hotspots (Diawara et al., 2006; Jacobs et al., 2002; Lanphear et al., 1996; Lynch, 2004; Mielke et al., 1999; Sargent et al., 1997; Stretesky, 2003;).

The Chicago school. In the 1920s and 1930s, sociologists affiliated with the University of Chicago and the Institute for Juvenile Research in Chicago, like Durkheim, became interested in the impact of industrialization on deviant behavior, crime and social disorganization. Specifically, these scholars were interested in the relationship between industrialization and urban ecology. At the turn of the century, the growth of industry in the United States spurred changes in the composition of American cities, including the expansion of industry as well as growth in immigrant populations. The city of Chicago exemplified much of the changes typical of American cities at the time, and therefore acted as "the perfect natural laboratory" (Kubrin, Stuckey, & Krohn, 2009, p.83) for the study of industrialization and urban sociology. These studies included observations of community level crime and delinquency. Given their university affiliation, and setting for their work, these scholars and their studies are commonly referred to as the Chicago school.

Two of the most prominent scholars of the Chicago school were Robert Park and Ernest Burgess. Park and Burgess (1925) drew parallels between patterns of survival and behavior in natural ecosystems and patterns of survival and behavior in cities. Park and Burgess argued that cities expanded outward in concentric zones, and developed a model referred to as the Concentric Zone Theory. Park and Burgess observed five concentric zones, with the first centermost zone being the Central Business District (CBD). At the turn of the century the CBD was quickly growing and expanding, and continually encroaching on communities in zone 2 -- the transitional zone. The second zone was termed the transitional zone because of the high rates of change the CBD imposed on this zone. The transitional zone was observed to carry higher concentrations of immigrant residents, deteriorated housing, and factories than other zones (Park & Burgess, 1925). Often, residents who could afford to leave the transitional zone did so, while residents of lower socioeconomic status were restricted to this area. Park and Burgess termed zone 3 the working-class zone, and this area was predominately occupied by skilled blue collar workers, housed in tenements. Finally, the outmost zones (zone 4 and 5) were termed the residential zone and commuter zone, respectively. These zones were comprised of suburban communities commonly occupied by middle and upper class families.

Park and Burgess were human ecologists, and were not analyzing crime and delinquency expressly. However, the concentric zone theory is relevant to the discussion of crime because the concentric zone model presented the composition of urban landscape in a way that would allow social scientists to explore the relationship between

community-level characteristics and human behavior (including crime) in the new American city.

Social disorganization theory. The first social scientists to incorporate the concentric zone theory in an explanation of community level differences in crime were Clifford Shaw and Henry McKay (1942). Shaw and McKay were interested in the relationship between community processes and delinquency. Shaw and McKay justified research in this area because a theory that describes why crime concentrates in some areas over others had yet to be proposed. To develop such a theory, Shaw and McKay mapped Park and Burgess' concentric zones in the city of Chicago, and simultaneously mapped the addresses of juvenile delinquents. In their study, Shaw and McKay found disproportionately high levels of delinquency in areas closest to the CBD (zones I and II). Their explanation as to why crime concentrates in these communities is called social disorganization theory (Shaw & McKay, 1942).

In its earliest form, social disorganization theory explained crime using concepts found in cultural, strain, and control theories. Most criminologists, however, understand social disorganization theory as it was interpreted in 1978 by Ruth Kornhauser. Kornhauser understands social disorganization theory as a community-level control theory. Social disorganization has been described as: "an inability of inhabitants to control the behavior of residents and users of neighborhood space because of deleterious social conditions," (Paulsen & Robinson, 2009, p.53). Social disorganization parallels Durkheim's discussion of anomie, and failure to recognize the collective conscience, because residents of socially disorganized communities are theorized to lack a unified set

of community values. Criminologists argue that residents of socially disorganized communities do not foster relationships with one another, and demonstrate few or no social ties with each other (Sampson, Raudenbush, & Earls, 1997). That is, residents may not spend time with one another, may be unable to identify their neighbors, or may have little in common with other residents (Kubrin et al., 2009).   Conversely, socially organized communities are understood as areas where residents interact, know each other, and share common interests and values (Kubrin et al., 2009).

Social disorganization theory suggests the degree to which residents are bonded to one another, and committed to a unified set of community values, translates into the degree of informal social control the community is able to exercise (Sampson et al., 1997). Informal social control is theorized to be an important mechanism for reducing community crime and delinquency. For example, in socially organized communities, residents may frequently occupy public space (walking dogs, jogging, etc.) and inadvertently reduce crime by maintaining physical presence in the community (e.g., reduce criminal opportunities). Residents who know and recognize each other's children may be more likely to intervene personally to stop delinquency and status offending. Thus these informal actions are theorized to decrease offending.

In contrast, in socially disorganized communities, the absence of informal social control is theorized to promote crime and delinquency (Kornhauser, 1978). Just as Durkheim related suicide to anomie, Shaw and McKay connected delinquency to lack of informal social control. For example, in socially disorganized communities, residents may be reluctant to occupy public spaces, as they may have little or no desire to interact

with neighbors. In these areas it is also possible that residents may not detect the presence of a community to integrate themselves into. Without uniform community values, the wants of residents become unrestrained, and residents may perceive desirable offending opportunities in their neighborhoods. Absent of relationships with neighbors, residents may be more likely to victimize their neighbors. Residents may also be dissuaded from intervening to stop delinquent acts or status offenses if the community's children are strangers to them.

Key variables. Shaw and McKay argue that three variables in particular impact community social (dis)organization. Shaw and McKay list these variables as (1) socioeconomic status (SES), (2) racial and ethnic heterogeneity, and (3) residential mobility. It is noteworthy that Shaw and McKay's three variables mirror the crime correlates established by the Cartographic School of Crime, demonstrating a time-tested stability between these factors and index crime. Social disorganization theory posits that these three factors act exogenously to impact informal social control and, in turn, crime. That is, social disorganization theory holds that informal social control mediates the relationship between SES, racial and ethnic heterogeneity, residential mobility and crime (Sampson & Groves, 1989). It is hypothesized that SES co-varies positively with informal social control. At the same time, it is hypothesized that racial and ethnic heterogeneity and residential mobility have an inverse relationship with informal social control (Kornhauser 1978; Morenoff et al., 2001; Sampson & Groves, 1989). Social disorganization theory holds that informal social control has an inverse relationship with crime and delinquency. In this section, the exogenous sources of social

disorganization—SES, racial and ethnic heterogeneity, and residential mobility-- are described in turn.

Socioeconomic status (SES). Social disorganization theory suggests that poverty weakens the strength of community ties, and in turn, threatens social control. Poverty has been defined by social disorganization theorists as, "the presence of lower class people in a community," (Paulsen & Robinson, 2009). Criminologists have theorized that poverty relates to crime because inequity drives individuals to engage in criminal behaviors (Michalowski, 1985; Sampson, 1995), and impoverished areas lack capital and resources that promote pro-social human behavior. In tests of social disorganization theory, poverty is often measured by calculating the proportion of lower class individuals in a community, often using census data.

The relationship between poverty and crime has been demonstrated empirically in numerous studies (Bursik, 1984; Krivo & Peterson, 1996; Pratt & Cullen, 2005; Sampson & Groves, 1989; Shaw & McKay, 1942; Venkatesh, 2000; Wilson 2009; for exceptions see: MacDonald, Hipp, & Gill, 2012; Ousey & Kubrin, 2009; Sampson, 2008; Wikström & Loeber, 2000). Shaw and McKay (1942) found that areas of Chicago with the highest rates of committed youth also had the highest percentages of families on welfare and lowest median monthly rent. In their test of social disorganization theory, Sampson and Groves (1989) found that as socioeconomic status increased, there was a corresponding decrease in community rates of burglary, auto-theft, vandalism, and presence of street corner peer groups. A meta-analysis of mainstream criminology's macro-level predictors and theories of crime finds the effect of poverty on crime to be strong and stable across

over 200 studies (Pratt & Cullen, 2005). Bursik (1984) finds a strong, positive correlation between community delinquency rates and community poverty levels (r=.676). Krivo and Peterson (1996) regressed tract-level property crime rates and violent crime rates on a number of theoretically relevant community level contextual variables. Their findings indicated that extreme poverty exerted a significant independent effect on property crime (b=.2486) as well as a significant independent effect on violent crime (b=17.3926).

Racial & ethnic heterogeneity. A second key variable theorized to impact community social control is racial and ethnic heterogeneity. Racial and ethnic heterogeneity has been described by criminologists as the degree to which a community is racially and/or ethnically diverse, or the extent to which differing racial or ethnic groups are present in a community (Paulsen & Robinson, 2009). Social disorganization theory proposes that individuals of differing racial and ethnic backgrounds are unlikely to share similar values, attitudes, and beliefs. Social disorganization theory further argues that language (and other communication) barriers prevent social ties from developing between individuals of differing racial and ethnic backgrounds. For these reasons, social disorganization theorists argue that communities with high levels of racial and ethnic heterogeneity are less capable of exercising informal social control, and in turn, carry higher crime rates. Racial and ethnic heterogeneity has often been measured by using Lieberson's Index of Heterogeneity (Lieberson, 1969), the index of diversity, (see, for example, Osgood & Chambers, 2000) and Herfindahl index (Gibbs & Martin, 1962) to

analyze census data. Recently, researchers have captured ethnic heterogeneity dynamically by calculating an ethnic churning variable (Hipp, Tita, & Boggess, 2009).

Empirical support exists for the link between racial and ethnic heterogeneity and crime (Hipp, 2007; Kubrin, 2000; Osgood & Chambers, 2000; Sampson & Groves, 1989; Shaw & McKay, 1942; for exceptions see: Desmond & Kubrin, 2009; Stowell & Martinez, 2007; Nielsen, Lee, & Martinez, 2005). In a study of 119 Seattle communities, Kubrin (2000) examined the impact of racial heterogeneity on violent and property crimes. Kubrin's (2000) findings revealed that racial heterogeneity and violent (r=.52) and non-violent (r=.23) crimes significantly and positively co-vary. Net of confounders, racial heterogeneity was found to be associated with increased rates of rape, robbery, assault, burglary, and auto-theft (Kubrin, 2000).   Hipp (2007) found that across census tracts in 19 U.S. cities, ethnic heterogeneity significantly predicted increases in rates of aggravated assault, robbery, burglary, and motor vehicle theft. In their study, Osgood and Chambers (2000) reported that a 43% increase in ethnic heterogeneity corresponded with a doubling of violent index crime arrests among juveniles.

Residential mobility.   The third key variable in social disorganization theory is residential mobility. Residential mobility can be described as the rate at which residents move in or out of a community (Kubrin et al., 2009). Researchers have observed that some communities are relatively stable in terms of residency -- that is, residents commit to living in their communities for decades. In contrast, some communities display a high degree of transiency -- that is, residents engage in shorter term commitments, and frequently move in or out of the area. Social disorganization theorists argue that

difference between stability and instability in residential composition impacts social control because residents are less able to know, trust, and interact with one another if residents are continually moving in or out of the community (Kubrin et al., 2009). In this way, the ties that do form between residents in unstable communities are constantly threatened by the high rates of population change. Moreover, social disorganization theorists argue that residents may be more committed to a community if they have a long-term investment in the property (e.g., mortgage) rather than shorter-term engagements (e.g., lease to rent; e.g.Alba, Logan, & Bellair, 1994; DiPasquale & Glaeser, 1999; Squires & Kubrin, 2006). That is, residents with long term commitments may be more compelled to stop crime in their communities, because they are less likely/able to leave the area in the event that crime becomes a widespread community problem. Furthermore, crime threatens property values, and mortgage holders may be more compelled to control crime if they stand to lose money. Residential mobility has been measured using census data, including percentages of renters, or proportion of individuals who had moved from another dwelling within the past five years (Kubrin, 2000; Osgood & Chambers, 2000; Sampson et al., 1997; Warner & Pierce, 1993). .

Numerous studies have documented a link between increases in residential mobility and increases in crime (Osgood & Chambers, 2000; Sampson, 1985; Sampson & Groves, 1989; Shaw & McKay, 1942; Warner & Rountree, 1997; For exceptions see: Kingston, Huizinga, & Elliott, 2009; Warner & Pierce, 1993). Shaw and McKay (1942) found that areas with the lowest percentages of home owners had the highest rates of juvenile delinquency. Osgood and Chambers (2000) find that rates of arrest for juvenile

violence double with every 24% increase in residential turnover over the course of a five year period. Warner and Rountree (1997) studied communities in Seattle and found that increases in residential stability are associated with significant decreases in assault and burglary rates, net of confounders. Sampson (1985) found that increases in residential mobility were associated with increased rates of personal victimization as reported on the National Crime Victims Survey (robbery or larceny with contact, rape, aggravated assault, and simple assault).

Following Shaw and McKay's 1942 analyses, studies that examined the relationship between SES, racial and ethnic heterogeneity, residential mobility and crime represented an important start for social disorganization theory. However, one criticism of Shaw and McKay's test, and a number of the subsequent studies, was that informal social control (or disorganization itself) was often not measured in the analysis. For many years, researchers *assumed* that SES, racial and ethnic heterogeneity, and residential mobility's impact on crime was mediated by social control (disorganization), without actually including measures for social control (disorganization) in their model(s). For these reasons, among others, social disorganization theory largely fell out of favor in crime studies through the 1970s.

This changed in the 1980s, particularly in 1989 when Sampson and Groves empirically tested social disorganization theory by including measures for social control (disorganization). To assess the endogenous relationship of social control (disorganization), Sampson and Groves (1989) measured strength of local friendship networks, presence of unsupervised teenage peer groups, and degree of organizational

participation. Results from a weighted least squares regression revealed that the relationship low SES, high ethnic heterogeneity, high residential mobility, and community crime and delinquency rates were mediated by social control measures (supportive of social disorganization theory's hypotheses) (Sampson & Groves, 1989). Sampson and Groves' study has been referred to as a "criminological classic" (Lowenkamp, Cullen, & Pratt, 2003, p.351), and a 2003 replication of the study demonstrated Sampson and Groves' findings tenable more than a decade after initial publication (Lowenkamp et al., 2003). Furthermore, re-analysis of Sampson and Groves' data using LISREL replication techniques revealed support for social disorganization theory (Veysey & Messner, 1999; Lowenkamp et al., 2003).

In more recent years, a meta-analysis of macro-level crime studies (n=214) finds social disorganization theory to garner strong support in the criminology literature (Pratt & Cullen, 2005). Eck et al. (2005) proclaim social disorganization and ecological theories of crime as pertinent theoretical explanations of crime in community areas. Furthermore, Eck et al. (2005) ascribe social fragmentation as a likely cause of community-level hotspots of crime[14].

Contemporary updates and expansions. As tests of social disorganization theory continued to appear in the literature, new variables were incorporated into community-level crime hotspot studies. The inclusion of these variables uncovered new correlates of crime that became relevant to social disorganization and community crime researchers. For example, Sampson and Groves (1989) included family disruption and urbanization as

[14] Recently, crime hot spot experts have claimed to find evidence that social disorganization theory may explain crime hotspots across micro-geographical areas. For more information, see Weisburd, 2012.

exogenous variables in their test of social disorganization theory, and found a positive, significant relationship between these variables, measures of social disorganization, and crime. In addition, contemporary tests of social disorganization theory uncover relationships between population density, unemployment, percent of young males and crime (Kubrin et al., 2009). Because a number of these variables are highly interrelated, researchers have needed to address multicolinearity in their models. To overcome this issue, social disorganization researchers have constructed a variable called "concentrated disadvantage" which contains measures for poverty, unemployment, racial composition, divorce, female-headed households, and households on public assistance (Kubrin et al., 2009; MacDonald & Gover, 2005; Sampson, Raudenbush, & Earls, 1997). MacDonald and Gover (2005) found concentrated disadvantage a significant predictor of youth-on-youth homicide across 159 U.S. cities.

As models of social disorganization expanded to include new variables, reformulations of social disorganization theory began to emerge in the criminology literature. Clear (2007) identifies three of the most prominent efforts to update social disorganization theory as: (1) Sampson's Collective Efficacy, (2) Bursik and Grasmick's Systemic Theory, and (3) Weatherburn and Lind's Economic Stress-Induced Offender Motivation (ESIOM) Paradigm. These theories focus on explaining community level crime differences, and add to social disorganization frameworks the idea of social cohesion and trust among community members (Sampson et al., 1997), differing types of social control (Bursik & Grasmick, 1993), and persistent economic hardship (Weatherburn & Lind, 2001). Clear (2007) also presents Coercive Mobility as a new and

relevant theoretical framework that includes the impact of concentrated incarceration on community level crime hotspots (see also Clear, Rose, Waring, and Scully, 2003).

In sum, with respect to mainstream criminology theories designed to explain community level crime hotspots, social disorganization theory emerges as a leading theoretical explanation (Eck, 2005). Moreover, contemporary reformulations, updates, and extensions of social disorganization theory imply that criminologists continue to perceive community level crime hotspots as a relevant social problem. It also implies that criminologists continue to search for more refined theoretical explanations of community level crime hotspots. In spite of these latter points, and in spite of lead's empirical relationship with race, ethnicity, residential mobility, urbanization, and poverty, lead has yet to be factored into empirical assessments of community level crime.

Crime Hotspot Policy Initiatives

Interest in crime hotspots is not restricted to criminologists and social science researchers. Policy makers, practitioners, government representatives, and law enforcement officials have also demonstrated a vested interest in addressing community level crime hotspots. That said, social disorganization theory has informed numerous policy initiatives, including some programs that have been in effect for over seventy years (Lersch & Hart, 2011). A number of these programs have grown in size and scope, and consume considerable amounts of tax dollars and resources. Lersch and Hart (2011) highlight three examples of policy initiatives influenced by the tenets of social

disorganization theory, including: The Chicago Area Project, community policing, and various federal government directives.

The Chicago area project (CAP). The Chicago Area Project (CAP) was founded in the 1934 by Clifford Shaw himself. CAP began in three Chicago communities which demonstrated high rates of juvenile delinquency. Shaw emphasized a "self-help" approach in reducing community crime rates, and believed that juvenile delinquency in these areas could be reduced by organizing parents and residents of the community as well as approaching youth and attempting to dissuade them from delinquency. Shaw's initiatives spread throughout Chicago. By the early 1970s, CAP was working with twenty-two community committees, and by the 1980s, CAP was inspiring similar programs across Illinois. CAP remains active today, and collaborates with over 40 grassroots organizations and projects that promote community-level advocacy, organizing, and service provisions. CAP proclaims its mission statement as one that has not changed from the programs inception: "To work toward the prevention and eradication of juvenile delinquency through the development and support of affiliated local community self-help efforts in communities where the need is greatest," (Chicago Area Project, 2012).

CAP's mission relates to the tenets of social disorganization theory in that CAP holds that the solution to community rates of juvenile delinquency rely in unifying and organizing community members. The parallels between social disorganization theory and CAP is even more clearly conveyed in CAP's goal, which is stated as: "to develop special projects and established locally controlled organizations that implement the

directives put forth in CAP's mission and philosophy. Projects and affiliates are mandated to positively impact areas in the Chicago vicinity with high rates of juvenile delinquency or other symptoms of social disorganization," (Chicago Area Project, 2012a). It would seems, then, that CAP is expressly interested in establishing community social control (e.g., "locally controlled organizations) and ameliorating social disorganization, because these directives are thought to reduce juvenile delinquency (CAP's mission).

While CAP's mission is amicable, some evaluations of CAP[15] describe CAP's impact on juvenile crime as, "negligible at best," (Lersch & Hart, 2011, p.132). It has been pointed out that even Shaw relied increasingly less on official juvenile crime data to demonstrate CAP's effectiveness (Lersch & Hart, 2011; Schlossman, Zellman, and Shavelson, 1984). Regardless, there are currently 55 organizations in high-risk communities in Chicago that utilize the CAP model, and over 200 across the state of Illinois (Chicago Area Project, 2012b) . Funding for CAP draws heavily from Illinois' Community Youth Services grant line, but CAP also obtains funding from donors. While funding for the Community Youth Services grant line continues to decline, and has been threatened with elimination, in 2010 $5.4 million was appropriated to the line (Illinois Human Services Commission, 2011). CAP representatives suggest this grant line serves 70,000 children, whom CAP argues may otherwise be at risk of entering the justice system (Sardin, 2011).

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[15] It is important to emphasize while some evaluations suggest CAP may not be a panacea for juvenile crime, this is not to say that CAP does not have other beneficial outcomes for children, families, and communities. For example, CAP's Women in Transition (WIT) program provides transition assistance for

Community policing. Social disorganization theory informs a widespread policy movement in law enforcement termed community policing. Community policing has been described as a philosophy of policing that emphasizes partnership between law enforcement and the community in identifying and resolving local crime problems (including delinquency, fear of crime, disorder, and decay). These sentiments are conveyed by Wilson and Kelling (1982), who state: "The essence of the police role in maintaining order is to reinforce the informal control mechanisms of the community itself." The key components of community policing have been listed as community partnerships, organizational transformation, and problem solving (Department of Justice, 2009). Examples of community policing initiatives include the Department of Justice's Weed and Seed Program, and Chicago's Chicago Alternative Policing Strategy (CAPS). Both of these programs are designed to encourage law enforcement to work in conjunction with the community residents to identify, prevent, and respond to local crime problems. These programs work towards these objectives by holding meetings with residents, or having community-assigned beat officers.

Community policing is related to social disorganization theory because it emphasizes the use of law enforcement to promote informal social control (Wilson & Kelling, 1982). In a review of research that studies police effectiveness, Weisburd and Eck (2004) find that community policing efforts appear to reduce community fear of crime, and show promise in reducing crime when paired with problem oriented policing strategies. However, the same study fails to find a consistent relationship between

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families moving from welfare to workforce. It has been estimated that WIT has successfully placed approximately one third of its clients into employment positions (Lersch & Hart, 2011).

community policing strategies alone and occurrences of crime or disorder (Weisburd & Eck, 2004). Regardless, recent reports suggest community policing strategies are widely implemented by law enforcement. A 1997 study of 1,637 law enforcement agencies revealed 58% of agencies had implemented a community policing strategies, and another 27% were in the process of implementing community policing (Fridell, 2004). The Bureau of Justice Statistics reported that in 2003, 58% of police departments (that employed 82% of all officers) used full-time community policing officers (Hickman & Reeves, 2006). Furthermore, almost half of all departments (employing 73% of officers), advertised a mission statement that included aspects of community policing (Hickman & Reeves, 2006). Since the 1990s, community oriented policing initiatives have received over $11 billion in federal grant support.

Federal government initiatives. In addition to CAP and community policing, social disorganization theory influences a number of policy initiatives at the federal level. In 1995, the Office of Juvenile Justice and Delinquency Prevention (OJJDP) compiled a matrix of community based initiatives designed to prevent violence and/or create economic opportunities that may, in turn, prevent delinquency. This matrix identified government and private entities. The OJJDP identified 36 programs in total, including: 7 through the Department of Housing and Urban Development, 6 through the Department of Justice (including community policing), 5 through the Department of Justice, 5 though the Department of Health and Human Services, and 3 though the Department of Labor. These projects vary in goals and implementation, but share the commonality that they all include an, "interdisciplinary local planning board that has included in its focus

improving the lives of at-risk children and families," (OJJDP, 1995, p.1). Because these programs work towards restoring communities and orienting neighborhoods towards self-help and informal social control, they incorporate social disorganization theory ideology.

One example of a federal government initiative with these objectives is the Department of Housing and Urban Development's Empowerment Zone (EZ), Enterprise Community (EC), and Renewal Communities (RC) endeavors. These initiatives designate communities as an EZ, EC, and/or RC, which in turn entitles communities to federal resources (e.g., programs which work with schools in designated areas to reduce truancy, increase academic performance, etc.). These designations also offer incentives to entrepreneurs to create market opportunities in such communities (e.g., recruit employees locally). Lersch and Hart (2011) estimate that collectively entrepreneurs who establish businesses in EZ/EC/RC zones are eligible for up to $10 billion in incentives from the federal government. Lersch and Hart (2011) identify EZ/EC/RC efforts to rebuild economically depressed areas as a "necessary ingredient" to reduce community crime and delinquency. Sherman et al. (1997) describe these programs as promising when a particular goal is explicated.

The Problem

Analysis of mainstream community and crime literature reveals that while many variables have been tested with respect to explaining the distribution of crime, to date, only one unpublished study examining community levels of lead and homicide (Lynch, McGurrin and Stretesky, 2001) has tested the role lead may play in explaining community level differences in crime and delinquency rates. This void creates

limitations in the study and control of crime across communities with respect to (1) theory and (2) policy.

Theory. The absence of lead from the study of community crime is problematic for mainstream macro level crime theory because it is possible that observed associations between mainstream predictors and crime are biased. There are a few reasons to suspect this.

One of which is lead's demonstrated ability to cause changes in human behavior (Canfield et al., 2003; Landrigan, 2000; Lanphear et al., 2005; Lanphear et al., 2000; Needleman et al., 1990; Needleman et al., 1979; Schwartz, 1994; Wasserman et al., 2000; White et al., 1993). Impacts that lead has on human behavior include diminished IQ, impulsivity, aggression, mood disorders, and decision making. Because many of these factors have been found to be correlates of crime, it is reasonable to suspect that the presence of lead in an environment may set into motion criminal behaviors and delinquency. For example, it is reasonable to infer that the presence of lead may adversely impact the ability of a community to exercise informal social control, and/or hamper collective efficacy. Because lead impacts IQ, intelligence, academic performance, and cognition (Canfield et al., 2003; Landrigan, 2000; Lanphear et al., 2005; Lanphear et al., 2000; Needleman et al., 1990; Needleman et al., 1979; Schwartz, 1994; Wasserman et al., 2000; White et al., 1993; Zahran et al., 2009), high lead body burden may adversely impact community residents' ability to communicate with each other. Diminished IQ and intelligence also may impact a community's ability to establish, recognize, or articulate a unified set of positive values and norms. Because

exposures to lead is associated with mood and affect (Burns et al., 1999; Cecil et al., 2008; Bouchard et al., 2009), lead exposure is highly likely to impact the social cohesion in a community. Relatedly, community context of collective efficacy is described as "the linkage of mutual trust and the willingness to intervene for the common good," (Sampson, Raudenbush, & Earls, 1997, pg. 919). Given lead's association with decision making (Cecil et al., 2008), it is reasonable to suspect that community lead levels may impact the "willingness to intervene" component of collective efficacy. Taken together, it is reasonable to infer that the presence of lead in a community may play out collectively as diminished social control and/or collective efficacy.

Moreover, because social disorganization theory is presented as a general theory of crime, it proposes to explain variation across all types of community crime. That is, informal social control is proposed by social disorganization theorists to suppress property crime as well as violent crime. Thus, if lead impacts the ability of a community to exercise informal social control, variations in both property and violent crime can be anticipated. This is consistent with findings that observe associations between lead, crime, and delinquency inclusive of violent and property offenses (Masters et al., 1994; Stretesky & Lynch, 2004). However, tests of mainstream macro-level crime theory do not include lead as a variable.

Another reason the relationship between mainstream macro level predictors of crime and community crime rates may be biased, relate to the patterns in the spatial distribution of lead and crime. Evidence suggests lead, crime, and mainstream theoretical predictors of crime follow similar spatial distribution patterns. For example, social

disorganization (emerging as a leading mainstream explanation for community-level differences in crime—see Eck, 2005; Pratt & Cullen, 2005) explicates three variables specifically that correlate with crime: SES, racial/ethnic heterogeneity, and residential mobility. However, as demonstrated in chapter two, literature that has studied the distribution of lead has found lead to be correlated with: impoverished communities (Diawara et al., 2006; Jacobs et al., 2002), neighborhood racial composition (Stretesky, 2003; Mielke et al., 1999; Lanphear et al., 1996), neighborhood ethnic composition (Jacobs et al., 2002), and areas with demonstrated residential mobility (Sargent et al., 1997). Thus, lead, crime, and delinquency appear pulled together in time and space (Lynch, 2004). This has yet to be empirically examined at the community level (but for exception, see Lynch, McGurrin, and Stretesky, 2001).

Results of macro-level assessments of lead and crime provide additional evidence that suggest observations between traditional crime predictors and community crime rates is bias (Lynch, 2004; Masters et al., 1994;Nevin, 2000; Nevin, 2007; Reyes, 2007; Stetesky & Lynch, 2001; Stretesky & Lynch, 2004). Because of lead's demonstrated association with criminal behavior in cities, counties, and countries, it is reasonable to suspect that high concentrations of lead in communities may lead to collective neighborhood dysfunction, including criminal behavior. This argument is strengthened by the fact that prior macro-level studies have found that lead exerts an effect on crime rates **net** of other factors including: unemployment (Masters et al., 1994; Nevin, 2007; Reyes, 2007; Stetesky & Lynch, 2004), poverty rate (Reyes, 2007), resource deprivation (Stretesky & Lynch, 2004), abortion (Reyes, 2007), race (Stretesky & Lynch, 2001),

population structure and density (Masters et al., 1994; Stretesky & Lynch, 2004), level of education (Masters et al., 1994; Strestesky & Lynch, 2001), percent of the population that is young (Reyes, 2007; Stretesky & Lynch, 2004), and percent divorced (Stretesky & Lynch, 2004). Moreover, these associations have been observed between lead and property crime and as well as lead and violent crime (Masters et al., 1994; Stretesky & Lynch, 2004). Consistent with these observations, Narag and colleagues (2009) summarize, "high levels of lead exposure add **an additional structural ill and obstacle** (*emphasis mine*) for residents of disadvantaged communities, perhaps adding to higher levels of crime in these areas," (pg. 965).

Empirical assessment is needed to assess whether tests of social disorganization theory may be omitting an important explanatory variable, implying results from traditional models may be biased. Given that social disorganization theory is grounded in control theory (Kornhauser, 1979), it is possible that the factors that suppress crime may be more effective in communities without lead than communities that contain lead. Since increased presence of lead in individuals, countries, counties, and cities has been associated with increased criminal behavior and crime rates, it is reasonable to infer that increased presence of lead in communities may be associated with increased rates of crime. That is, neurotoxicity, rather than *or* in addition to disorganization, may emerge is a relevant factor in explaining and theorizing about the distribution of crime across communities.

Policy. Not only is mainstream criminology theory limited with regard to lead's impact on community crime rates, but community crime control policies may also be limited by this void (Lersch & Hart, 2011). There are at least two ways in which policy may by adversely impacted by this omission in the literature. First, crime control policies that are informed by the tenets of social disorganization theory are costly and expansive initiatives. These efforts to promote community organizing represent multi-billion dollar investments from taxpayers. Should lead demonstrate to contribute to community level crime rates, it would appear that these expensive policy initiatives may be undermined by the presence of lead in those communities, if lead and crime are also related. This position is underscored by the fact that empirical assessments of a few of the programs designed to promote community organization (i.e., CAP) reveal these programs are not a panacea for crime. It would appear that these initiatives may be limited in some way, and an empirical assessment is needed to discern if this limitation is failure to address community lead exposure.

Second, in the event that an empirical assessment of the lead crime relationship reveals an association between lead and crime, new policy initiatives may be supported. For example, inform initiatives that reduce the presence of lead may present as promising new directions for reducing community crime rates. This suggestion would be consistent with extant research that suggests reducing lead levels may be a cost-effective initiative in reducing other social problems (Needleman 2004; Reyes, 2007). For instance, in 1991 the Public Health Service conducted a cost-benefit analysis on abatement of housing structures built using lead-based paint (approximately 80% of structures built before

1950), across a thirty year period. These estimates suggested that the project would cost approximately $33.7 billion. However, the return from raised IQ points and avoided health care costs alone was estimated to be $61.7 billion. Needleman (2004) called the Public Health Service's estimate conservative because it had not factored in avoided delinquency (or cardiovascular diseases), which Needleman provides as effects of lead exposure. A recent study by Gould (2009) suggests that a reduction in the average preschool blood lead level of 1 μg/dL would save $1.8 billion associated with the *direct* costs of crime alone. Considering crime among other costs, Gould (2009) went on to estimate that each dollar invested in lead paint hazard control would correspond with a return ranging from $17 to $221, or a total savings of at least $180 billion. The outcome of a community-level assessment of lead and crime rates may help to inform such cost benefit analyses.

To ensure that theoretical explanations of community crime rates are not miss-specified, and to ensure that costly policy ventures to promote community organizing to deter crime are not undermined by the presence of lead, a study is needed to empirically assess the relationship between lead and crime at the community level.

Chapter Four:

Bridging the Gap: Lead, Crime, and Chicago

The previous chapters have provided a review of the literature on distributions of lead and crime, justifying the need for an empirical assessment of lead and crime hotspots at the community level of analysis. To conduct such an assessment, this study analyzes lead and crime across communities in Chicago, Illinois. The purpose of chapter four is to justify the selection of the city of Chicago. Chapter four opens with a short background on the city of Chicago. Next, data and findings from extant publications are provided to demonstrate disproportionately high levels of both lead and index crime in Chicago. This chapter concludes with a discussion of community-level research in Chicago, noting prior studies and data that suggest a lead and crime hotspot overlap in Chicago communities.

About Chicago

The city of Chicago was incorporated in 1837 (City of Chicago, 2012). Chicago is located in Northeastern Illinois, within Cook County, along the shore of Lake Michigan. Because of the city's location, Chicago was regarded as a hub of trade and commerce through America's westward expansion in the 1800s (City of Chicago, 2012). Since 1790, Chicago has ranked within the top 10 most populous cities in the United States (U.S. Census, 2010). According to Shaw and McKay (1942) in 1840, Chicago had

a population of 4,470. By 1880, Chicago's population boomed to 500,000 persons, and by 1910, that figure quadrupled. In 1940, Chicago had a population of over 3 million, 91.7% of which identified as white, and 8.2% of which identified as black (Wirth & Furez, 1938). Along with a growing population, Chicago also expanded geographically over time. According to Shaw and McKay (1942), in 1830, the area designated as Chicago subsumed approximately one-half of a square mile of land. By 1889, Chicago would come to occupy over 40 square miles, and by 1940, Chicago consisted of approximately 134 square miles of territory (Wirth & Furez, 1938).

Today, according to the U.S. Census, the city of Chicago is approximately 227.63 square miles. In 2010, Chicago has a population of 2,695,598, concentrating approximately 21% of the entire population of Illinois (U.S. Census, 2010). Today, Chicago's population is 45% white, 32.9% black, and 28.9% Hispanic or Latino/a. Chicago currently houses eleven Fortune 500 companies, and it has been estimated that approximately 86 million people visit Chicago each year (City of Chicago, 2012). Chicago maintains its reputation as a trade and commerce epicenter, with the O'Hare and Midway International airports constituting the busiest aviation centers in the U.S, while 50% of all U.S. rail freight continues to pass through the city (City of Chicago, 2012). In 2010, Chicago was deemed by the U.S. census the third most populous city in the United States (U.S. Census, 2010).

Lead in Chicago

The presence of lead in Chicago may be unsurprising when one considers the level of pollution in Chicago. The Environmental Protection Agency's Toxic Release

Inventory (TRI) maintains data on the release, transfer, and handling of over 600 toxic chemicals, including, but not limited to, lead and lead compounds. Based on TRI data, in 2010, the Right-to-Know network (2012) ranked the state of Illinois in the top ten states for releases of toxic waste. Also according to 2010 TRI data, Chicago housed over one hundred facilities that reported the transfer or release of toxic chemicals into the air, water, or land, with each facility generating an average of nearly thirty thousand pounds of toxic waste (Right-to-Know Network, 2012). The American Lung Association's State of the Air report (2012) ranks the Chicago area as one of the nations' most polluted regions with regard to short-term particle pollution.

There is a documented presence of lead in Illinois, Cook County, and Chicago. According to the Illinois Department of Public Health (2011), the state of Illinois ranks especially high in the United States in terms of rates of lead-poisoned children (with lead poisoned being defined as testing with a blood lead level at or above 10 μg/dL). In 2009, the Illinois Department of Public Health (2011) provided case management services to 3,171 lead-poisoned children, and initiated 2,624 environmental investigations. Furthermore, the department estimates that currently approximately 2 million houses in Illinois contain leaded paint (Illinois Department of Public Health, 2011). In 1999, the EPA ranked Cook County in the 95th percentile nationally for highest emissions of lead compounds. TRI data reveals that in 2010, over one hundred thousand pounds of lead and lead compounds were released in Cook County (Right-to-Know Network, 2012).

The city of Chicago demonstrates a unique struggle with lead. Since 2005, over two hundred thousand pounds of lead and lead compounds have been generated in

Chicago (Right-to-Know Network, 2012). The Illinois Department of Public Health (2011) reports that in 2009 nearly 28 thousand children tested positive for a blood lead level at or above 5 μg/dL[16], strictly in Chicago. Most of the children tested (92%) were younger than six years of age, and these data suggest that in 2009 nearly 11% of *all* Chicago children age six and under have been identified as carrying a blood lead level of 5 μg/dL or higher. Figures 1 and 2 present data reported by the Illinois Department of Public Health from 2008 (2011). Figure 1 compares the rates at which tested children have been found to carry blood lead levels at or above 5 μg/dL**.** What these data reveal is that approximately one in four children tested for lead in Chicago carry a blood lead level at or above 5 μg/dL. Furthermore, a comparison of Chicago strictly to the rest of Cook County and Illinois reveals that children tested for lead in Chicago carry elevated blood lead levels at over twice the rate of the rest of the county and state, respectively. Figure 1 is congruent with Figure 2 which demonstrates that of 49,571 children with elevated blood lead levels in Illinois, 61% were concentrated in Chicago.

Because of the strong, positive correlation that has been detected between blood lead level and environmental lead presence (Hayes et al., 1994; Pirkle et al., 1994), figures 1 and 2 also imply that disproportionate amounts of lead in Illinois concentrate in Chicago's environment. Hayes' and colleagues (1994) analyze the relationship between air and blood lead levels among children in Chicago explicitly. Their study tests the relationship between air lead levels in Chicago and children's blood lead levels as

[16] The Illinois Department of Public Health does not report numbers or rates of children who tested with blood lead levels below 5 μg/dL. However, researchers have found relationships between adverse outcomes and very low (less than 5 μg/dL) blood lead levels (see, for example, Lanphear et al., 2000)

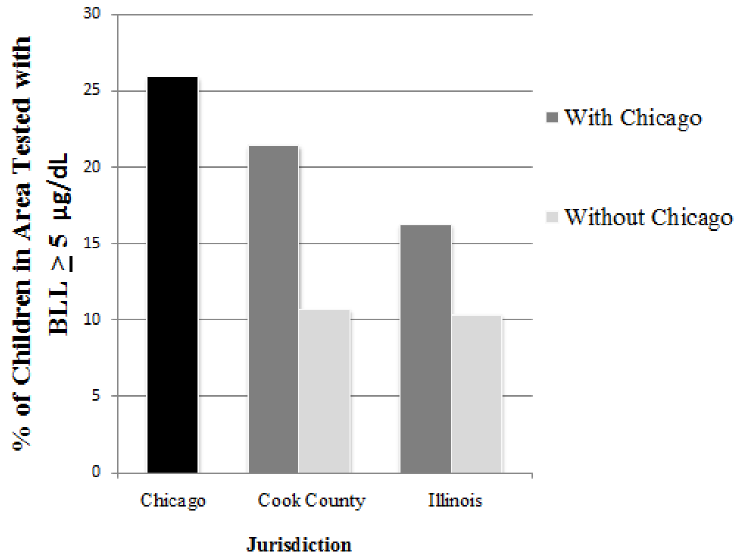

Figure 1. *Rate at Which Tested Children Found to Have Blood Lead Levels (BLL) at or Above 5 µg/dL Within Jurisdiction, 2008**

SOURCE: Illinois Lead Program Surveillance Data, 2006-2009 and Illinois Center for Health Statistics, as reported by the Illinois Department of Public Health (2011) in "Illinois Lead Program Surveillance Report – 2009".

* The number of total children tested includes children who have been tested more than once. However, in instances where children tested positive and were retested, only the highest venous or capillary result was recorded (Illinois Department of Public Health, 2011). For this reason, these figures are likely to provide a more conservative estimate.

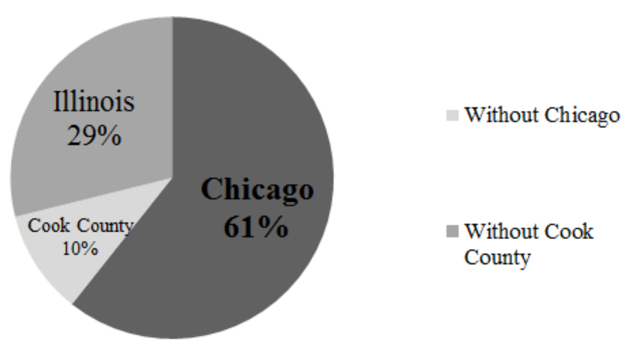

Figure 2. *Percentage of All Illinois Children Tested and Found to Have Blood Lead Levels at or Above 5 µg/dL by Jurisdiction, 2008, (n= 49,571)*

SOURCE: Illinois Lead Program Surveillance Data, 2006-2009 and Illinois Center for Health Statistics, as reported by the Illinois Department of Public Health (2011) in "Illinois Lead Program Surveillance Report – 2009".

captured by the City of Chicago Department of Health Division of Laboratories from 1968 through 1988. Hayes et al. (1998) observe that the median blood lead level declined from 30 μg/dL in 1968 to 12 μg/dL in 1988, corresponding significantly to air lead levels ($r=.8$, $p<.0005$). It may be reasonably inferred, then, that lead is present in both Chicago's physical environment and in the bodies of Chicago residents.

Crime in Chicago

Index crime also has a documented presence in Chicago's environment and surrounding areas. In the state of Illinois, 2010 UCR data indicate that index crimes occurred across the state at a rate of approximately 31.16 crimes per 1,000 residents (totaling 399,824 crimes). This can be broken down further into a violent crime rate of 4.35 crimes per 1,000 residents, and a property crime rate of 26.81 crimes per 1,000 residents. Index crime in Illinois, like index crime nation-wide, has steadily been on the decline since the early 1990s. According to the State of Oregon Criminal Justice Commission (2012), the state of Illinois ranked # 17 in the nation for violent index crime rate in 2010. The same report (2012) found Illinois violent crime rate to be higher than the three lowest ranked states for violent crime (New Hampshire, Vermont, and Maine) combined. The Circuit Court of Cook County of the State of Illinois represents the largest judicial circuit in Illinois, and is also one of the largest court systems in the world (State of Illinois Circuit Court of Cook County, 2012). By some accounts, the Cook County Criminal Courthouse is the largest and busiest felony courthouse in the United States (Bogira, 2005). The Circuit Court of Cook County employs more than 400 judges,

and handles over 1.2 million cases each year (State of Illinois Circuit Court of Cook County, 2012).

According to the Chicago Police Department's annual report (2010), there were 152,031 index crimes in the city of Chicago in 2010. Of these crimes, approximately 20% were violent crimes and 80% property crimes. Considering Chicago's population, the 2010 Index Crime rate in Chicago was approximately 56.3 crimes per 1,000 persons. By comparison, the national index crime rate in 2010 was approximately 33.5 crimes per 1,000 persons. Figure 3 compares rates of index offending in Chicago, Cook County, Illinois, and the United States from 2005 to 2009. What these data suggest is that index offending occurs at disproportionately higher rates in Chicago when compared to county, state, and national rates. The Illinois State Police (2009) also report that offenses reported by the Chicago Police Department account for 36.4% of the total index crime offenses in the state of Illinois.

Similar to the data that was reported for lead, Figure 4 charts index offense rates across Illinois. Calculations were based on data provided by the Illinois State Police in the Crime in Illinois' 2009 Annual Uniform Crime Report. These data reveal that the index crime rate in Chicago alone is substantially higher than index crime rates across the rest of Cook County and the state of Illinois. Moreover, this is a trend that maintains both when Chicago is included in the crime rate configuration for Cook County and Illinois, and when Chicago's figures are omitted. When compared to data in Figure 2, it would appear that trends in lead across Illinois are very similar to trends in index crime across Illinois.

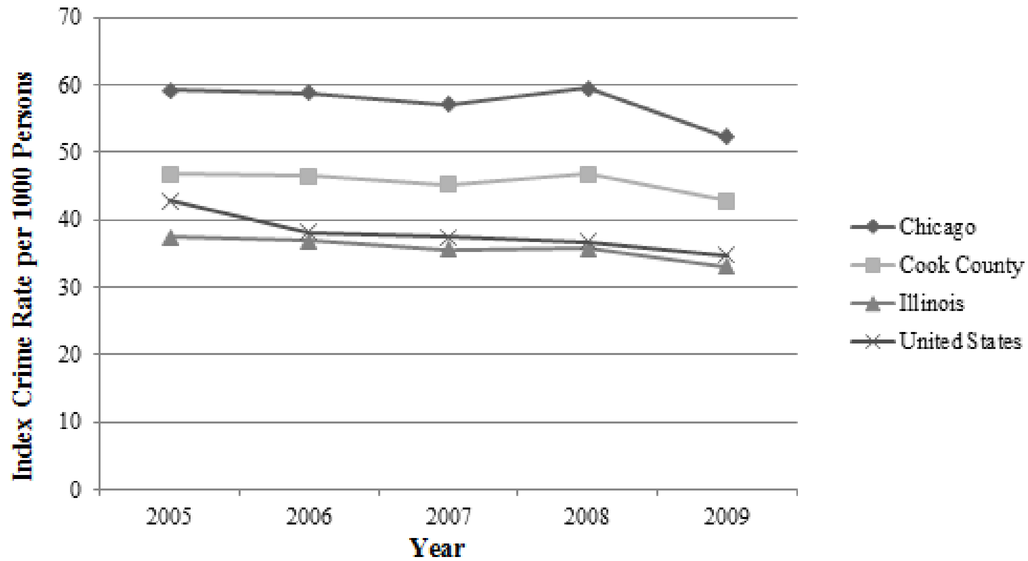

Figure 3. *Trends in Annual Index Crime Rate (per 1000 persons) By Jurisdiction, 2005-2009*

SOURCE: Illinois State Police (2009). The Executive Summary of the Crime in Illinois 2009, Annual Uniform Crime Report.

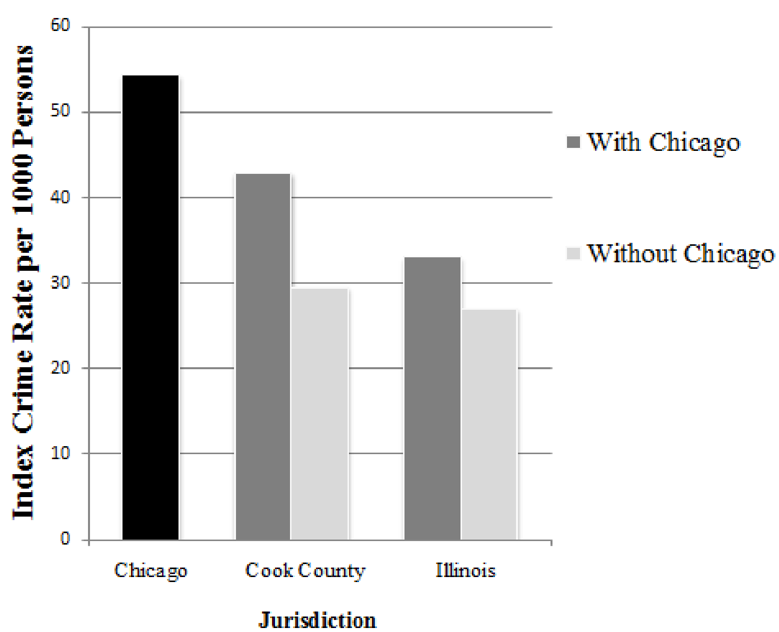

Figure 4: *Index Crime Rate across Illinois, Cook County, and Chicago, 2009*

SOURCE: Illinois State Police (2009). The Executive Summary of the Crime in Illinois 2009, Annual Uniform Crime Report.

In sum, it appears that just as rates of elevated blood lead are disproportionately high in Chicago, so are the crime rates. For these reasons the city of Chicago is especially well suited for an assessment of the lead and crime connection. However, because this study seeks to test this relationship at the community level of analysis, justification for the selection of Chicago would be further enhanced if it could be demonstrated that hotspots of lead and crime exist at the community level. To demonstrate that extant data and literature studying Chicago's communities illustrate the presence of such hotspots, a discussion of lead and crime across Chicago's communities is provided.

Lead, Crime, and Chicago's Communities

Chicago has interested researchers not only in its entirety as a city, but also as an amalgam of communities. Chicago's communities have posed such long-standing intrigue among researchers that Robert Sampson has referred to the history of community research in Chicago as "unparalleled" (2012, p.76). Indeed, the communities of the city of Chicago have captivated sociologists and criminologists alike since the work of the Chicago School scholars (Kotlowitz, 1992; Park & Burgess, 1925; Shaw & McKay, 1942; Sampson, 2012; Sampson, 2002; Sampson, Morenoff, & Raudenbush, 2005; Sampson et al., 1997; Venkatesh, 2000; 2008; Visher & Farrell, 2005; Zorbaugh, 1929).

One of the most renowned research endeavors to take up the study of Chicago's neighborhoods is undoubtedly the Project on Human Development in Chicago Neighborhoods (PHDCN). The PHDCN was established in 1994 by Robert Sampson and colleagues to examine development and context across neighborhoods in the city of

Chicago (Sampson, 2012; Sampson et al., 1997; Earls & Visher, 1997). The PHDCN broke up the Chicago area into 343 neighborhood clusters (NCs). NCs were neighborhoods larger than a single census tract, but smaller than the Chicago Community Areas. NCs were designed to maintain relative internal socio-demographic homogeneity.

Studies from the PHDCN and otherwise have detected differentials in the distribution of crime across communities in Chicago, suggesting community-level crime hotspots in Chicago (Block and Block, 1993; Lyons, 2006; Sampson, 2012; Sampson & Raudenbush, 1999; Sampson et al., 1997; Visher & Farrell, 2005). For example, Block and Block's (1993) study of street-gang motivated crimes in Chicago found that the two communities with the highest mean rates of street crime (East Garfield Park and Humboldt Park), had mean rates of street crime that were seventy-six times higher than the rate of street gang crime in the two safest communities (Mount Greenwood and Edison Park). The same study explores rates of street-gang motivated homicide, and finds concentrations of street-gang motivated homicide in two corridors of Chicago community areas along the Northwest and Southwest sides. Analyses demonstrated that across Chicago, 22% of communities had no street-gang related homicides, while one community (Lower West Side) averaged over six per year (Block & Block, 1993). Sampson and Raudenbush (1999) found that Chicago neighborhoods with higher levels of concentrated disadvantage also experienced significantly higher rates of homicide, robbery, and burglary. Visher and Farrell (2005) found that over half of former male prisoners returning to Chicago were released to one of seven community areas (Austin, Humboldt Park, North Lawndale, West Englewood, East Garfield Park, Roseland, and

Auburn Gresham). Of all released prisoners, 52.4% returned to prison (Visher & Farrell, 2005).

Studies also illustrate unequal distributions of lead across Chicago communities. Oyana and Margai (2010) studied spatial and temporal patterns in pediatric lead exposure across Chicago census tracts in 1997, 2000, and 2003. The distribution of blood lead level was skewed, with some census tracts emerging with no cases of elevated blood lead levels among children, and one tract reporting as many as 106 cases. These researchers found that Chicago's Westside emerges as the region with the highest risk of elevated child blood lead levels, followed by Chicago's Southside and Far Southside regions (Oyana & Margai, 2010). Oyana and Margai observe that, "the high-risk areas are fairly consistent over the seven-year period, yielding persistent and visually distinct hot spots for pediatric lead poisoning," (2010, p. 56). Oyana and Margai's (2010) findings are consistent with data released from the Chicago Department of Public Health. The Chicago Department of Public Health (2008), identifies seven Chicago communities where 4.5% or more tested children had blood lead levels $\geq$10 μg/dL: Austin, West Garfield Park, Fuller Park, Avalon Park, West Englewood, Englewood, and Greater Grand Crossing. By comparison, in thirty Chicago communities only 1.5% or fewer tested children were found to have blood lead levels $\geq$ 10 μg/dL.

When taken together, findings from extant data and community-level crime and lead studies in Chicago allude to hotspot overlay. For example, Block and Block's (1993) findings indicate Humboldt Park and East Garfield Park as among the most dangerous in terms of gang-crimes. Data from the Chicago Department of Public Health

(CDPH) (1998) report rates of children tested and found to carry blood lead levels $\geq$10 μg/dL. CPDH data indicate that children tested in the Humboldt Park and East Garfield Park Communities had elevated blood lead at rates of 23% and 28%, respectively. By comparison, Block and Block (1993) name Edison Park and Mount Greenwood as two of the safest communities in terms of gang-crime. The CDPH (1998) indicates that children tested in both of these communities report elevated blood lead levels at rates of 1%. Likewise, the 1998 Chicago Police Department's Annual Report reveals that 60 homicides occurred in Austin in 1998, indicating that more homicides occurred in 1998 in Austin than in any other Chicago community. The CDPH (1998) indicated that in 1998, 32% of children tested in Austin carried blood lead levels $\geq$ 10 μg/dL. Alternatively stated, in 1998, over 1,000 children in Austin were found to have elevated blood lead levels.

In sum, both lead and index crime have a documented presence in the city of Chicago. This chapter presented data from the UCR, Illinois State Police, and Illinois Department of Public Health to demonstrate that both lead and crime are disproportionately high in Chicago. Moreover, graphical depictions of the data illustrate the substantial impact that the Chicago area has on state and county rates of lead exposure and index crime. Because this study is concerned with community level hotspots of lead and crime, a brief discussion of Chicago's numerous community-level crime studies is presented. It is noted that Chicago's communities are among the most widely studied in criminology and sociology, giving Chicago a uniquely extensive history

of community-level studies. Prior work demonstrates that the skewed distribution of crime produces hotspots in Chicago communities. Likewise, extant studies and data illustrate a non-normal distribution of lead across the city of Chicago. Finally, merging these findings intimates overlap between lead and crime in Chicago communities, making Chicago a truly ideal setting for assessing the relationship between lead and crime hotspots.

Chapter Five:

Data, Methods, & Measures

A review of the literature finds that prior studies suggest a causal relationship between lead exposure and crime. While this association appears tenable across varying levels of analysis (individual, county, city, nation, time), and linkages between lead and homicide hotspots have been demonstrated (Lynch et al, 2001), additional assessment at the community level of analysis is needed (Lersch & Hart, 2011; Narag et al., 2009). Because findings from prior studies imply overlap between hotspots of lead and hotspots of crime across communities in Chicago, Illinois (Block & Block, 1993; The Chicago Department of Public Health, 1998; Lynch et al., 2001; Oyana & Margai, 2010), the city of Chicago is selected for this assessment. Chapter five details the methodology employed for this study. To begin, the relationships to be tested and hypotheses statements are listed. Details on the unit of analysis, data, and sample follow. Finally, the conceptualization and operationalization of independent, dependent, and control variables is provided.

Research Questions & Hypotheses

This study has very specific research aims. First, this study sets out to understand the distribution of lead and crime across communities in the city of Chicago. Next, this study seeks to examine the relationship between lead and crime across communities in

the city of Chicago. Finally, this study explores the distribution of lead as an environmental justice concern for Chicago residents. As such, this study's research questions are broken down into thirteen testable hypotheses.

The Distribution of lead and crime across communities. This study seeks to address a very straightforward research question: Is there a relationship between hotspots of lead and hotspots of crime? With respect to this research question, three hypotheses are explicated:

H1: Lead is distributed non-randomly across Chicago communities, creating lead hotspots.

H2: Crime is distributed non-randomly across Chicago communities, creating crime hotspots.

H3: Communities which are lead hotspots will also emerge as crime hotspots.

Prior literature suggests that crime and lead have heavily skewed distributions across place (Hanchette, 2008; Lynch et al., 2001; Lynch, 2004; Masters et al., 1994; Mielke et al., 1999; Stretesky & Lynch, 2001; 2004). The criminological literature offers no clear definition of a hotspot. On this point, Chainey, Reid and Stuart (2003) note:

> "Several techniques and algorithms are used in practice for the generation of continuous surface hotspot maps, all of which have different merits. These mainly relate to their ease of use, applications to different types of events, visual results, and interpretation. Few of these methods help to distinguish a consistent defining threshold that helps the analyst decide when a cluster of crimes can be defined as a hotspot," (pg. 23).

For example, Eck (2005) described a crime hotspot as, “an area that has a greater than average number of criminal or disorder events,” (p.2). While “greater than average” may not be the only way to describe a hotspot of crime or lead, this is one approach for defining hotspots. As such, this study conceptualizes a hotspot as a community area with a *significantly* greater than average presence of lead or crime, and assumes a background level of lead and crime throughout all of Chicago.

Tests of hypotheses 1 and 2 set out to examine if lead hotspots and crime hotspots emerge across the city of Chicago. To assess if lead and crime concentrate in the same areas of Chicago, tests of hypothesis 3 specifically sets out to examine overlay between hotspots of crime and hotspots of lead, should they emerge following tests of hypothesis one and two. Hypotheses 1, 2, and 3 are based on prior findings, and are theoretically grounded in the concept that political economic arrangements force lead and crime together in time and space (Hanchette, 2008; Lynch, 2004; Lynch & Stretesky, 2003; Stretesky & Lynch, 2004).

The Relationship between lead and crime in communities. This study also addresses related question if a relationship between lead and crime emerges, such as what is the nature and extent of the relationship between lead and crime at the community level? Specifically, this study explores the conditions under which a relationship between lead and crime remains tenable. Based on prior research, it is predicted that:

H4: Community lead presence is consistently associated with increases in community crime, controlling for traditional criminological predictors of crime.

H5: Community lead presence will be a more consistent predictor of violent crime than property crime.

H6: Community lead presence will be a more consistent predictor of juvenile crime than adult crime.

H7: Community lead presence will be a more consistent predictor of juvenile property crime than adult property crime.

H8: Community lead presence will be a more consistent predictor of juvenile violent crime than adult violent crime.

Tests of hypothesis 4 concern the relationship between community levels of lead and crime with respect to the predictors of crime documented in social disorganization research. Specifically, hypothesis 4 examines whether in the presence of social disorganization variables, lead accounts for increases in crime. Contingent on support for Hypothesis 4, tests of Hypotheses 5 through 8 examine lead's impact on crime across varying traits of offenders and types of offenses. Prior literature suggests that lead promotes violence and aggression particularly (Burns et al., 1999; Needleman et al., 1996), and previous studies have found lead to be a stronger predictor of violent crime than property crime (Pihl & Ervin, 1990). Hypothesis 5 is informed by these findings. Likewise, extant studies have argued that children are particularly vulnerable to environmental contaminants (Landrigan & Carlson, 1995; Moore, 2003), including lead. For this reason, Hypothesis 6 predicts that lead will be a more consistent predictor of juvenile offending than adult offending. Hypotheses 7 and 8 build on Hypotheses 5 and 6, exploring the conditions under which lead may have the most persistent explanatory

power. It is hypothesized that lead will be an especially consistent predictor of variation in violent juvenile offending.

Environmental justice issues. Finally, this study takes into consideration environmental justice literature which documents a disproportionately high presence of environmental hazards in disenfranchised communities (Lerner, 2005; Brulle & Pellow, 2006; Bullard 1994; 1996; Checker, 2007; Hipp & Lakon, 2010; Krieg, 2005; Opp, 2012; Pastor, Morello-Frosch, & Sadd, 2006; Stretesky & Lynch, 2002). As such, an exploratory assessment of lead and environmental justice in Chicago hypothesizes:

H9: Percentage of black residents in a community will correspond positively and significantly with level of lead in a community.

H10: Percentage of Hispanic residents in a community will correspond positively and significantly with level of lead in a community.

H11: Disadvantage will correspond positively and significantly with level of lead in a community.

H12: Disadvantage and percentage of black residents will interact and correspond positively and significantly with level of lead in a community.

H13: Disadvantage and percentage of Hispanic residents will interact and correspond positively and significantly with level of lead in a community.

These last five hypotheses are informed by environmental justice literature and race and political economy theory (Stretesky & Lynch, 2002; 2004). Chicago's diverse population and ethnic enclaves provide an opportunity to assess lead and environmental justice concerns in the city (Sampson, 2012). With respect to race and ethnicity, because

prior work finds levels of lead higher in minority communities than non-minority communities (Brulle & Pellow, 2006; Bullard 1994; 1996; Checker, 2007; Hipp & Lakon, 2010; Opp, 2012; Pastor, Morello-Frosch, & Sadd, 2006; Ringquist, 2005), Hypotheses 6 and 7 anticipate an overrepresentation of lead in predominately black and Hispanic communities. Hypothesis 8 anticipates an over-representation of lead in economically disadvantaged areas (see also Krieg, 2005). Hypotheses 9 and 10 examine the presence of lead when both community minority status and economic status interact and are simultaneously considered. Hypotheses 11, 12 and 13 present variations of hypotheses 9 and 10 which may also be evident.

Unit of Analysis

Because this study contributes to the literature by studying lead and crime at the community level, the necessary unit of analysis is the community. In this study, community is conceptualized as Chicago Community Area (CCA). Currently, Chicago is divided into 77 distinct CCAs. Each community is assigned a name and its own unique number ranging from 1 through 77. The CCAs are recognized by politicians, community leaders, and government entities, and as such, are meaningful to residents and to the city of Chicago (Sampson, 2012). Moreover, the CCAs have historical relevance, and have been recognized in Chicago for decades.

In the 1920's, to facilitate the study of communities across Chicago, the University of Chicago's Social Science Research Committee established 75 community areas across the city (Hudson, 2006). These 75 community areas were non-overlapping and contiguous. The committee used five criteria to distinguish the communities from

one another: (1) settlement, growth, and history of the area, (2) local identification with the area, (3) local trade area, (4) distribution of membership of local institutions, and (5) natural and artificial barriers (Hudson, 2006, pg. 23). In subsequent years, when the U.S. Census Bureau began defining the boundaries for census tracts in Chicago, boundaries were drawn so that they overlapped with the predefined boundaries of the 75 community areas. That is, census tracts aggregate up to corresponding community areas (Hudson, 2006; Visher & Farrell, 2005), and Chicago's community areas exist as aggregates of census tracts (Block & Block, 1993; Zhang, 2012).

In 1960, O'Hare was annexed as the 76th community area, and in 1980, Edgewater became recognized as the 77th community area (Zhang, 2012). The boundaries of the tracts have undergone only minor changes over time[17], and construe what are contemporarily recognized as the 77 Chicago Community Areas (CCA). Today, the city of Chicago officially recognizes the CCAs for city planning and service delivery purposes (Hudson, 2006; Visher & Farrell, 2005), and the CCAs are also readily known by residents, the media, and administrative agencies (Sampson, 2012). Researchers have used the CCAs as the unit of analysis in their studies of street-gang crime (Block & Block, 1993), homicides (Sampson, 2012), prisoner re-entry (Visher & Farrell, 2005), and hate crime (Lyons, 2006).

The use of the CCAs to measure community has many benefits. For example, CCA's are recognized by the local government and policy makers in terms of service delivery and regional planning, making results from this study more amenable to policy

[17] In the 2010 Census, a few minor changes were made to the boundaries of the census tracts in the city of Chicago, resulting in 112 tracts merging and 132 tracts splitting (Zhang, 2012).

implications. Residents also identify and recognize the CCAs. Additionally, because the boundaries of the CCAs have remained relatively stable over several years, the CCAs bear historical relevance, and contemporary studies of the CCAs can be meaningfully compared to prior works given the long term stability of these community areas. Relatedly, because other researchers have utilized the CCAs, the use of the CCAs as the unit of analysis in this study allows for findings to be readily interpreted in the context of extant work. A map of the Chicago Community Areas is provided in Appendix A.

The Ecological fallacy. In 1950, W.S. Robinson published “Ecological Correlations and the Behavior of Individuals,” in the American Sociological Review. In this seminal piece, Robinson articulates the distinction between individual correlations (descriptive properties of individuals) and ecological correlations (descriptive properties of groups, often rates, means, or percentages). Robinson explains that the purpose of the essay was to express the mathematical difference between individual correlations and ecological correlations, and in the process, illustrate the consequences of using ecological correlations in place of individual correlations. To make his point, Robinson uses race, ethnicity, and illiteracy data to argue how the strength and/or direction of a relationship between two variables is dependent upon the level at which (individual, ecological) the data was collected. The methodological pitfall Robinson calls attention to -- using aggregate data to draw conclusions about individuals -- has come to be known as “the ecological fallacy.” Selvin (1958) coined the phrase and described the ecological fallacy as occurring when, “relationships between characteristics of individuals are wrongly inferred from data about groups,” (p. 613).

Robinson's essay was critical of aggregate data, and the ecological fallacy had far reaching consequences for social science research[18]. One of those consequences is the development of the tradition of methodological individualism in the social sciences (Mills, 1959), including criminology (Michalowski, 2009; Sampson, 2012; Subramanian et al., 2009). Robinson's critique of aggregate data is limited, however, by his inherent assumption that social science researchers are only concerned with individual level processes (Sampson, 2012; Subramanian et al., 2009). When social science researchers seek to understand community level processes, it is most appropriate to analyze ecological data. On this point, Sampson (2012) explains:

> "Robinson's mistake, and that of many readers, was to assume that ecological researchers only cared about individual-level inferences. Rather than arguing against ecological or neighborhood-level research, the right message was to make clear distinctions among units of analysis and to appropriately frame analytical questions… It follows that if the main goal is to explain rates of variation across neighborhoods rather than individual differences, Robinson's critique does not hold…" (p. 39).

Following Sampson's argument, the current study is not making an ecological fallacy since its emphasis is on the community level of analysis, and **not** the individual.

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[18] Researchers have critiqued Robinsons essay, and subsequent discussions of the ecological fallacy, as distracting from fallacies in individual level research. In 1969, Alker coins the term "individualistic fallacy" to refer to conditions when, "ideologically motivated social scientists try to generalize from individual behavior to collective relationships, " (p. 78). While outside the scope of this study, it is arguable that the combination of (1) mainstream criminology's emphasis on individual-level studies and (2) empirical tests of "general theories of crime," has amassed a literature that is highly vulnerable to the individual fallacy. Sampson (2012) argues, "worry about the ecological fallacy distracted attention from the 'individualistic fallacy'- the often-invoked and also erroneous assumption that individual-level relations

The research questions addressed in this study concern variation in *community crime and lead rates*: not variation across the health and behavior of individuals. All data used in this study are qualities or traits *of communities* represented as rates and percentages.

Data & Sample

Data for this study were obtained from multiple secondary sources, each source providing relevant data on the total sample of 77 CCAs (n = 77). These sources include the City of Chicago (2012), the U.S. Census Bureau (2000; 2010), the American Community Survey (2010), the Chicago Department of Public Health (2008), and The Chicago Police Department (2008). The City of Chicago[19] provides shapefiles for the city of Chicago, including files identifying: the boundaries of the CCAs, Chicago census tracts, and each Chicago census tract's corresponding CCA. The city of Chicago provides this data for 2000 census tracts and 2010 census tracts. Given the overlap between census tracts and CCAs in the city of Chicago, it is possible to aggregate census data to CCA (Block & Block, 1993; Lyons, 2006; Zhang, 2012). In 2010, the city of Chicago identified 873 census tracts within Chicago that comprised CCAs, and in 2010 identified 801 census tracts within Chicago that comprised CCAs. Socio-demographic information for this sample was obtained for each of these tracts from the 2000 U.S. Census, 2010 U.S. Census, and 2010 American Community Survey. It follows then, that data from each tract was aggregated up to the appropriate CCA[20].

are sufficient to explain collective outcomes," (p. 40). Both the individual and ecological fallacy are explored empirically in a contemporary re-analysis of Robinson's data (see Subramanian et al., 2009).

[19] See: https://data.cityofchicago.org/

[20] While some census tract boundaries changed (merged, split) between 2000 and 2010, the boundaries for the Chicago Communtiy Area remained unchanged. The city of Chicago provides 2010 census tract data,

Data for this study was also obtained from the Chicago Police Department. The Chicago Police Department produces an annual report on index crime, case clearances, domestic violence, traffic safety, calls for service, and related law enforcement information. These annual reports are available for download on the Chicago Police Department website for years 1967 through 2010. Beginning in 1998, the Chicago Police Department began providing data on index crime as it occurred in the CCAs. Crime data for this study was obtained using figures publicly available from the 2000 through 2010 Annual report. To obtain information about age of offenders (juvenile vs. adult index offenses), a Statistical & Crime Data Request was filed with the Research and Development Division of the Chicago Police Department. Data on arrests for index crimes by CCA and age of offender (adult or juvenile) was provided for the year 2008, and translated into age-based rates of offending for each community.

Finally, data from the Chicago Department of Public Health was collected for this study. Per the Illinois Lead Poisoning Prevention Act, Illinois law mandates every practicing physician in the state to screen children age 6 months through 6 years old for lead, if the child resides in a zip code that the Illinois Department of Public Health deems "high risk," (Illinois Lead Poisoning Prevention Act, 410 ILCS 45). Currently, the department deems *all* zip codes in Chicago to be high risk (Lead Safe Illinois, 2006). According to the Illinois Department of Public Health, a blood lead level (BLL) less than 10 μg/dL, is considered to be permissible for children age 16 and younger (regardless of

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and designates tracts to CCA. Census data was obtained by requesting from American Fact Finder data for all census tracts (or parts) fully within/partially within the city of Chicago, Illinois. As a measure of quality assurance, after tracts were aggregated, population totals for each CCA were matched to CCA population

the fact that findings from the medical literature recommend much lower thresholds). However, if a child is screened and found to carry a BLL greater than or equal to 10 μg/dL, that child is considered to have an elevated BLL. Physicians are required to report results of lead screenings (elevated and otherwise) to the Illinois Department of Public Health (which oversees the Illinois Lead Program) (Illinois Lead Poisoning Prevention Act, 410 ILCS 45). In turn, the Chicago Department of Public Health uses laboratory results reported to the IPHD, to construct rates of children tested and found to have elevated BLLs by Chicago Community Area. This information is publicly available and was accessed online via the City of Chicago Data Portal.

Independent Variable

The independent variable of interest in this study is lead. To measure lead, this study relies upon the Chicago Department of Public Health's data on children age six and under screened for lead (Chicago Department of Public Health, 2012), as an indicator for the presence of lead in a community. Specifically, this study uses the variable "Percent Elevated," for the years 1999 through 2010. According the Chicago Department of Public Health, in this dataset, percent elevated is the proportion of children tested that were found to have elevated BLLs. This figure is determined by dividing the number of children found to have elevated BLLs by the total number of children tested and multiplying by 100, and produces the community measure of lead in this study. Per the Department's standards, "elevated" is defined as a venous blood sample found to be at a BLL at or above 10 μg/dL. The Chicago Department of Public Health reports this

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totals reported by the city of Chicago and the Chicago Police Department for 2000 and 2010, respectively. Results indicate tracts were aggregated accurately.

proportion for each of the Chicago Community Areas[21]. Increases in proportion of children under age six tested with elevated BLL will be interpreted as increases in community presence of lead.

The use of proportion of children with elevated BLL is an appropriate indicator for community presence of lead because the link between body lead burden and presence of lead in the environment is robust and well documented (Aschengrau et al., 1994; Brunkenreff, 1984; Hayes et al., 1994; Laidlaw et al., 2012; Lanphear et al., 1996; Lanphear et al., 1998; Pirkle et al, 1994; Reyes, 2007; Schwartz & Pitcher, 1989; Stretesky & Lynch, 2001; Zahran et al., 2011). Because the presence of blood lead has been found to be positively, significantly correlated with presence of lead in the environment (e.g., air, soil), it acts as a strong indicator of community lead presence. These associations in prior literature establish that it is reasonable to infer that if the residents of a community are carrying high levels of lead in their bloodstreams it is related to a corresponding high level of lead present in their community. Conversely, it is reasonable to infer that if a community has relatively few residents with lead in their blood, it is reasonable to infer that the community has less of a presence of lead. For this reason, presence of lead is measured using this indicator across all hypotheses.

Dependent Variable

The dependent variable in this study is crime. In this study crime is conceptualized as index crime. Index crimes refer to the eight offenses labeled Part I-Index crimes by the FBI, and include: murder, rape, aggravated assault, robbery,

[21] For the years 2003 through 2010, the Chicago Department of Public Health claimed the community of Riverdale (CCA # 54), had insufficient data. As such, some analyses omit Riverdale. These instances are

burglary, larceny-theft, motor vehicle theft, and arson. The Chicago Police Department documents each of these acts as index crimes, with the exception of rape, as the Chicago Police Department documents instead acts of sexual assault. Sexual assault is described in Chicago Police Department Annual Reports as "broader than the traditional definition of 'rape,'" and includes, "any sexual assault- completed or attempted, aggravated, or non-aggravated- committed against any victim, female or male," (Chicago Police Department, 2008, pg. 29). The number of reported *incidents* of index crimes occurring in each CCA is provided in the Chicago Police Department's Annual Report, with counts for each offense listed separately (e.g, counts are provided for each type of index offense). This study uses crime data from 2000 - 2010 to test the relation between lead and crime. To test H4, crime is measured using each CCA's total number of index crime, as reported in Chicago Police Department Annual Reports. Next, the count of index crime is transformed into the rate of index crime. Rate is determined by dividing the number of CCA index crimes by the corresponding CCA total population.

To test H5, it is necessary to distinguish types of crime for the dependent variable. Testing of H5 will measure violent crime rate by using the total count of murders, sexual assaults, aggravated assaults, and robberies as reported in the Chicago Police Department's Annual Reports from 2000 to 2010. Testing of H5 will measure property crime rate by using the total count of burglaries, thefts, motor vehicle thefts, and arsons as reported in the Chicago Police Department's Annual Reports from 2000 to 2010.

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noted in Chapter 6.

To test H6, H7, and H8, it is necessary to distinguish the age of the offender (juvenile vs. adult) as well as type of offense (violent vs. property). This data was provided by the Chicago Police Department in response to a Statistical & Crime data request for a breakdown of index crimes committed by adults and index crimes committed by juveniles by CCA. In tests of H6, juvenile crime is defined as an *arrest* of a person age 17 or under for an index crime. In tests of H6, adult crime is defined as an *arrest* of a person age 18 or over for an index crime. In tests of H7, juvenile property crime is captured using the total count of arrests of a person age 17 or under for burglaries, thefts, motor vehicle thefts, or arsons. In tests of H7, adult property crime is captured using the total count of arrests of a person age 18 or over for burglaries, thefts, motor vehicle thefts, or arsons. In tests of H8, juvenile violent crime is measured by taking the total count of arrests of a person age 17 or under for murders, sexual assaults, aggravated assaults, or robberies. In tests of H8, adult violent crime is measured by taking the total count of arrests of a person age 18 or over for murders, sexual assaults, aggravated assaults, or robberies . Data for tests of H6, H7, and H8 rely on index crime arrests in 2008. Rate is determined by dividing juvenile arrests by the total population age 17 and under, and dividing adult arrests by the total population 18 and over. It was necessary to use incident arrest rate as opposed to incident rate, because demographics of offender (e.g., age), are not always known or accurately reported for incident rates. Naturally, this limits the ability of results from tests H6, H7, and H8 to be compared to findings from H1 – H5. This will be reiterated throughout the analysis chapter, and in the discussion chapter.

Control Variables

Social disorganization theory and communities and crime research informed the decision to include a number of control variables in the analysis. As such, this study uses data from the 2000 U.S. Census, 2010 U.S. Census, and 2010 American Community Survey to include measures for socio-economic status, racial/ethnic heterogeneity, and residential mobility as informed by the social disorganization literature (Kornhauser, 1978; Shaw & McKay, 1942). Additional control variables were added based on findings from the communities and crime literature. These variables include: percent black, percent Hispanic, percent divorced (Liska & Bellair, 1995), population size and density (Morenoff, Sampson, & Rauenbush, 2001; Sampson & Raudenbush, 1999), and percent population between 15-24 (Pridemore & Grubesic, 2011).

Disadvantage. Socioeconomic disadvantage is measured using a principle component index of the following variables: median income, percentage of families living below the poverty level, percentage of households receiving public assistance, percent unemployed, and percentage of female headed households. Higher values on this index will be interpreted as increased levels of economic disadvantage, and conversely, lower values on this index will be interpreted as decreased levels of economic disadvantage. The inclusion of an index for economic status is informed by social disorganization theory, which predicts that increases in disadvantage weakens community informal social control, and in turn, increases crime (Kornhauser, 1978; Sampson & Groves, 1989; Shaw & McKay, 1942). The selection of the indicators for disadvantage

is informed by prior research (Sampson, Raudenbush, & Earls, 1997; Stretesky & Lynch, 2004).

Two disadvantage indices were created for 2000 and 2010, respectively. For the 2000 SES index, the first component extracted had an Eigenvalue of 4.22, which is well above the recommended cutoff of 1 (Kaiser, 1961). Additional factors obtained Eigenvalues less than 1 (ranging from .021 to .529), and thus, were not retained. Four of five indicators loaded positively onto the retained factor at .4120, .4502, .4638, and .4762. Median income loaded inversely at -.4309. The 2000 SES index obtained a Cronbach's α = .8029. For the 2010 SES index, the first component extracted had an Eigenvalue of 3.95, which is well above the recommended cutoff of 1 (Kaiser, 1961). Additional factors obtained Eigenvalues less than 1 (ranging from .0546 to .6034), and thus, were not retained. Four of five indicators loaded positively onto the retained factor at .4092, .4736, .4692, and .4199. Median income loaded inversely at -.4602. The 2010 SES index obtained a Cronbach's α = .7539. Tests of hypotheses four through eight, as well as hypotheses nine, eleven, and thirteen will employ this index to measure disadvantage.

Racial & ethnic heterogeneity. Population heterogeneity was measured using the Herfindahl index (Gibbs & Martin, 1962; Hipp, Tita, & Boggess, 2011; Vélez & Richardson, 2012). The Herfindahl Index will be used to capture the degree to which communities are racially or ethnically diverse with respect to four racial/ethnic groups: white, black, Hispanic, and other populations. Following Hipp et al., (2011), this study estimates the Herfindahl Index applying the following formula:

$$H = 1 - \sum_{j=1}^{J} G_j^2$$

WHERE:

G = the proportion of a given racial/ethnic group present in a community
j = a given racial/ethnic group (white, black, Hispanic, other)
J = the total number of racial/ethnic groups

Higher values on the Herfindahl index are to be interpreted as higher levels of heterogeneity, and likewise, lower values on this index will be interpreted as lower levels of heterogeneity (with a value of zero indicating perfect homogeneity). The inclusion of an index for racial/ethnic heterogeneity is informed by social disorganization theory, which predicts that increases in racial/ethnic heterogeneity weaken community informal social control, thereby increasing crime.

For this study, ethnicity was captured by classifying Chicago's population into those that identified on the Census as either Hispanic or Non-Hispanic. To capture race, those who identified as Non-Hispanic were classified into one of four categories: White, Black, Asian, and Other. Here, the Other category includes individuals who identify as Native American Indian, Hawaiian, as a race outside of the options provided on the Census, or individuals who identify as multi (2 or more) racial. Tests of Hypotheses 4 through 8 will use this measure to control for racial/ethnic heterogeneity.

Residential mobility. Residential mobility will be measured using a principle component index of the following variables: percentage of families who have moved from another residence in the past five years, percentage of vacant houses, and percentage of houses occupied by a renter. Higher values on this index will be

interpreted as higher rates of residential mobility, and lower values on this index will be interpreted as lower rates of residential mobility. The inclusion of an index for residential mobility is informed by social disorganization theory, which predicts that increases in residential mobility will decrease informal social control, and in turn, increase crime (Kornhauser, 1978; Sampson & Groves, 1989; Shaw & McKay, 1942). Tests of Hypotheses 4 through 8 will use this measure to control for residential mobility.

Two residential mobility indices were created for 2000 and 2010, respectively. For the 2000 residential mobility index, the first component extracted had an Eigenvalue of 2.00, which is well above the recommended cutoff of 1 (Kaiser, 1960). Additional factors obtained Eigenvalues less than 1 (.7731 and .2179), and thus, were not retained. Factor loadings ranged from .4957 to .6599, and a Cronbach's $\alpha = .7449$ was obtained. For the 2010 residential mobility index, the first component extracted had an Eigenvalue of 2.244, factor loadings ranging from .5373 to .6368, and a Cronbach's $\alpha = .8281$ was obtained.

Other controls. Since the inception of social disorganization theory, a number of studies examining communities and crime have uncovered additional variables that bear significant associations with community crime rates (Hipp, 2007; Liska & Bellair, 1995; Logan & Stults, 1999; Lyons, 2007; Morenoff, Sampson, & Rauenbush, 2001; Sampson & Raudenbush, 1999; Velez & Richardson, 2012). These variables include *percent black, percent Hispanic, percent divorced, percent population between 15-24,* and *population density*. These variables were measured with responses taken from U.S. census data, with the exception of population size and density, which will be calculated

by dividing the total population of a CCA (determined from the U.S. Census) by the land area in square miles (provided by the city of Chicago shapefile for the CCAs). Because these variables have proved to be significantly associated with crime in prior studies, they are also included in the present analysis. In addition, the analytic approach of this study calls for tests of spatial autocorrelation. Thus, spatial lag variables will be employed as necessary. These variables are used as controls in tests of hypotheses four through eight. Percent black and percent Hispanic are also used in the exploratory analysis of environmental justice concerns.

Statistical & GIS Software Used

In this study, data were analyzed using Stata 11 (StataCorp., 2009), GeoDa (Anselin, Syabri, & Kho, 2006), and ArcMap 10 (ESRI, 2011). Creation of principal component indices, bivariate, and multivariate techniques was carried out with the use of Stata 11. The generation of spatial weights, the spatial lag variable, and the Morans I statistic was carried out using GeoDa. Finally, maps of the Chicago Community Areas provided in Figures 5, 6, and 7 were generated using ArcMap10.

In sum, this study aims to explore the relationship between hotspots of lead and hotspots of crime. In doing so, three hypothesis statements are tested to explore the existence of lead and crime hotspots, and their potential overlap. To understand the nature and extent of the relationship between lead and crime at the community level, additional hypotheses statements are tested addressing the conditions under which the relationship does (or does not) remain tenable. Five final hypotheses are tested to explore

potential environmental justice concerns across Chicago's communities. Data from a variety of secondary sources are used in this analysis, including the Chicago Department of Public Health (2007), the Chicago Police Department, and the U.S. Census (2000). Chapter five has specified the measurement of each variable in this analysis, thus setting the foundation for the analysis and results detailed next in chapter six.

Chapter Six:

Analysis and Results

Chapter six presents the analysis and results for this study. Before the results related to tests of hypotheses statements are presented, a series of preliminary analyses are performed, and descriptive statistics on the sample are provided. Next, the results from tests of the first three hypotheses statements are presented to explore whether there are hotspots of lead and hotspots of crime among Chicago communities. Then, five hypotheses relating to the nature and extent of the lead-crime relationship are tested. Finally, the results from the empirical tests of the final five hypotheses are presented. Those hypotheses explored the distribution of lead in Chicago in relation to environmental justice theory and explanations.

Preliminary Analyses

Before addressing this study's research hypotheses, a short series of preliminary analyses were performed. The purpose of the preliminary analysis was to describe the data and examine the bivariate relationships between the lead, crime, and control variables. The preliminary analysis begins by presenting means and standard deviations for variables that convey key demographic information about the sample. Next, the bivariate relationships among the variables are assessed empirically.

Descriptive data. Descriptive data for all the control variables (years 2000 and 2010, respectively) are presented in Table 3. These data reveal that in 2000, the average Chicago Community Areas concentrated an average of 37,610 individuals. In 2000, the Chicago Community Areas were approximately 31.1% white, 40.89% black, and 21.76% Hispanic. These data also indicate that the average

Table 3. *Sample Demographics for Chicago Community Area Control Variables, 2000 and 2010 Census (n = 77)*

Variable	M	SD	Minimum	Maximum
Area (in square miles)	2.999	1.970	.6067	13.3377
2000				
Total Population	37610.6	24443.8	3294	117527
Density	13741.91	7282.774	896.402	35789.09
% Hispanic	.2176	.2514	.0059	.8890
% Black	.4089	.4109	.0016	.9809
% Divorced	.0902	.0258	.0422	.1560
% 15 – 24 yrs old.	.1465	.0292	.0840	.2238
Heterogeneity*	.3713	.2114	.0437	.7119
% White	.3118	.2984	.0032	.9328
% Asian	.0435	.0862	.0003	.6071
% Other	.0615	.0915	.0052	.6213
SES Index	0	2.05	-3.834	6.225
% Female HH	.2186	.1259	.0366	.5979
% Under Poverty	.1714	.1238	.0150	.5358
% Public Assist.	.0812	.0682	.0023	.2903
% Unemployed	.0660	.0358	.0175	.1825
Median Income	46298.32	29408.28	13979.00	138336.5

Residential Mobility	0	1.417	-2.457	3.371
% Vacant	.0824	.0540	.0198	.2736
% Moved	.3805	.0939	.2143	.6540
% Rent	.5174	.2208	.0886	.9106
2010				
Total Population	35007.77	22361.95	2876	98514
Density	12886.35	6736.292	956.3817	32522.51
% Hispanic	.2553	.2809	.0068	.8920
% Black	.3918	.4027	.0025	.9778
% Divorced	.0943	.0291	.0393	.1738
% 15 – 24 yrs old.	.1490	.0323	.0771	.2550
Heterogeneity	.3713	.2111	.0437	.7119
% White	.2826	.2817	.0027	.8836
% Asian	.0541	.1022	0	.7259
% Other	.0159	.0084	.0032	.0413
SES Index	0	1.97	-3.920	4.578
% Female HH	.2146	.1265	.0302	.6074
% Under Poverty	.1800	.1100	.0190	.5521
% Public Assist.	.0397	.0271	.0046	.1354
% Unemployed	.0811	.0353	.0290	.1983
Median Income	58491.64	29408.4	17687.	167163.
Residential Mobility	0	1.498	-2.899	3.004
% Vacant	.1243	.0581	.0442	.2941
% Moved	.3704	.1150	.1733	.6276
% Rent	.5027	.1952	.1088	.8860

* Indented items indicate those which were included in scales, but not expressly in models

population of the Chicago Community Area declined from 2000 to 2010. With respect to race and ethnicity, Chicago Community Areas in 2010 have slightly fewer white or black residents and slightly more Hispanic residents. The median income across all Chicago Community Areas was $46,298.32 in 2000 and rose to $58,491.64 in 2010.

The means and standard deviations for lead and crime (from 1999 through 2010) are presented separately in Table 4. With respect to lead, the average percentage of tested children who had elevated blood lead level (BLL$\geq$ 10 μg/dL) per year is presented along with standard deviations. The data reveal that in 1999, on average, approximately 12.64% of a Chicago Community Area's tested children carried an elevated blood lead burden. The data also reveal that this rate declined annually, with the most recent estimates indicating approximately 1% of a Chicago Community Area's tested children carry an elevated blood lead burden. A similar trend emerged across crime rates. Table 4 includes means and standard deviations for annual rates of violent, property, and total index crimes in Chicago Community Areas (per 1,000 residents). Across all years, the highest average rates of violent, property, and total crime per community occurred in 2000, at approximately 18, 61, and 79 per 1,000 residents, respectively. In 2010, these rates dropped to approximately 12, 45, and 57 per 1,000 residents, respectively.

Finally, descriptive information for arrests for juvenile and adult index crime in 2008 are presented in Table 5. Because of missing data, the Riverdale community (#54) is excluded from this analysis. Overall, in 2008, these data suggest that the rate of juvenile arrests for index crime surpassed the rate of adult arrests for total, property, and violent index crimes, respectively. With respect to frequency, arrests for property crime are more frequent than arrests for violent crimes. Similar to the total distribution of index crimes, arrests for juvenile and adult index offenses appears skewed. For example, the rate of arrests per 1,000 for violent juvenile offenses ranged from communities

Table 4. *Sample Means, Standard Deviations, Minimums, and Maximums for Lead, Violent Crime, Property Crime, and Total Crime, 1999 through 2010*

	Year											
Variable	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
% Children. Elevated Blood Lead												
M	12.64	10.87	8.61	6.82	4.78	4.23	2.79	1.96	1.73	1.15	.96	.93
SD	10.04	9.11	7.17	6.02	4.27	3.78	2.15	1.57	1.39	.85	.59	.71
Min	0	.4	0	0	0	0	.2	0	0	0	0	0
Max	39.5	35.6	30.2	23.2	17.3	16.7	9	7.2	6	3.5	2.4	3
Violent Crime Rate†												
M	---	17.80	17.03	16.62	14.35	13.53	13.31	13.06	12.70	12.71	12.00	12.11
SD	---	14.47	13.47	13.00	10.94	10.28	10.29	9.95	10.11	10.40	9.49	10.19
Min	---	1.07	1.27	1.33	.80	.99	1.03	.71	1.03	.71	1.04	.536
Max	---	65.50	57.47	51.39	45.45	41.56	45.10	40.64	37.25	47.66	34.50	36.86
Property Crime Rate†												
M	---	60.87	56.07	53.40	53.47	52.36	48.71	48.88	46.44	46.46	43.63	45.30
SD	---	50.11	44.56	38.99	37.32	38.09	34.51	35.20	33.64	33.68	30.52	24.04
Min	---	16.34	16.24	10.92	9.32	9.76	12.17	11.37	9.33	11.81	11.90	7.78
Max	---	417.44	376.92	327.31	307.30	313.83	287.1	279.53	274.35	278.62	261.66	144.45
Total Crime Rate†												
M	---	78.67	73.11	70.02	67.82	65.89	62.03	61.95	59.15	59.18	55.63	57.41
SD	---	57.50	51.15	45.75	43.15	43.53	40.60	41.49	39.84	39.85	35.94	32.30
Min	---	17.41	17.67	12.26	10.13	11.19	12.23	12.08	10.39	12.52	13.06	8.31
Max	---	442.76	396.93	348.73	323.84	329.63	306.51	299.79	296.00	298.08	281.73	160.29

* Lead is computed for all 77 communities each year with the exception of the Riverdale (#54) community for the years 2003 through 2010. In these years, for lead only the means and standard deviations for n=76 are provided.
† Rate per 1,000 residents

with 0 (Edison Park- #9 and Forest Glen- #12) to communities with 34 (Fuller Park- #37). Adult violent offenses ranged from .07 per 1,000 (Forest Glen- #12) to 39 (Fuller Park- #37).

Table 5. *Sample Means, Standard Deviations, Minimums, and Maximums for Juvenile Index Crime Arrest Rate and Adult Index Crime Arrest Rate, 2008 (n = 76)*

Variable	M	SD	Minimum	Maximum
Juvenile Crime	16.57	40.96	.43	356.49
Adult Crime	11.64	15.06	.57	107.40
Juvenile Property	11.38	37.45	.43	327.89
Adult Property	8.75	11.27	.50	68.53
Juvenile Violent	5.19	5.67	0	34.08
Adult Violent	2.89	4.71	.07	39.28

Bivariate relationships. The next analyses involved testing the bivariate relationships between the variables of theoretical interest. The first analysis explored the bivariate relationship between the control variables, lead, and crime. Results are presented below in Table 6. Here, associations between the Census 2000 control variables, 1999 lead variable and 2004 crime average are tested. The data are drawn from different years to reflect causal processing order and assumptions concerning effect lags made in prior studies. Because prior literature suggests lead may have a lagged effect on crime, a five year lag for lead was examined (the percent of tested children who had elevated blood lead levels in 1999). To control for annual variations in crime rates, the

average rate of index crime for the years 2003, 2004, and 2005 were used. Results from theses analyses suggest significant, positive relationships with crime and: (1) percent black (r=.4582, p <.01), percent divorced (r=.4889, p <.01), (2) disadvantage (r=.3054, p <.01), (3) population density (r=.4989, p <.01), and (4) lead (r=.4920, p <.01). A significant inverse relationship emerged between percent Hispanic and crime (r=-.3238, p <.01). The inverse relationship observed between crime and heterogeneity (r=-.2024, p = .0775) was insignificant.

An additional analysis examined the bivariate relationship between the control variables, lead, and crime 2010. Results from Pearson product-moment correlations are presented below in Table 7. Here, associations between the Census 2010 control variables, 2005 lead variable and 2010 crime average are tested. To control for annual variations in crime rates, the average rate of index crime for the years 2009 and 2010 were used (2011 Annual Data has not yet been made available). Also, because lead data was not available from Riverdale (Community # 54), Riverdale was not included in this bivariate assessment (n = 76). Results of this analysis indicate significant, positive associations between crime and: (1) percent black (r=.5934, p<.01), (2) percent divorced (r=.4214, p<.01), (3) percent of population between 15 and 24 (r = .4703, p<.01), (4) disadvantage (r = .4323, p <.01), (5) residential mobility (r = .5911, p <.01), and (6) lead (r = .6234, p <.01). As illustrated, the largest relationship was between lead and crime. Significant inverse relationships were found between crime and: percent Hispanic (r = -.4066, p <.01), and heterogeneity (r = -.3772, p <.01). The bivariate associations between

2005 lead, 2010 census variables, and 2010 crime appear relatively similar to associations found using 1999 lead, 2000 census, and 2004 crime.

In sum, results from the preliminary analysis appear congruent with this study's research hypotheses with respect to the association between lead and crime. In both series of tests, there was a significant, positive association between mean BLL concentrations in communities and community levels of crime. In addition, the descriptive statistics suggest a skewed distribution for both lead and crime. For example, in 1999, the distribution of lead ranged from 0% to 39.5%, and had a mean of 12.64%. Likewise, crime in 2004 ranged from rates of 11 crimes per 1,000 residents to 329 crimes per 1,000 residents, with a mean of 65.89 crimes per 1,000 residents. These findings are consistent with the hypotheses that lead and crime are not normally distributed in Chicago. A lagged association between lead and crime was also observed in the bivariate analysis. Thus, additional analysis assessing the relationship between lead and crime appear justified.

Hypothesis Tests

The results section of this study proceeds by re-stating the research questions and corresponding hypotheses from chapter 5. Following each hypothesis is a description of the analytic approach taken to test the hypothesis. Results are reported for each hypothesis in turn.

Table 6. *Bivariate Associations between Lead (1999), Crime Incidents (2004), and Census Control Variables (2000), (n= 77)*

Correlation Matrix	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. Area	---										
2. Density	-.2545*	---									
3. Hispanic	.0244	.2784*	---								
4. Black	-.0748	-.2250*	-.5912**	---							
5. Divorced	.0240	-.1118	-.6150**	.7071**	---						
6. 15 – 24	-.0280	.3101**	.4736**	.0621	-.2676*	---					
7. Heterogeneity	.1145	.3055**	.4543**	-.6630**	-.3784**	.1647	---				
8. Disadvantage	-.0834	-.1254	-.2183	.7935**	.3369**	.3736**	-.5246**	---			
9. Mobility	-.1622	.3528**	-.1358	.3214**	.3051**	.4144**	-.0764	.5155**	---		
10. Lead	-.0623	.0122	-.2171	.7438**	.4104**	.3027**	-.4962**	.7220**	.4019**	---	
11. Crime	-.0759	-.1741	-.3238**	.4582**	.4889**	.1187	-.2024†	.3054**	.4989**	.4920**	---

****p<.01; *p<.05**

Table 7. *Bivariate Associations between Lead (2005), Crime Incidents (2010), and Census Control Variables (2010), (n= 76)*

Correlation Matrix	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. Area	---										
2. Density	-.2772*	---									
3. Hispanic	.0335	.1774	---								
4. Black	-.0718	-.3294**	-.5935**	---							
5. Divorced	-.1366	-.2733*	-.5828**	.7578**	---						
6. 15 – 24	-.1194	.1387	.1146	.2172†	.0159	---					
7. Heterogeneity	.1329	.3121**	.2712*	-.6716**	-.4320**	-.1089	---				
8. Disadvantage	-.0831	-.2670*	-.0685	.7405**	.3952**	.3402**	-.5942**	---			
9. Mobility	-.1404	.3768**	-.2162†	.3425**	.2145†	.4584**	-.1157	.4243**	---		
10. Lead	-.0215	-.1130	-.2349*	.7020**	.3468**	.3832**	-.5327**	.7822**	.5167**	---	
11. Crime	-.0239	-.1193	-.4066**	.5934**	.4214**	.4703**	-.3772**	.4323**	.5911**	.6234**	---

****p<.01; *p<.05; †p <.10**

The Distribution of lead and crime across communities. The first research question posed by this study was stated previously as “is there a relationship between hotspots of lead and hotspots of crime?” To address this research question, the distribution of lead and crime across the Chicago Community Areas must be examined. As such, three hypotheses are explicated. The first of these hypotheses is:

H1: Lead is distributed non-randomly across Chicago communities, creating lead hotspots.

To test this first hypothesis, the distribution of lead across Chicago’s communities was examined. To begin, Shapiro-Francia and Shapiro Wilk tests were performed on the data to examine the distribution of the lead variable in the year 1999 (Shapiro & Francia, 1972; Shapiro & Wilk, 1965). In this case, both the Shapiro-Francia and Shapiro-Wilk test the null hypothesis that lead is normally distributed. Results for the Shapiro-Wilk ($W = .8927$, $p < .01$) and Shapiro-Francia ($W' = .90556$, $p < .01$) reject the null that lead is distributed normally across Chicago communities. The 1999 lead variable was also tested for skewness and kurtosis, using Stata’s skewness and kurtosis normality test (Acock, 2008). Results indicate that based on skewness, there is a statistically significant lack of normality ($p < .01$). Lead did not appear significantly non-normal based on kurtosis ($p = .315$), and a joint test of normality based on both skewness and kurtosis indicates significant non-normality in the lead variable ($p < .01$).

Because the research question in this study concerns spatial dependence, additional analyses were performed to examine the spatial distribution of lead across Chicago. As such, the data were examined for spatial autocorrelation To test for spatial autocorrelation, a global Moran's I statistic was calculated[22]. The Moran's I statistic tests the null hypothesis that there is no spatial dependence associated with a given feature across a geographic area (Anselin, 1988). Values of the Moran's I range from -1 to +1, with higher positive values indicating high, positive spatial autocorrelation (similar values clustered together), and lower negative values indicating high negative spatial autocorrelation (values surrounded by dissimilar values). Results produced a Moran's I of .536, associated with a z-score of 7.68 ($p <.01$), signifying spatial autocorrelation in the distribution of lead across Chicago communities. That is, communities that have higher levels of lead tend to be significantly closer in proximity to one another.

To test for lead hotspots, the lead variable was standardized into z-scores. In the present study, the average presence of lead in a Chicago Community Area in 1999 was 12.64% (i.e, the percent of a community's tested children carrying elevated blood lead burdens). Eighteen communities ranked above average with respect to this indicator for the presence of lead in the communities of Chicago. An analysis of the standardization distribution of the lead variable revealed six communities with a presence of lead that was significantly above the standardized average. In ascending order, these communities are: Austin (34.2% of tested children, $p <.05$), West Englewood (34.4% of tested children, $p <.05$), West Garfield Park (35% of tested children, $p <.05$), East Garfield Park

[22] First-order contiguity-based spatial weights were generated from the Chicago community area polygon shape file using queen criteria in GeoDa. Queen criteria include neighbors that share contiguous boundaries as well as vertices.

(37.8% of tested children, $p < .05$), Englewood (38.9% of tested children, $p < .01$), and Fuller Park (39.5% of tested children, $p < .01$).

Importantly, when employing the data to identify and isolate lead hotspot, it becomes clear that lead is not randomly distributed across Chicago communities. Results indicate approximately six lead hotspots or communities carrying lead burdens which are significantly higher than the rest of Chicago community areas. As such, these results are supportive of the first hypothesis.

H2: Crime is distributed non-randomly across Chicago communities, creating crime hotspots.

To test the second hypothesis, the distribution of crime across Chicago's communities was examined. First the Shapiro-Francia and Shapiro Wilk tests were performed on the data to examine the distribution of the crime rate variable in the year 2004 (Shapiro & Francia, 1972; Shapiro & Wilk, 1965). Again, to control for annual fluctuation in crime rates, the average crime rate across 2003, 2004, and 2005 was used. In this case, both the Shapiro-Francia and Shapiro-Wilk test the null hypothesis that lead is normally distributed. Results for the Shapiro-Wilk ($W = .74894$, $p < .01$) and Shapiro-Francia ($W' = .73429$, $p < .01$) reject the null hypothesis that crime is distributed normally across Chicago communities. Next, the 2004 crime variable was tested for skewness and kurtosis, using Stata's skewness and kurtosis normality test (Acock, 2008). Results indicate that based on skewness, there is a statistically significant lack of normality (p

$< .01$). Crime in 2004 also appeared significantly non-normal based on kurtosis ($p < .01$). A joint test of normality based on both skewness and kurtosis indicates significant non-normality in the 2004 crime variable ($p < .01$).

Similar to tests of H1, additional analyses were performed to examine the spatial distribution of crime across Chicago. As such, the data were examined for spatial autocorrelation again using a global Moran's I. Results produced a Moran's I of .536, associated with a z-score of 8.50 ($p < .01$), signifying spatial autocorrelation in the distribution of crime across Chicago communities. That is, communities that have higher levels of crime tend to be significantly closer in proximity to one another.

To test for crime hotspots, the crime variable was standardized into z-scores. The variable was examined for areas with crime rates above average and significantly above average. This analysis found the average crime rate in a Chicago Community Area to be approximately 65 crimes per 1,000 persons. This analysis found thirty two communities where crime rates exceeded the average crime rate in Chicago. The standardization of the crime variable revealed three communities with a crime rate that was significantly above average. In ascending order, these communities are: Near South Side (approximately 154 crimes per 1,000 persons, $p < .05$), Fuller Park (approximately 154 crimes per 1,000 persons, $p < .05$), and Loop (approximately 319 crimes per 1,000 persons, $p < .01$).

These results suggest that crime is not randomly distributed across Chicago communities. Results identify approximately three crime hotspots or communities in

which crime rates are significantly higher than the rest of Chicago community areas. As such, these results are supportive of the second hypothesis.

H3: Communities which are lead hotspots will also emerge as crime hotspots.

The results from tests of hypotheses 1 and 2 are mapped simultaneously in Figure 5. These results indicate nine communities in total which have significantly high rates of lead and/or crime. However, only one community, Fuller Park (# 37), emerged as having significantly high levels of lead *and* significantly high rates of crime. Of the remaining communities, six had significantly high levels of lead, but not significantly high rates of crime. Two communities had significantly high rates of crime, but not significantly high levels of lead.

While these results suggest that the communities with the highest levels of lead and highest levels of crime may not overlap, a relationship between community levels of lead and community crime rates may still exist. To examine this possibility, the bivariate relationship between community lead level and community crime rate was tested using Pearson product-moment correlations. The results of this test are presented in Table 8. Significant relationships were detected between lead and crime for all years measured, with the sole exception of 2009 lead and 2009 crime rate. Significant coefficients range from a minimum value of .2929 to a maximum value of .7941. Bivariate results suggest the strongest significant association was

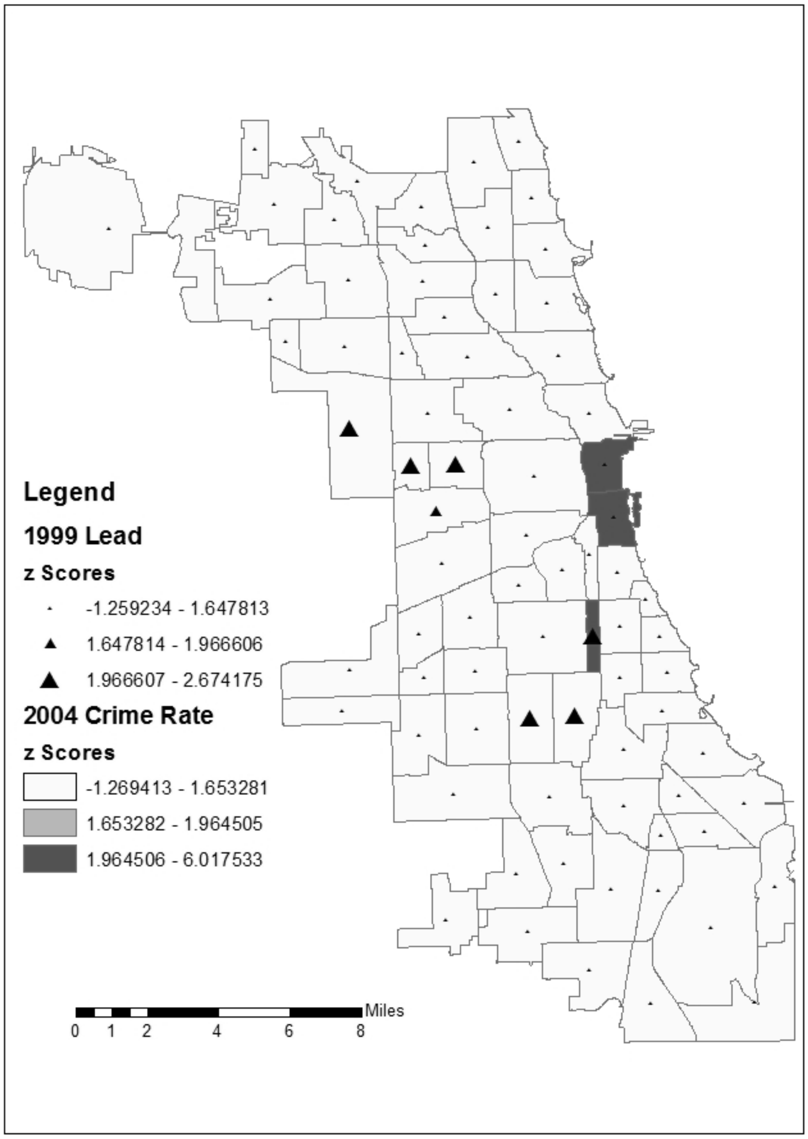


Figure 5. *Distribution of Lead (1999) and Average Total Crime Rate (2004) Across Chicago Community Areas, (n=77)*

found between lead in 1999 and crime rate in 2010, while the weakest significant association was found between lead in 2008 and crime rate in 2009. Sizes of correlation

coefficients suggest that, in general, the association between lead and crime appeared strongest overall in 2010. The magnitudes of the coefficients also suggest that the relationship between lead and crime becomes stronger as lead lingers in the environment.

Taken together, it would seem that with the exception of Fuller Park, communities with significantly high levels of lead and significantly high rates of crime generally do not coincide precisely as dual lead hotspot and crime hotspot locations. Communities may not overlap specifically with respect to hotspots for a number of reasons, including the fact that lead is not the sole cause of crime, and other features of communities contribute to the aggregate level of crime in a community. While crime and lead hotspots do not overlap exactly, bivariate associations between community lead level and community crime rates provide empirical support of a relationship between the distribution of lead and crime. Specifically, when lead and crime are examined continuously, positive, significant relationships emerge between lead and crime, revealing that community levels of lead and crime do positively and significantly co-vary. With the exception of 2009 levels of lead and 2009 rates of crime, the bivariate association between community levels of lead and rates of crime emerged as significant in Chicago from 1999 through 2010.

Thus, given the prevailing definition of hotspots, and the overlap of lead and crime hotspots, it is appropriate to conclude that no support is found for the third hypothesis in the strictest sense. However, the correlation between community lead level and community crime rate warrants further investigation. This relationship is examined in greater depth in the section that follows.

Table 8. *Correlation Coefficients for Lead and Total Crime Incident Rate 1999 through 2010*

	Lead											
Total Crime Rate †	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
2000	.4074**	.3651**	---									
2001	.4437**	.4010**	.3938**	---								
2002	.4671**	.4177**	.4162**	.3894**	---							
2003	.4885**	.4398**	.4343**	.4063**	.3952**	---						
2004	.4755**	.4272**	.4191**	.3938**	.3818**	.4092**	---					
2005	.5097**	.4658**	.4612**	.4375**	.4164**	.4500**	.4535**	---				
2006	.5220**	.4803**	.4710**	.4462**	.4301**	.4586**	.4700**	.4013**	---			
2007	.5311**	.4880**	.4762**	.4513**	.4475**	.4621**	.4718**	.3972**	.3478**	---		
2008	.5372**	.4886**	.4824**	.4552**	.4515**	.4772**	.4845**	.4133**	.3647**	.2841*	---	
2009	.5185**	.4722**	.4725**	.4448**	.4362**	.4572**	.4670**	.3885**	.3393**	.2929*	.1578	---
2010	.7941**	.7766**	.7822**	.7520**	.7261**	.7615**	.7491**	.7081**	.6714**	.6015*	.3641**	.4139**

* p<.05; **p<.05
† Per 1,000 Residents

NOTE: Crime data were available for all communities for the years 1999 through 2010. However, lead data were only available for all communities from 1999 through 2002. From 2003 through 2010, one community- Riverdale (Community #54)- was missing data for lead. Thus, lead's relationship with crime from the year 2003 forward is assessed using only lead and crime rates for 76 communities.

The Relationship between lead and crime in communities. The second research question that this study asks is, "what is the nature and extent of the relationship between lead and crime at the community level?" Results from tests of hypotheses 1 and 2 revealed that lead and crime appear to concentrate in some communities more so than others. A test of hypothesis 3 finds that while hotspots may not overlap completely, community crime level and community lead level have a significant, positive relationship to one another. The next four hypothesis tests in this study explore the conditions under which (if any) the positive, significant relationship between a community's lead level and a community's crime rate persists.

H4: Community lead presence is consistently associated with increases in community crime, controlling for traditional criminological predictors of crime.

Hypothesis four examines whether the relationship between community lead level and community crime rate consistently endures while controlling for the theoretical predictors put forward in the orthodox criminology literature on the distribution of crime at the community level. The test of this hypothesis proceeded in four steps. First, a cross sectional assessment was conducted examining the association between lead and crime while controlling for relevant variables from the 2000 census. Next, a cross sectional assessment was conducted examining the associations between lead and crime while controlling for theoretically relevant variables from the 2010 census. Finally, a fixed-effects negative binomial regression is used to examine lead and crime across the Chicago community areas over time (Allison, 2009). Due to missing data, the Riverdale community (#54) was excluded from these analyses.

The statistical technique selected for assessing the cross-sectional relationships between lead (lagged) and total crime rate was a negative binomial regression. This technique is justified because key assumptions of the OLS regression are violated when a count-based dependent variable (such as crime rate) is analyzed as if it were continuous (Osgood, 2000). Particularly, crime rates are sensitive to population size, impacting the variance of the error term differentially across ecological units of different sizes, a condition known as heteroskedasticity. Also, since the crime rate can only take on positive values, the data distribution will always be skewed, potentially producing error terms with highly skewed distributions. Heteroskedasticity is problematic because it impacts the size of the standard error, and in turn, may bias results of hypothesis tests (Schroeder, Sjoquist, & Stephan, 1986). Criminologists have addressed this issue by relying on Poisson regression models and negative binomial regression models when working with count-based outcomes. Here, the negative binomial regression model is preferred to the Poisson regression model, because overdispersion was detected in the dependent variable. That is, the variance (s^2=1792) greatly exceeded the mean (M=65), making the negative binomial regression preferable (Long, 1997).

Because the independent variable in this study has demonstrated to be spatially dependent, the measurement of lead may potentially introduce redundancy into a multivariate model (Mitchell, 2005). To account for spatial autocorrelation in regression models, a spatial lag variable was generated for lead. A spatial lag can be understood as a "weighted average of neighboring values," (Anselin, 2004). In this case, "neighboring" was modeled using the queen criterion. That is, communities that share contiguous boundaries as well as vertices were considered to be "neighboring." "Values," were the lead levels of a given neighboring

community. To generate the spatial lag variable, a first-order contiguity-based spatial weights matrix, utilizing the queen criterion, was generated in GeoDa using the Chicago Community Area polygon shape file. Next, the spatial weights file was used to generate the weighted average of lead in neighboring communities per each Chicago Community Area. These values were retained to include in subsequent multiple regression models. Thus, controlling for spatial autocorrelation.

Next, data for this study were also examined for multicollinearity. While multicollinearity does not impact the underlying assumptions required of regression, multicollinearity can impact the size of standard errors and slopes for highly correlated independent variables (Allison, 1999). Ecological data, such as the data used in this study are particularly susceptible to multicollinearity. To test for multicollinearity, the variance inflation factor and condition index number test (Belsley, Kuh, & Welsch, 1980) were examined across lead and the control variables. VIF values suggest multicollinearity among these variables (mean VIF of 6.05), particularly among disadvantage (VIF of 8.03) and percent black (VIF of 20.80). To address this, the percent black variable was log transformed, and collinearity diagnostics were re-assessed only on variables with significant bivariate associations with lead and crime in 2000 *and* 2010. These adjustments reduced the VIF for percent black to 4.55 and the VIF for disadvantage to 4.36. The mean VIF following these adjustments was 3.19, and the conditional index number was 20.0655. All VIFs fell under recommended cutoffs of 5 (Walker & Madden, 2012), and the conditional index number falls under the suggested cutoff of 30 (Walker & Madden, 2012). Collinearity diagnostics for all models are reported in Appendix B.

Following these diagnostics, three negative binomial regressions were performed to examine the relationship between lead and crime, controlling for other sociologically relevant predictors. Results of these regressions are presented in Table 8.

In the first model, the average total crime rate in 2004 was regressed on variables that emerged as having significant bivariate associations with crime. Specifically, average crime rate in 2004 was regressed on disadvantage, mobility, heterogeneity, logged percent black, percent Hispanic, percent divorced, lead, and the spatial lag of lead. Both lead and the spatial lag of lead emerged as having a positive and significant association with average total crime rate. Mobility and percent divorced also emerged has having positive, significant relationships with average total crime rate. Counter to what was hypothesized, disadvantage emerged as having a significant inverse association with crime rate in 2004. Percent black wasnot significantly associated with crime rate (p=.088).

The next negative binomial regression regressed crime rates in 2010 on lead, the spatial lag for lead, residential mobility, racial/ethnic heterogeneity, the log of percent black, percent Hispanic, and percent divorced. To capture the five year lagged effect of lead, the 2005 community lead and the spatial lag of lead were used. Annual fluctuation in crime rate was adjusted for by averaging the total crime between the years 2009 and 2010 (data from 2011 are not yet available). Control variables are drawn from the 2010 Census. Results are presented in Table 9. Controlling for confounders, the relationship between 2005 lead and 2010 crime rate was outside the range of the test for statistical significance (p = .075). The spatial lag of lead did not emerge as significant in 2010, nor did percent Hispanic or percent divorced. Increases in the log of percent black, and residential mobility were associated with significant increases in crime

rate. The relationship between disadvantage and crime rate again emerged as significant and inverse.

Table 9. *Negative Binomial Regressions and Fixed Effects Negative Binomial Regression Predicting Total Average Crime Rate with Lead and Other Sociological Predictors, (n = 76)*

	Crime 2004		Crime 2010		Crime 2004-2010 Fixed Effects	
Variables	b	SE	b	SE	b	SE
Lead	.017*	.007	.054†	.031	.009**	.001
Spatial Lag: Lead	.024*	.011	.076	.054	---	---
Disadvantage	-.122**	.034	-.118**	.036	---	---
Mobility	.163**	.031	.158**	.029	---	---
Heterogeneity	.150	.254	-.427†	.241	---	---
(ℓn)% Black	.070†	.041	.147**	.043	---	---
% Hispanic	.001	.002	.003	.002	---	---
% Divorced	.058**	.022	.019	.019	---	---
Intercept	2.77**	.253	3.10**	.272	4.78**	.075
Model Diagnostics						
χ^2	89.99		93.06		115.42	
-2 log likelihood	-326.177		-312.857		-2839.983	
Pseudo-R^2	.1212		.1295		---	

† p <.10, *p < .05, **p < .01

Finally, a third model examined the associations between lead and crime over time. The association between lead and crime is assessed longitudinally using a fixed effects negative binomial regression model (Allison, 2005; 2009). The fixed effects regression technique was selected for many reasons. First, the fixed-effects approach is well suited to examine within-unit change, and this study seeks to examine within-community associations between lead and crime

(Allison, 2009). This is relevant theoretically, as social disorganization theory aims to explain why some communities are more crime-prone than others (Shaw & McKay, 1942), and the fixed-effects negative binomial regression has been employed for this purpose in prior literature (for example, see Martinez, Stowell, & Lee, 2010). Second, the fixed effects model provides researchers an analytical technique for modeling change over time, and its utilization here allows for a longitudinal assessment of the relationship between lead and crime. Third, the fixed effects regression model controls for time-invariant factors that have not been measured and expressly included in the model. That is, the fixed-effects model is especially well suited to handle omitted variable bias (Allison, 2009). The negative binomial regression was selected because of the count-based nature of the dependent variable.

Results for the fixed effects negative binomial regression model are presented in Table 9. In this analysis, the total count of crime in a community area was regressed on lead. A five year lag was used for the lead variable. Because data for control variables were only available for census years (2000 and 2010, respectively), these variables were not included in the fixed effects regression model. Overall, the fixed effects model fit the data well ($X^2 = 115.42$, $p<.01$). Results indicate that lead and crime are positively and significantly associated, even while controlling for time-invariant community characteristics ($b=.009$, $p<.01$). This observation is consistent with the observations from the two cross-sectional models.

In sum, a significant, positive relationship emerges between the presence of lead and the presence of crime in a community in two out of three assessments for total crime. This association is detected in a cross sectional assessment of lead's impact on crime in 2004. These data suggest that the relationship remains tenable even when controlling for other theoretically

relevant predictors: disadvantage, racial/ethnic heterogeneity, mobility, percent black, percent Hispanic, and percent divorced in 2004. However, in an examination of the same variables in 2010, the significant association between lead and crime did not persist. Finally, a third analysis evinced a positive, significant relationship between lead and crime longitudinally, controlling only for time invariant factors. What these results imply is a somewhat inconsistent association between lead and total rates of crime. As such, support for hypothesis four is not found. However, because the inconsistency may be attributable to offense type, further analyses are justified. This issue is explored in the test of hypothesis five.

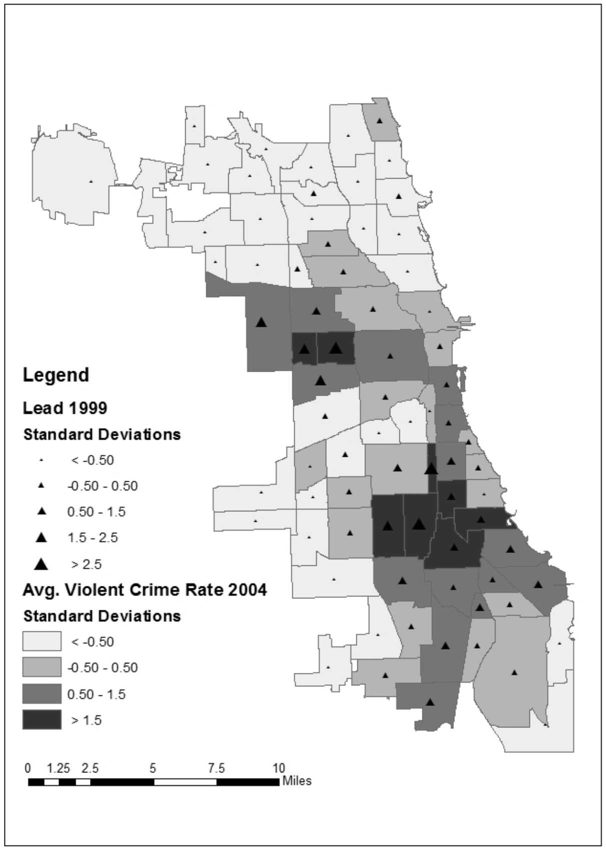
H5: Community lead presence will be a more consistent predictor of violent crime than property crime.

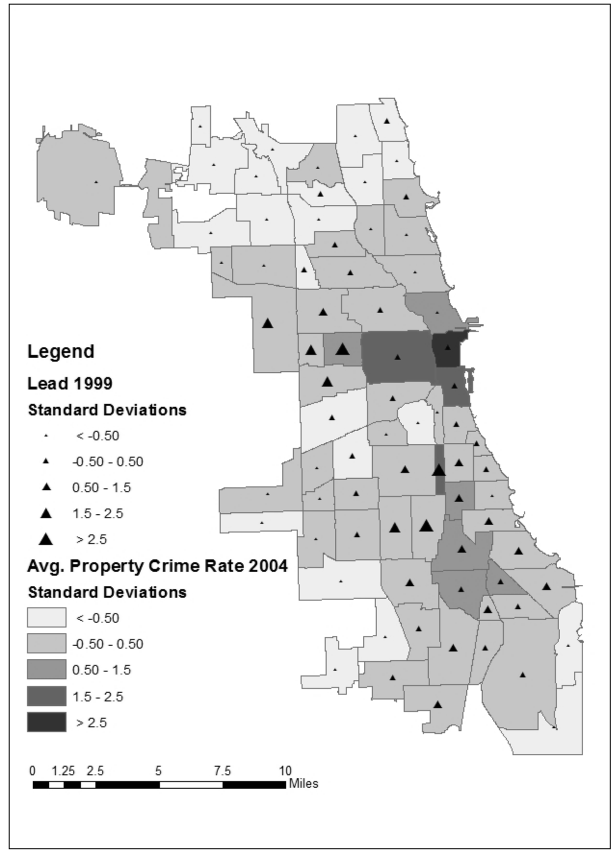
Hypothesis five concerns the strength of the relationship between lead and crime with respect to type of crime. Based on prior literature, it is hypothesized that lead will be a stronger predictor of violent crime than property crime (Stretesky and Lynch, 2004). Total crime rates are divided separately into rates of violent crime and rates of property crime. The test of this hypothesis proceeded in three steps. First, a cross sectional assessment was conducted examining the association between lead and 2004 violent crime and property crime while controlling for relevant variables from the 2000 census. Next, a cross sectional assessment was conducted examining the associations between 2010 lead and violent crime and property crime while controlling for theoretically relevant variables from the 2010 census. Negative binomial regressions are used for the cross sectional assessments. Finally, a fixed-effects negative

binomial regression is used to examine lead and violent crime and property crime across the Chicago community areas over time (Allison, 2009). Due to missing data, the Riverdale community (#54) was excluded from these analyses.

The distribution of lead and violent crime and lead and property crime are mapped in Figures 6 and 7, respectively. While both maps contain the same lead data (1999), Figure 6 displays the distribution of average violent crime rates in 2004, while Figure 7 displays the distribution of average property crime rates in 2004. A side by side comparison of these maps suggests differences in the distribution of violent crime as opposed to property crime. For example, Loop (#32) emerges as a community that is 2.5 standard deviations above the Chicago community mean in terms of property crime, but only .35 standard deviations above the mean for violent crime. Likewise, Englewood (#68) is nearly 2 standard deviations above the mean with respect to violent crime (1.9), but less than one half of a standard deviation above the mean for property crime (.41). Together, these maps elucidate a possible explanation for the somewhat contradictory findings in the test of hypothesis four. However, multivariate statistics are necessary to employ more stringent criteria to examine this possibility.

As such, the average violent crime rate in 2004 was regressed on lead, the spatial lag of lead, disadvantage, mobility, heterogeneity, the log of percent black, percent Hispanic, and percent divorced. Annual fluctuation in crime rate was adjusted for by averaging the violent crime rate across the years 2003, 2004, and 2005. Results are presented in Table 10. In this analysis, both lead and the spatial lag of lead emerge as significantly and positively associated





LEFT: Figure 6. *Distribution of Lead (1999) and Average Violent Crime Rate (2004) Across Chicago (n=76)*
RIGHT: Figure 7. *Distribution of Lead (1999) and Average Property Crime Rate (2004) Across Chicago (n=76)*

with the violent crime rate in 2004. Likewise, mobility, the log of percent black, percent Hispanic, and percent divorced also emerge as positively and significantly associated with the violent crime rate in 2004. Of the predictors, only disadvantage and heterogeneity do not emerge as significantly associated with violent crime in 2004.

Results differed in the next analysis, which regressed the average property crime rate in 2004 on predictors. Annual fluctuation in property crime rate was adjusted by averaging the property crime rate across the years 2003, 2004, and 2005. Findings from this analysis are presented in Table 10. Lead's effect in this analysis was outside the range of the test for statistical significance ($p = .053$), while the spatial lag of lead emerged as positive and significantly related to property crime. Mobility and percent divorced also emerged as positively and significantly associated with property crime rates. Disadvantage emerged as significantly related to property crime, although in the opposite direction as hypothesized by social disorganization theory.

Property crime and violent crime were also regressed on predictors for the year 2010. Results from these analyses are presented in Table 11. With respect to violent crime rate in 2010, results closely paralleled the 2004 analysis. Lead emerged as positively and significantly related to violent crime in 2010. Mobility, the log of percent black, and percent Hispanic again emerged as positively and significantly related to violent crime in 2010. Percent divorced was no longer significant, and heterogeneity and disadvantage continued to remain below significance.

Table 10. *Negative Binomial Regressions Predicting 2004 Violent Crime and Property Crime with Lead and Other Sociological Variables, (n = 76)*

	Violent Crime		Property Crime	
Variables	b	SE	b	SE
Lead	.019**	.005	.014†	.007
Spatial Lag: Lead	.021*	.009	.023*	.012
Disadvantage	.038	.035	-.155**	.036
Mobility	.076*	.032	.171**	.033
Heterogeneity	-.149	.237	.190	.268
(ℓn)% Black	.166**	.048	.050	.043
% Hispanic	.005*	.002	.000	.002
% Divorced	.047*	.022	.060**	.023
Intercept	.919*	.245	2.59**	.266
Model Diagnostics				
χ^2	175.66		76.93	
-2 log likelihood	-182.405		-313.035	
Pseudo-R^2	.3250		.1094	

† p <.10, *p < .05, **p < .01

With respect to property crime in 2010, a few notable changes emerged compared to the 2004 analysis. Neither lead nor the spatial lags for lead were significantly associated with property crime rates in 2010. Mobility and the log of percent black emerged as significantly associated with property crime rates in 2010. Specifically, as mobility and log of percent black increased, associated increases in rate of property crime were observed. Disadvantage emerged as being significantly related to property crime rates. The relationship, however, was again in the opposite direction than hypothesized

Table 11. *Negative Binomial Regressions Predicting 2010 Violent Crime and Property Crime with Lead and Other Sociological Variables, (n = 76)*

	Violent Crime		Property Crime	
Variables	b	SE	b	SE
Lead	.063*	.027	.049	.032
Spatial Lag: Lead	.098†	.052	.061	.056
Disadvantage	.022	.040	-.140**	.038
Mobility	.097*	.031	.161**	.032
Heterogeneity	-.424	.269	-.382	.254
(ℓn)% Black	.264**	.056	.129**	.046
% Hispanic	.006**	.002	-.002	.002
% Divorced	.026	.020	.018	.020
Intercept	.782*	.304	3.00**	.286
Model Diagnostics				
χ^2	170.25		73.87	
-2 log likelihood	-177.595		-300.199	
Pseudo-R^2	.3240		.1096	

† p <.10, *p < .05, **p < .01

Table 12. *Fixed Effects Negative Binomial Regressions Predicting Violent Crime and Property Crime with Lead, 2004 through 2010*

	Violent Crime		Property Crime	
Variables	b	SE	b	SE
Lead	.010**	.001	.009**	.001
Intercept	4.25**	.091	4.72**	.076
Model Diagnostics				
χ^2	77.46		96.78	
-2 log likelihood	-2222.1209		-2760.0981	

† p <.10, *p < .05, **p < .01

by social disorganization theory. Racial/ethnic heterogeneity, percent Hispanic, and percent divorced did not appear to be significantly associated with property crime rate in 2010.

Next, the longitudinal relationship between lead and violent crime as well as lead and property crime was assessed using negative binomial fixed effects regression. Based on results from prior studies, a five year lag of lead was used to predict crime rates from 2004 through 2010. Results from this assessment are presented in Table 12. Lead emerged as positively and significantly associated with both violent crime ($b=.010$, $p<.01$) and property crime ($b=.009$, $p<.01$), while controlling for all time-stable factors. These results suggest that increases in percent of lead are positively and significantly associated with increases in community violent crime rates, net of time-stable factors. Results also suggest that increases in percent of lead are positively and significantly associated with increases in community property crime rates, net of time-stable factors.

In sum, the relationship between lead and crime does appear to differ slightly with respect to violent and property crime. For example, in the 2004 cross sectional model, lead was positively and significantly associated with violent crime, but the lead's impact on property crime in 2010 was outside the range of the test for statistical significance. In 2010, lead was positively and significantly associated with violent crime, but not with property crime. Results from the fixed effects regression reveal a positive and significant association between lead and *both* property and violent crime. The coefficient for violent crime is only slightly larger than the coefficient for property crime. The results suggest that the association between lead and property crime appears to weaken when controlling

for the sociologically relevant variables in the cross sectional models. Overall, data appear to support hypothesis 5.

H6: Community lead presence will be a more consistent predictor of juvenile crime than adult crime.

Hypothesis six concerns the persistence of the relationship between lead and crime with respect to age. Prior literature finds that young people are especially vulnerable to environmental toxins (Chatham-Stephens, Mann, Schwartz, & Landrigan, 2011-2012; Landrigan & Carlson, 1995; Moore, 2003). As such, it is hypothesized that lead will be a stronger predictor of juvenile arrest rates than adult arrest rates. To test this hypothesis, first the juvenile arrest rates for index offenses in 2008 were regressed on relevant sociological predictors, including lead. Next, the adult arrest rates for index offenses in 2008 were regressed on relevant sociological predictors, including lead. A five year lag of lead was used (2003 lead levels) in both models, as were controls from the 2000 census. Negative binomial regressions are used to examine associations between juvenile arrest rates and adult arrest rates. Due to missing data, the Riverdale community (#54) was excluded from these analyses.

Results from the negative binomial regression testing the association between juvenile arrests and adult arrests are presented in Table 13. In this analysis, lead emerges as positively associated with the juvenile arrest rate, but the association is slightly beyond the test for statistical significance (p=.056). The spatial lag for lead is not significantly

associated with juvenile arrest rate in 2008, and neither is heterogeneity or percent Hispanic. Mobility and the log of percent black emerge as positively and significantly associated with juvenile arrest rates. Disadvantage emerges as significantly related to juvenile arrests, but the two variables are inversely related.

Table 13**.** *Negative Binomial Regressions Predicting 2008 Arrests for Juvenile Index Crime and Arrests for Adult Index Crime with Lead and Other Sociological Variables, (n = 76)*

	Juvenile Arrests		Adult Arrests	
Variables	b	SE	b	SE
Lead	.076†	.040	.119**	.032
Spatial Lag: Lead	.057	.067	.030	.053
Disadvantage	-.414**	.073	-.179**	.064
Mobility	.284**	.065	.248**	.057
Heterogeneity	-.202	.602	.236	.472
(ℓn)% Black	.273**	.094	.108	.078
% Hispanic	.007	.005	.007†	.004
% Divorced	.112*	.052	.103*	.042
Intercept	.010	.584	.024	.496
Model Diagnostics				
χ^2	76.74		77.58	
-2 log likelihood	-253.235		-224.433	
Pseudo-R^2	.1316		.1474	

† p <.10, *p < .05, **p < .01

Next, adult arrest rates in 2008 were regressed on lead and other relevant predictors. Findings are presented in Table 13. Results differ slightly from juvenile arrest rates. Unlike the juvenile arrest rate model, lead emerges as positively and

significantly associated with the adult arrest rate in 2008. Also unlike the juvenile arrest rate model, the log of percent black is no longer significantly related to arrest rate; also, percent Hispanic emerges as positively associated but insignificant predictor (p=.100). Similar to the juvenile arrest model, mobility is positively and significantly associated with adult arrests, as is percent divorced. The spatial lag for lead and heterogeneity are not significantly associated with either juvenile or adult arrests.

Taken together, the relationship between lead and arrest rate does appear to differ slightly with respect to adult and juvenile arrests. However, the differences are the inverse of the association predicted by this hypothesis. Specifically, the association between lead and juvenile arrests emerges as outside the range of significance (p=.056), while the relationship between lead and adult arrests emerges as significant (p=.000). As such, support is not found for hypothesis 6.

H7: Community lead presence will be a more consistent predictor of juvenile property crime than adult property crime.

Hypothesis seven concerns the persistence of the relationship between lead and crime with respect to age of offender and property crime. While support for hypothesis 6 was not found (and results suggested the opposite- that effects of lead may be more robust for adult arrests), tests of hypothesis five indicate differences among predictors of violent crime and property crime. Hypothesis seven anticipates that lead will be a more persistent predictor of juvenile property crime arrests than adult property crime arrests.

To test this hypothesis, first the juvenile property crime arrest rates in 2008 were regressed on relevant sociological predictors, including lead. Next, the adult arrest rates for index offenses in 2008 were regressed on relevant sociological predictors, including lead. A five year lag of lead was used (2003 lead levels) in both models, and predictors from the 2000 census were included. Negative binomial regressions are used to examine associations between juvenile property crime arrest rates and adult property crime arrest rates. Due to missing data, the Riverdale community (#54) was excluded from these analyses.

Table 14. *Negative Binomial Regressions Predicting 2008 Arrests for Juvenile Property Crime and Arrests for Adult Property Crime with Lead and Other Sociological Predictors, (n = 76)*

	Juvenile Property Arrests		Adult Property Arrests	
Variables	b	SE	b	SE
Lead	.091†	.048	.114**	.035
Spatial Lag: Lead	.057	.080	.041	.057
Disadvantage	-.516**	.086	-.221**	.068
Mobility	.337*	.077	.279**	.061
Heterogeneity	-.505	.736	.272	.510
(ℓn)% Black	.267*	.110	.109	.084
% Hispanic	.007	.006	.006	.005
% Divorced	.097	.061	.095*	.045
Intercept	-.272	.693	-.169	.534
Model Diagnostics				
χ^2	74.01		68.57	
-2 log likelihood	-226.016		-208.374	
Pseudo-R^2	.1407		.1413	

† p <.10, *p < .05, **p < .01

Table 14 displays results from the negative binomial regression examining predictors of 2008 juvenile property crime arrests. Results of this model were very similar to the regression of total juvenile arrests on the same predictors. Again, increases in lead are slightly outside the range of a significant effect ($p = .059$). The spatial lag for lead did not emerge as significantly associated with juvenile property crime arrests. Increases in mobility and the log of percent black emerged as significantly associated with increases in juvenile property crime arrests. Disadvantage demonstrated to be inversely related to juvenile property crime arrests. Unlike the association between divorce and total juvenile arrests, the association between divorce and juvenile property crime arrests did not emerge as significant.

Results from the negative binomial regression model examining predictors of 2008 adult property crime arrests are also presented in Table 14. The results of this model are also very similar to the regression examining total adult arrests on the same predictors. Lead was related positively and significantly to arrests for adult property crimes. Residential mobility and percent divorced were also positively and significantly associated with adult property crime arrest rates. An inverse association was detected between disadvantage and adult property crime arrests. Unlike the model examining total adult arrest rates, percent Hispanic was not found to be significantly related to arrests for adult property crimes.

Taken together, the relationship between lead and adult property crime arrests and juvenile property crime arrests is very similar to trends in lead and adult and juvenile arrests overall. Lead’s impact on juvenile property crime arrests falls outside the range of

significance (p=.059), while lead impact on adult property crime arrests remains significant (p=.001). What this suggests is, similar to total arrest rates for juveniles and adults, lead appears to be a stronger predictor of adult arrest rates than juvenile arrest rates. These results are similar to results of the test for hypothesis six. Thus, these data do not appear to support hypothesis seven.

H8: Community lead presence will be a more consistent predictor of juvenile violent crime than adult violent crime.

Hypothesis eight concerns the strength of the relationship between lead and crime with respect to age of offender and violent crime. While support for neither hypothesis 6 nor hypothesis 7 was found (and results suggested the opposite effect - that the effect of lead may be stronger for adult arrests), tests of hypothesis five indicate differences among predictors of violent crime and property crime. Hypothesis eight anticipates that lead will be a stronger predictor of juvenile violent crime arrest rates than adult violent crime arrest rates. To test this hypothesis, first the juvenile violent crime arrest rates in 2008 were regressed on relevant sociological predictors, including lead. Next, the adult violent crime arrest rates for index offenses in 2008 were regressed on relevant sociological predictors, including lead. A five year lag of lead was used (2003 lead levels) in both models, and predictors from the 2000 census were included. Negative binomial regressions are used to examine associations between juvenile violent crime arrest rates

and adult violent crime arrest rates. Due to missing data, the Riverdale community (#54) was excluded from these analyses.

Results from the negative binomial regression testing the association between predictors and juvenile violent crime arrests are presented in Table 15. In this analysis, lead emerges as positively associated with the juvenile arrest rate, but the association is once again slightly outside the measure of statistical significance (p=.062). The spatial lag for lead is not significantly associated with juvenile violent crime arrest rate in 2008, and neither is heterogeneity or percent Hispanic. Mobility, the log of percent black, and percent divorced emerge as positively and significantly associated with juvenile violent crime arrest rates. Disadvantage emerges as significantly related to juvenile arrests, but the two variables are inversely associated.

Results from the negative binomial regression testing the association between adult violent crime arrests are also presented in Table 15. Results illustrate differences between predictors of arrests for juvenile violent crime and arrests for adult violent crime. Unlike the juvenile arrest rate model, lead emerges as positively and significantly associated with the adult violent crime arrest rate in 2008. Also unlike the juvenile arrest rate model, the percentage of Hispanic residents emerges as significant, but the log of percent black, mobility, and disadvantage do not emerge as significantly related to violent crime arrest rate. The only predictor that appears to be significantly associated with both arrests for juvenile violent crime and adult violent crime is percent divorced.

Taken together, results from both models are similar to findings from tests of hypotheses six and seven. Specifically, lead's relationship with arrests for violent

juvenile crime falls outside the range of significance. However, lead's relationship with arrests for adult violent crime remains significant. As such, it does not appear as though lead is a more consistent predictor of juvenile violent crime than adult violent crime. Instead, these results imply that lead may actually be a more consistent predictor of adult violent crime than juvenile violent crime. Thus, the data does not appear to support hypothesis eight.

Table 15. *Negative Binomial Regressions Predicting 2008 Arrests for Juvenile Violent Crime and Arrests for Adult Violent Crime with Lead and Other Sociological Predictors, (n = 76)*

	Juvenile Violent Arrests		Adult Violent Arrests	
Variables	b	SE	b	SE
Lead	.065†	.035	.154**	.039
Spatial Lag: Lead	.020	.059	-.062	.067
Disadvantage	-.206**	.070	.009	.098
Mobility	.162**	.061	.116	.085
Heterogeneity	-.045	.506	.014	.622
(ℓn)% Black	.281**	.093	.109	.115
% Hispanic	.005	.005	.012*	.006
% Divorced	.103*	.045	.122*	.055
Intercept	-.754	.541	-1.38*	.691
Model Diagnostics				
χ^2	65.04		73.16	
-2 log likelihood	-171.880		-129.903	
Pseudo-R^2	.1591		.2197	

† p <.10, *p < .05, **p < .01

In sum, results from tests of hypotheses four through eight suggest that the relationship between lead and crime is sensitive to type of crime and age of offender. The findings discussed here appear to support hypotheses four and five. That is, the

relationship between lead and crime appears to persist even when controlling for other sociologically relevant variables. Also, lead appears to be a stronger, more consistent predictor of rates of violent crime over rates of property crime. Findings do not, however, appear to support hypotheses six, seven, or eight. These data suggest that lead may be a stronger predictor of adult arrest rates rather than juvenile arrest rates. This observation appeared to persist regardless of type of crime (property or arrest).

Environmental justice issues. The last five hypotheses take into consideration environmental justice literature which documents a disproportionately high presence of environmental hazards in disenfranchised communities (Lerner, 2005; Brulle & Pellow, 2006; Bullard 1994; 1996; Checker, 2007; Hipp & Lakon, 2010; Krieg, 2005; Opp, 2012; Pastor, Morello-Frosch, & Sadd, 2006; Stretesky & Lynch, 2002). This final series of hypothesis tests represent a brief exploratory analysis that examines associations between the distribution of lead and race, class, and ethnicity across Chicago Community Areas. It is expected:

H9: Percentage of black residents in a community will correspond positively and significantly with level of lead in a community.

H10: Percentage of Hispanic residents in a community will correspond positively and significantly with level of lead in a community.

H11: Disadvantage will correspond positively and significantly with level of lead in a community.

H12: Disadvantage and percentage of black residents will interact and correspond positively and significantly with level of lead in a community.

H13: Disadvantage and percentage of Hispanic residents will interact and correspond positively and significantly with level of lead in a community.

Tests of hypotheses 9 through 10 proceeded by examining the distribution of lead in 2010 and race, ethnicity, and class variables from the 2010 census (as this was the most recent year of data available). Disadvantage was captured using the principal component index from 2010 census variables. An interaction term was developed between disadvantage and percent black to test hypothesis 12. An interaction term was also developed between disadvantage and percent Hispanic to test hypothesis 13. Next, Pearson product moment correlations were used to examine the strength and direction between race, ethnicity, and class variables and lead.

Results of the Pearson product moment correlation are presented in Table 16. With respect to hypothesis nine, a positive and significant association between percent black and lead is found. The size of the relationship ($r=.6340$, $p <.01$) implies a moderately strong association between percentage of black residents and a communities lead level. Regarding hypothesis ten, percent Hispanic and level of lead do not appear to

be significantly related. With respect to hypothesis eleven, a positive and significant association between community disadvantage and lead emerges. The size of the relationship (r=.6312, p <.01) suggests a moderately strong association between degree of community disadvantage and level of lead. Regarding hypothesis twelve, a strong, significant, positive relationship was detected between percent black and disadvantage (r=.7424, p<.01), illustrating interaction. An interaction term between percent black and disadvantage was also found to be significantly related to percent of lead. The value of the coefficient (r=.5860, p<.01) suggests a positive, moderately strong relationship between lead and communities that are both economically disadvantaged and have a high percentage of black residents. Lastly, a test of hypothesis thirteen does not detect a significant relationship between percentage of Hispanic residents and level of disadvantage. An interaction term between percent Hispanic and disadvantage does produce a relatively weak significant relationship with lead (r=.2558, p<.01). However, given that percent Hispanic by itself is not significantly associated with lead or disadvantage, the significance of the interaction term with lead is likely attributable to the larger influence of disadvantage.

Table 16. *Bivariate Associations between Percent Black, Percent Hispanic, Disadvantage, Interaction Terms, and Lead, 2010 (n= 77)*

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
1. Lead	---					
2. % Black	.6340**	---				
3. % Hispanic	-.1525	-.5935**	---			
4. Disadvantage	.6312**	.7424**	-.0709	---		
5. %Black*Disadvantage	.5860**	.7689**	-.3778**	.8565**	---	
6. %Hispanic*Disadvantage	.2558*	.2825*	.1858	.5639**	.2821*	---

*=p<.05; **p<.01

With respect to environmental justice questions, support is detected for some, but not all, hypotheses. Pearson product moment correlations detect significant associations between lead and percent black, disadvantage, and an interaction between disadvantage and percent black. Thus, the data appear to support hypotheses nine, eleven, and twelve. However, Pearson product moment correlations fail to detect significant associations between lead and percent Hispanic. Thus, the data do not appear to support hypothesis ten. Findings also suggest that percent Hispanic and disadvantage do not co-vary, and as such, support is not found for hypothesis thirteen.

Conclusion

In sum, chapter six presents the analytic procedure and results for tests of all thirteen study hypotheses. A summary of the results for the tests of each hypothesis can be found in Table 17. Both lead and crime appear to have skewed distributions across Chicago Community Areas. However, an examination of communities that are crime hotspots (communities with significantly high rates of crime) and communities of lead hotspots (communities with significantly high levels of lead) does not detect consistent overlap. The relationship between lead and crime does appear to be sensitive to type of offense, with more consistent associations found for rates of violent offenses. The relationship between lead and crime also appears sensitive to age, but with lead appearing to lend more predictive power to adult arrest rates than juvenile arrest rates. Finally, lead appears positively and significantly related to percent black, disadvantage, and the interaction of percent black and disadvantage. However, lead does not emerge as

significantly associated with percent Hispanic. The implications of these findings are discussed in detail in chapter 7.

Table 17. *Summary of Hypotheses Tests*

Hypothesis	Supported? Yes	No
H1: Lead is distributed non-randomly across Chicago communities, creating lead hotspots.	X	
H2: Crime is distributed non-randomly across Chicago communities, creating crime hotspots.	X	
H3: Communities which are lead hotspots will also emerge as crime hotspots.		X
H4: Community lead presence is consistently associated with increases in community crime, controlling for traditional criminological predictors of crime.		X
H5: Community lead presence will be a more consistent predictor of violent crime than property crime.	X	
H6: Community lead presence will be a more consistent predictor of juvenile crime than adult crime.		X
H7: Community lead presence will be a more consistent predictor of juvenile property crime than adult property crime.		X
H8: Community lead presence will be a more consistent predictor of juvenile violent crime than adult violent crime.		X
H9: Percentage of black residents in a community will correspond positively and significantly with level of lead in a community.	X	
H10: Percentage of Hispanic residents in a community will correspond positively and significantly with level of lead in a community.		X
H11: Disadvantage will correspond positively and significantly with level of lead in a community	X	
H12: Disadvantage and percentage of black residents will interact and correspond positively and significantly with level of lead in a community.	X	
H13: Disadvantage and percentage of Hispanic residents will interact and correspond positively and significantly with level of lead in a community.		X

Chapter Seven:

Discussion and Conclusion

The purpose of this final chapter is to briefly summarize the results of this study, as presented in chapter six. Following this summary, the limitations of this study are acknowledged and discussed. Next, the implications these results have on criminological theory are presented, as well as the implications these results have for community crime reduction endeavors. Lastly, directions for future research are proposed, followed by this study's conclusion.

Summary of Findings

The objective of this study was to address three interrelated research questions: Is there a relationship between hotspots of lead and hotspots of crime? Stemming from this question, this study also asked, what is the nature and extent of the relationship between lead and crime? Lastly, does the distribution of lead pose environmental justice concerns with respect to race, class, and ethnicity in Chicago communities? To resolve these questions, thirteen research hypotheses were explicated, and empirically evaluated in the previous chapter.

The Distribution of lead and crime across communities. The first research question asked in this study asks if there is a relationship between hotspots of lead and hotspots of crime. As such, the first three hypotheses addressed the issue of identification

and overlay of crime and lead hotspots. In doing so, the distribution of lead and crime across Chicago's community areas was examined. It became apparent that lead and crime hotspots do, in fact, exist among Chicago's communities.

Counter to what was hypothesized, however, a geographic overlay did not emerge between lead and crime hotspots; of the nine lead or crime hotspots, only one community (Fuller Park) appeared to concentrate significantly high levels of lead *and* crime. One explanation for this may be that in this sample, the distribution of index crime appeared sensitive to type of offense. That is, the communities with the highest rates of property crime (top five, in ascending order: Chatham, Fuller Park, Near West Side, Near South Side, and Loop) were not synonymous with the communities with the highest rates of violent crime (top five, in ascending order: Englewood, West Garfield Park, East Garfield Park, Fuller Park, and Washington Park)[23]. The observation that hotspots differ with respect to offense type has been observed previously in the literature (see, for example: Sherman, Gartin, & Buerger, 1989; Weisburd et al., 1993). Moreover, prior literature suggests lead may be a stronger predictor of violent crime than property crime (Pihl & Ervin, 1990), and differential distributions of hotspots of violent crime versus hotspots of property crime are consistent with this. A Pearson product moment correlation reveals a consistent, significant, positive bivariate association between lead and total crime every year from 1999 through 2010 (with the sole exception of the 2009 lead rate and 2009 crime rate). Multivariate analyses testing this association appeared justified. Finally, it is also plausible that the measure of hotspots itself impacts the analysis. As indicated in

[23] Refer also to Figures 5 and 6 in chapter 6

chapter six, the literature suggests that there may be more than one way to measure hotspots, and that the results provided here may be a result of the methodology that has been employed. Thus, future research needs to address this issue in greater depth before any definitive conclusion about the relationship between crime and lead hotspots can be offered.

The Relationship between lead and crime in communities. The next research question this study addressed the nature and extent of the relationship between lead and crime. Specifically, hypotheses four through eight examined the condition(s) under which the observed bivariate association between lead and crime persists. While a significant relationship is observed between lead and total crime rate in 2004, net of confounders, the association falls beyond the range of significance in 2010. Controlling only for time invariant factors, a significant association is observed between changes in lead and changes in crime rate. Taken together, lead does not appear to *consistently* have a significant impact on incidents of total crime.

To examine if these somewhat conflicting results are attributable to type of crime, additional analyses were performed. A chart summarizing outcomes of all multivariate analyses (tests of hypotheses four through eight) is presented in Table 18, with X denoting a significant association at a minimum of at least the .05 level. Overall, results of the multivariate analyses suggest that the relationship between lead and crime is sensitive to: (1) the measurement of crime (arrest versus incident), and subsequently, (2) type of offense, and (3) age of offender.

Results of this study illustrate important differences with respect to lead's impact on crime when the measurement of the dependent variable ("crime") changes from crime incident rate to crime arrest rate. Arrests for crime (capturing traits of an offender) are distinguishable from incidents of crime (demographics like age may be unknown). That is, results from tests examining lead's impact on *arrests* for crime may not be directly comparable to tests examining lead's impact on *incidents* of crime. For example, lead does not appear to consistently predict *total* crime incident rates- that is, lead is significantly associated with total crime incident rates in 2004 net of confounders, but not 2010. Lead is also significantly associated with change in total crime incidents between 2004 and 2010, net of time-stable variables. Separating property crime incident rates and violent crime incident rates reveals important differences with lead's influence on crime incident rates. Specifically, lead appears to be significantly and consistently associated with violent crime incident rates. That is, lead appears to significantly predict violent crime, net of mainstream sociological predictors as well as unmeasured time-stable variables. However, the association between lead and incidents of property crime appears less consistent. Specifically, a significant relationship is found between lead and the change on incidents of property crime net of time-stable variables. However, when other sociological variables are included in the model, the association between lead and property crime incidents is no longer found to be significant. Because prior findings substantiate a relationship between lead, violence, and aggression, it was hypothesized that lead would emerge as a more consistent predictor of violent crime than property

Table 18. *Summary of Multivariate Findings*

	Total Crime					Property Crime					Violent Crime				
Variable	2004	2010	Change	Adult*	Juvenile*	2004	2010	Change	Adult*	Juvenile*	2004	2010	Change	Adult*	Juvenile*
Lead	X		X	X				X	X		X	X	X	X	
Lag	X		--			X		--			X		--		
Disadv.	X	X	--	X	X	X	X	--	X	X			--		X
Mobility	X	X	--	X	X	X	X	--	X	X	X	X	--		X
Heterog.			--					--					--		
ln%Black			--		X		X	--		X	X	X	--		X
%Hisp			--					--			X	X	--	X	
%Divrcd.	X		--	X	X	X		--	X		X		--	X	X

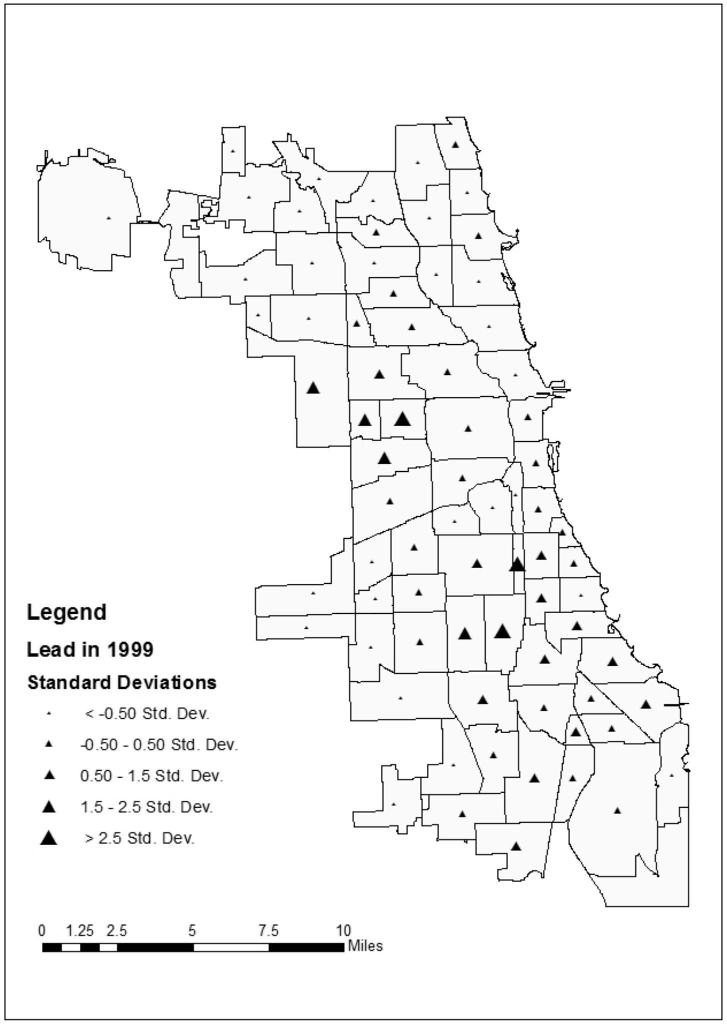
X = p <.05 * = 2008 Arrest Rate -- = Not Tested

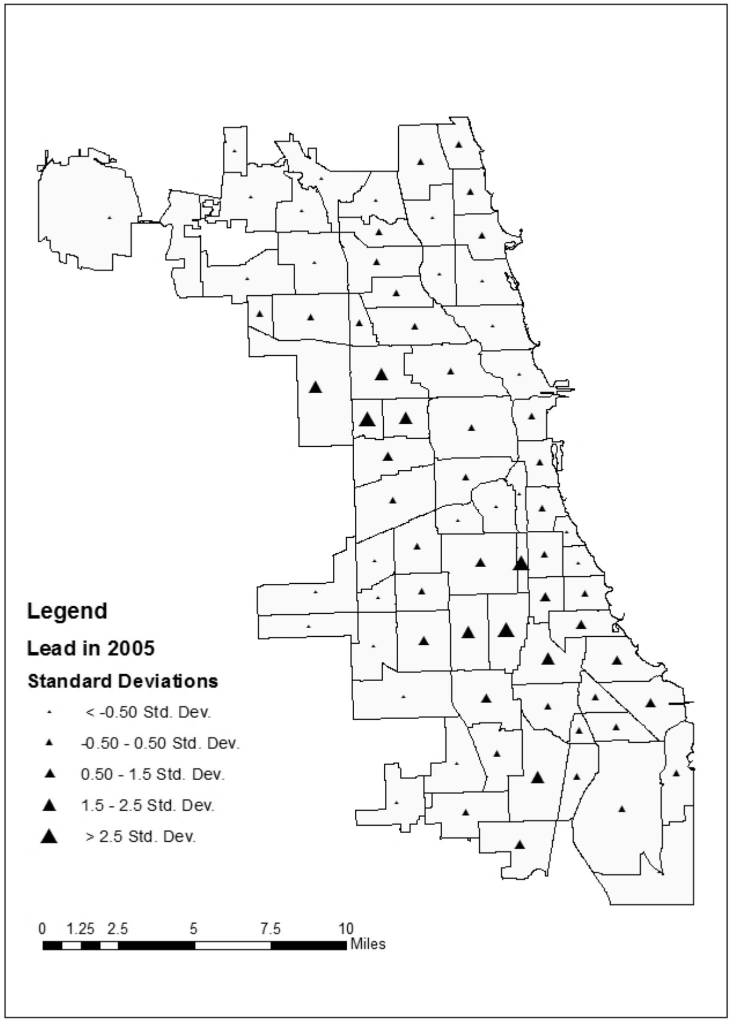
crime. Overall, observations with respect to crime incidents were consistent with this hypothesis.

These associations between lead and type of offense did not, however, emerge in the examination of crime arrests. Overall, the relationship between lead and crime arrests appears similar across arrests for total crime, property crime, and violent crime. That is, while significant changes were observed between lead and type of offense when the dependent variable was crime incidents, the same relationships were not observed when the dependent variable was crime arrests. Thus, these data suggest that lead impacts arrests for property crimes and violent crimes similarly. One reason the data may show this may be that counts for reported crime arrests were lower overall than counts of reported crime incidents. As such, the heterogeneity which existed in the crime incident data may not have been as pronounced in the crime arrest data. Consider, for example, these data suggest that in 2008 there was an average of approximately 59 crime incidents (per 1000 persons) reported, as opposed to approximately 12 arrests (per 1000) persons reported.

Relatedly, the spatial lag of lead was not found to exert a significant impact on arrest rates. Across total, violent, and property arrests, the association between the spatial lag of lead and arrests was found to be null. This also may be attributable to the comparatively low frequency of arrests. On the other hand, the spatial lag of lead does appear to exert an impact on crime *incident* rates. The spatial lag of lead exerts a significant, positive impact on incidents of total crime, violent crime, and property crime but only in 2004. The spatial lag of lead does not appear to exert significant influence on

crime incident rates at all in 2010. To better understand this discrepancy, the distribution of lead in 1999 and 2005 were mapped and compared. These maps are presented in Figures 8 and 9, respectively. What these maps suggest are changes with respect to the amount and distribution of lead from 1999 to 2005. Specifically, changes emerge which may impact the amount of lead present in the calculation of the weighted average of lead in communities surrounding areas with the highest levels of lead. For example, the Austin community (#25) carries a lead presence greater than 1.5 (but less than 2.5) standard deviations above the mean in both 1999 and 2005. However, lead levels in both communities bordering Austin on the north (#18 Montclair and #19 Belmont Cragin) "increased" from 1999 to 2005 with respect to distance from the mean. That is, in 1999 these communities were more than .50 standard deviations below the mean, while in 2005 they were within a half a standard deviation of the mean. Similarly, lead levels in Austin-bordering West Garfield Park (#26), appeared to move farther above the mean, while lead levels in the contiguous East Garfield Park (#27) appeared to decrease towards the mean. Likewise, in 1999 both West (#26) and East (#27) Garfield Park carried lead levels greater than 1.5 standard deviations from the mean. However, lead levels in North Lawndale (#29) decreased from 1.76 standard deviations above the mean in 1999 to 1.39 standard deviations above the mean in 2005. Together, these changes suggest that





LEFT: *Figure 8.* Distribution of Lead (1999) Across Chicago Community Areas (n=76)
RIGHT: *Figure 9***.** Distribution of Lead (2005) Across Chicago Community Areas (n=76)

the impact of the spatial lag of lead on communities may be attributable to changes in lead levels that impact the calculation of the spatial lag variable.

Analyses examining the association between lead, age, and crime arrest rate revealed unexpected nuances between lead and arrest rates. Specifically, it was anticipated that lead would exert more of an impact on juvenile arrest rates than adult arrest rates. This was not observed. Overall, the relationship between arrests for total juvenile index crimes, juvenile property crimes, and juvenile violent crimes consistently emerged as outside the range of significance. Conversely, the association between arrests for total adult index crimes, property crimes, and violent crimes was consistently found to be positive and significant ($p<.01$). What these results seem to imply is that the impact of lead on adult crime is positive and consistent, while lead bears no significant impact on juvenile arrests. One possible explanation for this may be that the threshold for lead's impact on crime arrest rates may be longer than anticipated. This would be consistent with prior literature which finds early childhood lead exposure impacts adult criminality (Nevin, 2007; Wright et al., 2008). Alternatively, it may be plausible that lead's relationship with juvenile behavior simply does not manifest in the form of criminal behaviors (but, for contradiction, see Needleman et al., 1996 & Olympio, 2010). It would appear that additional studies are necessary to further specify the age-graded effects of lead on crime. In any event, with respect to a five year lag, age of offender *does* seem to influence in the relationship between lead and crime arrest, albeit not the type of influence that was anticipated.

It is also possible that the lead-crime association measured here as a function of arrest also plays a role in impacting the outcomes. That is to say, since arrests represent some dimension of police discretion, when used as a measure of crime, arrests will tend to under-represent the total universe of crime. Moreover, it is possible that some aspect of police discretion is distributed in ways that reduce the relationship between lead and crime when measured by arrest. Thus, additional research on this issue is desirable, and is needed to address other aspects of the lead-crime relationship. Additional studies, for example, could include alternative indicators of crime, if available, such as reported crimes, or as some studies suggest, calls for police services.

In sum, what multivariate results imply (with respect to lead and crime), are that the relationship between lead and crime appears sensitive to measurement of crime, and subsequently, type of crime, and age of offender. Specifically, these data suggest that lead's impact on crime incident rates is not directly comparable to lead's impact on crime arrest rates. Data suggest that this is true with respect to community level of lead as well as the spatial lag of lead. The association between lead and crime incident rate appears sensitive to type of offense. Specifically, lead was observed to be a more consistent predictor of violent crime than property crime. On the other hand, the association between lead and crime arrests appears robust to type of offense. That is, lead appears to impact crime arrests similarly; regardless of if the arrest is for a property offense or violent offense. The association between lead and crime arrest does, however, appear sensitive to age of offender. Unexpectedly, lead emerges as a more consistent predictor of adult arrest rates than juvenile arrest rates. All significant cross sectional associations

emerged net of confounding sociological variables. All significant longitudinal associations emerged net of unobserved time-invariant factors.

Environmental justice issues. The last research question posed in this study asks, does the distribution of lead pose environmental justice concerns with respect to race, class, and ethnicity in Chicago communities? To answer this question, an exploratory analysis examined the bivariate associations between community lead level and community: percentage of black residents, percentage of Hispanic residents, score on the disadvantage index, interactions between race and class, and interactions between ethnicity and class. Overall, results suggest positive, significant relationships between lead and: percent black, disadvantage, and both interaction terms. What this suggests is that there does appear to be covariance between the distribution of lead and the distribution of race and class across Chicago communities. That is, as the percentage of black residents, percentage of economically disadvantaged residents, or the percentage of residents who are both black and economically disadvantaged increases, corresponding increases in lead can also be anticipated.

This observation is consistent with extant findings in the environmental justice literature (Brulle & Pellow, 2006; Bullard, 1994; 1996; Checker, 2007; Krieg, 2005; Opp, 2012). Moreover, these results suggest a relationship between political disenfranchisement and the distribution of lead. Under-resourced and disenfranchised communities may not only bear a higher presence of lead from industrial sources and expressways, but also may lack the capital to promote lead abatement or other lead clean up initiatives. Residents of these communities may also face additional hurdles with

respect to medical treatment and interventions. Additionally, these communities may lack the resources to compel politicians and other policy makers to address environmental justice concerns in their communities. These results suggest lead exposure adds to a host of public health issues confronted by disenfranchised communities.

Contrary to what was hypothesized, observations with respect to percent Hispanic and the distribution of lead were not consistent with findings from prior studies (for example, see Diawara et al., 2006; Jacobs et al., 2002). It was anticipated that lead and percent Hispanic would positively co-vary. However, the association between lead and percent Hispanic did not emerge as significant. Moreover, the association between percent Hispanic and the disadvantage index also failed to emerge as significant. Thus, while the interaction term between percent Hispanic and disadvantage did emerge as having a relatively weak, significant relationship, it is highly likely that this was solely the influence of disadvantage. What these data suggest is that Chicago Community Areas that concentrate the highest values of disadvantage are not necessarily the same communities that have the highest concentrations of Hispanic residents. This observation may set this study apart from environmental justice research that examines locations where ethnicity, disadvantage, and lead positively co-vary.

Taken together, these latter findings from exploratory environmental justice analyses suggest a need for future study with respect to the distribution of lead, class, and race in Chicago. Additional research appears justified especially in regards to the distribution of lead and percent black and economic disadvantage. Previous literature also has called attention to this matter. For example, Moore (2003) observes: “African

American children in low-income families in the United States have the highest exposure to lead of any segment of the American population," (pg. 13). In 2001, the National Association for the Advancement of Colored People (NAACP) also called attention to the disparate exposure of minority youth to lead, especially leaded paint in older homes (Moore, 2003). Findings from this study suggest evidence of environmental racism and classism across Chicago's community areas. Given that these findings come from data seven years after Moore's observation, and over ten years following the NAACP's call for action, it would appear that lead exposure still may be of particular concern for communities with high concentrations of minority residents.

Study Limitations

This study is not without limitation. One way in which this study may be limited, is the reliance on official data (incident and arrest counts from the Chicago Police Department) to measure crime. Use of official data to measure crime has been critiqued by criminologists because many forms of crime go unreported and/or undetected by police. Some studies suggest significant differences in reports of crime when self-report data are compared to official data, with respect to the same sample (Farrington et al., 2003; Kirk, 2006). To be sure, data in this study suggest differences in predictors when measurement of the dependent variable changes from counts of crime incidents to counts of crime arrests. Relatedly, given that juveniles may be less likely than adults to be arrested, official arrest data may underestimate the "true" amount of juvenile crime. However, with respect to this study, there are several benefits to using official data. First, availability of data over multiple years allowed for both cross sectional and longitudinal

analyses. While offender demographics (e.g., age) escape measurement in crime incident data (in some cases, this information is unknown, or potentially inaccurate), the use of arrest data allowed this study to consider juvenile and adult arrest rates. Moreover, that lead demonstrates associations with incidents of violent crime, and arrests of adult crime, adds confidence to the conclusion that lead matters with respect to community crime rates. Interestingly, a prior study's comparison of self reported crime and official arrest data in Chicago, suggests that while the counts of self report and arrest data differ significantly, the relative impact of predictors of crime across the two data types did not (Kirk, 2006). This implies that even if crime data on the Chicago Community Areas had been obtained via self report (instead of via official records), at least one prior study using data from the same city suggests that the outcome of the analyses may have stayed the same.

Another limitation of this study is in the measurement of community via boundaries for the Chicago Community Areas. The average area for a Chicago Community Area is approximately 3 square miles, and each Chicago Community Area concentrates an average of approximately 38,000 people. Relative to other studies of community crime rates, this may be perceived as quite large, and potentially "too big" to capture neighborhood effects. For example, Sampson and colleagues' Project on Human Development in Chicago Neighborhoods (PHDCN) aggregates Chicago census tracts into approximately 300 neighborhood clusters (compared to 77 community areas). However, a number of reasons make the Chicago Community Areas a meaningful unit of analysis for this study. One of which is that the Chicago Community Areas represent a smaller

unit of analysis than has been used in prior ecological studies of lead and crime; the Chicago community areas are smaller units than, for example, counties or cities. Moreover, the Chicago Community Areas are identifiable to residents, politicians, community leaders, and government entities (Sampson, 2012). The Chicago Police Department states in annual reports that, "the Community Areas remain the most widely used geographic units by Chicago planning agencies, advocacy groups, and service providers," (2009, p. 34). Finally, the Chicago Community Areas have been relied upon in prior criminological analyses (Block & Block, 1993; Lyons, 2006; Sampson, 2012; Visher & Farrell, 2005).

A closely related limitation of this study is that data is drawn from one geographical region (the city of Chicago). This may limit the generalizability of findings to communities in other locations. However, Chicago's similarities to other northeastern cities make it particularly well suited for studies of urban ecology. That said, a replication of this study using communities within other cities represents an important direction for future research. Likewise, data that captures *annual* neighborhood change (such data was not available for this sample) as opposed to strictly on census years, may provide for the ability to capture lead's influence while controlling for dynamic neighborhood change.

Finally, the measurement of lead introduces additional limitations. Specifically, the percentage of children in a community with elevated blood lead levels only represents children who have blood lead levels above 10 µg/dL. As such, children who tested with blood lead levels greater than 0 µg/dL but less than or equal to 10 µg/dL are not included.

This is problematic with respect to the research question, because the amount of lead in each community may actually be underestimated. That is, 10 µg/dL creates a “floor” that may have a censoring effect on the actual amount of lead present in a community. However, there are reasons this indicator for community lead presence remains appealing. One of which is that the amount of lead in community resident’s blood allows for the fact that there are multiple sources of lead in a given community (e.g., soil, air, water). The use of one structural characteristic (e.g., houses built prior to 1950) fails to capture other community lead sources[24] (e.g., lead in soil, lead in air from gasoline, leaded paint on playground structures, lead in new pipes). Moreover, because of the use of a threshold which is deemed by many researchers to be too high, this makes the indicator a conservative estimate. Alternatively stated, the relationship between lead and crime may actually be *more* consistent than results suggest.

Implications for Theory

These results pose implications for future theorizing about communities and crime. Specifically, it was argued that the omission of lead from mainstream crime theory may be problematic, given leads demonstrated association with crime rates at other macro levels of assessment (Masters et al., 1994; Nevin, 2007; Reyes, 2007; Stretesky & Lynch, 2004). Given social disorganization theory’s enduring popularity in orthodox criminology (Kubrin & Weitzer, 2003; Pratt, 2005) it becomes especially

[24] Appendix C presents a correlation matrix including houses built prior to 1950. Interestingly, lead is significantly associated with crime incident (total, violent, and property) rates *and* houses built prior to 1950 ($r=.3414$, $p<.010$). Crime, however, is *only* significantly related to lead- *not* with houses build prior to 1950. That is, houses built prior to 1950 is not significantly associated with incidents of total crime, violent crime, or property crime. This is consistent with the notion that multiple sources for lead exposure exist in the community environment.

prudent to examine any hypothesized macro-level predictor of crime concurrently with social disorganization variables. As such, the community impact of lead on crime was examined while holding constant disadvantage, racial/ethnic heterogeneity, and residential mobility in twelve different negative binomial regressions. These regressions captured three different time frames, and multiple dependent variables. Multivariate results in particular bear relevance for future tests of social disorganization theory.

Overall, predictors of social disorganization theory performed relatively consistently across crime incidents as well as crime arrests. Additionally, social disorganization predictors performed relatively consistently across juvenile arrests and adult arrests, as well as incidents of property crime and violent crime. It was expected that social disorganization theory would perform consistently across all models, as social disorganization theory is designed to be a general theory of crime. That is, social disorganization theory proposes to explain community crime, regardless of type of offense or age of offender.

However, there were nuances with respect to disadvantage, heterogeneity, and mobility's respective associations with community crime. For instance, while disadvantage emerged as significant in nine out of twelve models, in all nine instances, the association with crime was *inverse*. That is, an increase in disadvantage was found to be significantly associated with decreases in crime. This appeared true of all property crime measures (incidents, arrests, adult, and juvenile). The relationship was also inverse across all instances of total crime. Some differences were observed with respect to violent crime, however. For example, disadvantage was not found to be significantly

associated with violent crime incident rates in 2004 or 2010. Nor was disadvantage found to be significantly associated with adult arrests for violent crime. Although, disadvantage did emerge as significantly associated with arrests for juvenile violent crime.

While the direction of these relationships was unexpected, there are a few possible explanations for the inverse relationships. One of which may be the different distributions of crime with respect to violent crime versus property crime. While this has been observed in other hotspot studies, this observation is conflicting with social disorganization theory, which presents as a general theory. Given that the highest proportion of property crime incidents were reported in the Loop community (central downtown area), perhaps this suggests that Loop concentrates more "suitable targets," (Cohen & Felson, 1977). Another reason for the disparity may be that perhaps incidents are more likely to be reported in areas where social organization is high. That is, these observations may be a function of reliance on official data.

With respect to racial/ethnic heterogeneity and residential mobility, these associations also appeared to have a more nuanced relationship with crime. Interestingly, racial/ethnic heterogeneity did not emerge as significantly related to crime in any model. That is, the relationship between community racial/ethnic heterogeneity and crime emerges as null each time. While these results were contrary to what was hypothesized, these findings are somewhat consistent with the mixed impact of racial and ethnic heterogeneity on crime that recent tests of social disorganization are finding (Martinez, Stowell, & Lee, 2010).

In contrast to both heterogeneity and disadvantage, residential mobility performed very consistently, and in the hypothesized direction. Residential mobility emerged as significantly and positively associated with crime in every model, with the exception the examination of violent adult arrest rates. Given mobility's robustness across most dependent variables used in this study, it appears residential mobility is an important component to consider in community crime rates.

Moving forward, given that lead was found to bear significant associations with crime, net of pertinent sociological variables, these results suggest that lead be considered in future theoretical models. Additionally, researchers may be interested in testing integrated models of lead and crime, centering around testing multiple pathways between lead exposure, relevant sociological predictors, and crime. Such models are presented by Narag et al. in 2009. Moreover, this study illuminates the role that green macro level predictors of crime in estimation procedures. That is, criminology may continue to look towards relevant environmental information with respect to the distribution of crime. The integration of mainstream criminology theories with green perspectives is emergent, and can be observed with respect to other theories and other criminal outcomes (for example, Agnew, 2012).

Implications for Policy

These results also bear importance for community crime policy initiatives. Chicago in particular seems to host a number of policy initiatives geared towards crime prevention and reduction (i.e., Chicago Area Projects). One such initiative that has recently garnered attention is the work of the Violence Interrupters. The Violence

Interrupters initiative is an operation of the Chicago Project for Violence Prevention (formerly CeaseFire Chicago), and the program identifies as a community crime prevention and violence prevention program. The Violence Interrupters are a team of interventionists committed to responding personally to instances of violence in Chicago communities. The Violence Interrupters aim to change community norms and attitudes about violence through public outreach and education. The Violence Interrupters operate across Chicago and target their efforts in communities experiencing high levels of violence. These communities include communities identified by this study as high violence communities- for example, Englewood and West Garfield Park. The Violence Interrupters Initiative is identified as a promising program initiative by the Office of Justice Programs, has been associated with reductions in shots fired and gang involvement across micro-geographical units (Skogan, Hartnett, Bump, & DuBois, 2008), and recently received a $1 million grant from the Mayor of Chicago to continue its efforts (Benzine, 2012).

While the efforts of the Violence Interrupters, for example, are associated empirically with reductions in shots fired, gang participation, and are undoubtedly amicable, results from this study imply that the endeavors of the Violence Interrupters (and similar programs) may be enhanced by policy initiatives that also address community lead levels. Given that findings in this study reveal lead an especially consistent predictor of violence crime incidents (net of confounders), violence prevention initiatives that address the clean up of lead *concurrently* with initiatives like the Violence Interrupters, may witness more profound reductions in violence, or other enhanced

benefits. Likewise, policy endeavors that criminalize the inclusion of lead in products may also serve to add additional public health benefits. Findings from this study suggest that reductions in community rates of violent crime may be an example of such a benefit.

Directions for Future Study

The findings from this study present several important directions for future study. For example, the mixed findings with respect to the distribution of incidents of violent crime versus incidents of property crime invite additional study. For example, criminologists may wish to examine these distributions further, perhaps using additional mainstream criminological frameworks. Frameworks may include examining the impact of relative deprivation, routine activities, or strain perspectives and their association with the distribution of crime, net of lead. Future examinations of community crime may wish to incorporate lead into the theoretical framework. Moreover, data that can capture the organization of the community may allow for a more complete test of social disorganization theory.

Future studies may also wish to examine a mediating or moderating association between lead, social disorganization, and crime. This may be accomplished, for example, through the use of structural equation models to more specifically explicate pathways from community lead presence, social disorganization, and crime. Narag et al. (2009) introduce a number of possibilities with respect to theoretical integration. Results from this study suggest that these integrated pathways may be well worth exploring.

Additionally, future studies may wish to replicate this study in different areas, or different measures of crime. For example, if the association between lead and violent

crime incidents and/or adult arrest rates were found to be persistent when measuring crime with self report data, or through the use of qualitative data, this would strengthen the argument that lead should be integrated into theory and policy initiatives.

Conclusion

The objective of this study was to address three interrelated research questions: Is there a relationship between hotspots of lead and hotspots of crime? Stemming from this question, this study also asked, what is the nature and extent of the relationship between lead and crime? Lastly, does the distribution of lead pose environmental justice concerns with respect to race, class, and ethnicity in Chicago communities?

Chapter one introduced the aims of the study, and provided an organizational overview of the proceeding chapters. Chapters two and three reviewed relevant literature on distributions of lead and crime, and argue why a study that examines the geographic overlay of lead and crime is needed. Chapter four provided background on the study setting, Chicago, Illinois- an area with a documented presence of both lead and crime. Chapter five provided details on the research methodology, and presented the translation of the three major research questions into thirteen testable hypotheses. These hypotheses were tested subsequently in chapter six, and results were discussed in previous sections of this chapter.

Is there a relationship between hotspots of lead and hotspots of crime? The answer to this question appears to be dependent on type of offense. When measuring crime incidents, there appears to be an observable overlap between the distribution of lead and violent crime across communities. The overlay appears less consistent when

measuring property crime incidents, or total crime incidents (the latter of which is largely influenced by property crime).

What is the nature and extent of the relationship between lead and crime? These data suggest that a positive, significant relationship between lead and incidents of violent crime that endures even while controlling for mainstream predictors of community crime rates. These data also suggest that when the weighted average of lead in *neighboring* communities is high enough, the lead in neighboring communities may impact incidents of crime (property and violent) within a community. Results also suggest that changes of lead level within a community are associated with changes in crime rates (total, violent, and property), while holding constant unobserved, time-stable attributes. However, these associations are most consistent with respect to incidents of violent crime. Finally, increases in lead are associated with significant increases in adult arrest rates (regardless of offense type). These data do not find evidence that lead is significantly associated with juvenile arrest rates.

Does the distribution of lead pose environmental justice concerns with respect to race, class, and ethnicity in Chicago communities? These data suggest that the distribution of lead does seem to positively co-vary with race and class. Specifically, communities with high concentrations of black residents, economically disadvantaged residents, and concentrations of residents that are both black and economically disadvantaged, appear to carry higher levels of lead. Associations between percent Hispanic and lead, however, did not emerge as significant. Thus, these data imply

environmental concerns with respect to race and class, but not with respect to ethnicity as measured by percent Hispanic.

Given that under certain conditions, the relationship between lead and crime persists net of confounders, this study offers criminologists examining communities and crime a new variable to contend with when theorizing about community crime rates. Additionally, the empirical associations between lead and violent crime especially provide policy makers with a relevant issue to address when confronting community crime and violence. Future studies will be necessary in elucidating where lead falls in a theoretical pathway to community crime. Future studies may also help inform the role lead reduction/removal may play in policy initiatives that address community crime, especially violent crime.

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Appendices

Appendix A: The 77 Chicago Community Areas

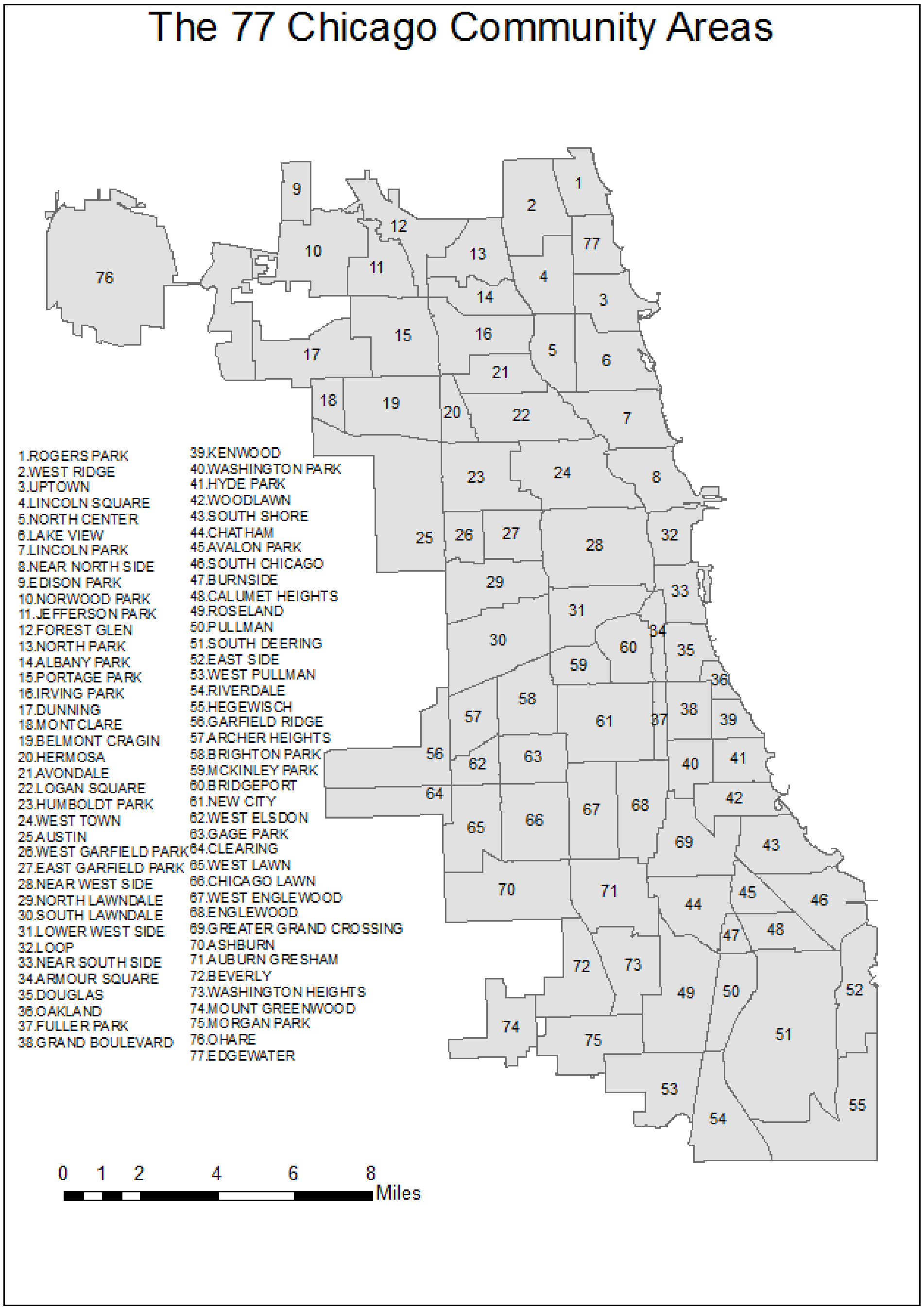

Figure A1. *The 77 Chicago Community Areas*

Appendix B: Multicollinearity Diagnostics

Table B1. *Multicollinearity Diagnostics*

	VIF	**Tolerance**	**Cond. Index**
Variable			
Lead 99	4.44	0.2252	1.0000
Lead lag 99	4.00	0.2499	1.723
Disadvantage 2000	8.03	0.1246	2.815
Mobility 2000	2.89	0.3464	3.6201
Heterogeneity 2000	2.17	0.4614	7.1854
%Black 2000	20.80	0.0481	8.6684
%Hispanic 2000	4.02	.2489	11.9453
%Divorced 2000	4.98	0.2009	18.1659
%Age 15-25	3.18	0.3148	.6852
Mean	6.05		
Total			39.0506

Table B2. *Multicollinearity Diagnostics*

	VIF	**Tolerance**	**Cond. Index**
Variable			
Lead 99	4.32	0.2314	1.0000
Lead lag 99	3.97	0.2517	1.6584
Disadvantage 2000	4.36	0.2292	2.7681
Mobility 2000	1.57	0.6350	3.3264
Heterogeneity 2000	2.13	0.4696	6.4357
(ℓn) %Black 2000	4.55	0.2196	8.5295
%Hispanic 2000	2.36	0.4496	9.0960
%Divorced 2000	2.22	0.4231	11.3794
Mean	3.19		
Total			20.0655

Table B3. *Multicollinearity Diagnostics*

	VIF	**Tolerance**	**Cond. Index**
Variable			
Lead 05	4.32	0.2453	1.0000
Lead lag 05	3.97	0.2207	1.7195
Disadvantage 2010	4.36	0.2159	2.8834
Mobility 2010	1.57	0.6511	3.1119
Heterogeneity 2010	2.13	0.5007	6.9225
(ℓn) %Black 2010	4.55	0.2363	7.9517
%Hispanic 2010	2.36	0.4444	10.2164
%Divorced 2010	2.22	0.4398	12.5275
Mean	3.19		
Total			21.2947

Table B4. *Multicollinearity Diagnostics*

	VIF	**Tolerance**	**Cond. Index**
Variable			
Lead 03	4.47	0.2235	1.0000
Lead lag 03	4.33	0.2312	1.6489
Disadvantage 2000	4.43	0.2258	2.6995
Mobility 2000	1.61	0.6200	3.2473
Heterogeneity 2000	2.06	0.4860	6.0864
(ℓn) %Black 2000	4.40	0.2272	7.3670
%Hispanic 2000	2.19	0.4570	8.8776
%Divorced 2000	2.39	0.4190	11.7636
Mean	3.23		
Total			19.8961

Appendix C: Bivariate Associations between Lead (1999), Percent of Homes Built Prior to 1950 (2000), and Crime Incident Rate (2004), (n = 76)

Table C1. *Bivariate Associations between Lead (1999), Percent of Homes Built Prior to 1950 (2000), and Crime Incident Rate (2004), (n = 76)*

Correlation Matrix	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
1. Lead	--				
2. % Homes Prior 1950	.3414**	--			
3. Total Crime	.4930**	-.1311	--		
4. Violent Crime	.8949**	.1385	.6439**	--	
5. Property Crime	.3172**	-.1913†	.9761**	.4622**	--

* p < .05 ; **p<.01; † p = .0979