2014

Spatial and Temporal Analysis of Selected Birth Defects and Risk Factors in the Baton Rouge, Louisiana Metropolitan Statistical Area

Aimee H. Moles
Louisiana State University and Agricultural and Mechanical College, amoles@lsu.edu

SPATIAL AND TEMPORAL ANALYSIS OF SELECTED BIRTH DEFECTS AND RISK FACTORS IN THE BATON ROUGE, LOUISIANA METROPOLITAN STATISTICAL AREA

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geography and Anthropology

by
Aimee Moles
B.A., University of North Carolina at Charlotte, 1982
M.S.W., Louisiana State University, 1990
December 2014

ACKNOWLEDGEMENTS

To all who made the journey with me, peace, love, and joy in large measure. My advisor, Michael Leitner, and my committee members, especially Fauhi Wang for his assistance and encouragement and of course my wonderful family and friends.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

About three percent of all infants are born with a congenital defect each year ranging from minor variants to life threatening abnormalities. The investigation and treatment of these problems is both costly and emotionally trying for all involved. Finding their origins is a complex process. Birth defects create the ultimate mystery in terms of trying to tease out the various influences created by the environment of both the infant and the mother. Two genetically different individuals are simultaneously affected both by their individual makeup and by the outside world impacting the air they breathe, the food they eat, and the various stressors both big and small that are part of the world they live in. The availability of birth certificate data allows researchers to begin the process of sorting out the factors linked with birth defects. This dissertation employs data from 2005 to 2008 for live births occurring in the Baton Rouge Metropolitan Statistical Area (MSA). Geographic Information Systems (GIS) mapping, cluster analysis, spatial-temporal analysis, geographically weighted regression, and multilevel modeling were employed for the purpose of producing a baseline picture of the area in regard to the locations of mothers giving birth to infants with birth defects, the types and rates of those birth defects, and their correlates. The Baton Rouge MSA proved to be typical in terms of rates of birth defects worldwide, however there were areas which exceeded expected overall rates and some clustering of certain types of defects. Heart defects and hypospadias rates were slightly above anticipated percentages predicted by The U.S. Centers for Disease Control and Prevention. Temporal analysis revealed increases in rates of several types of birth defects in 2006 and 2007 but there were not enough years to analyze these rates statistically. Analysis of correlates did not reveal any models

which could be used to impact rates in the future. However, this project provides baseline data on types and rates of birth defects and information on the best locations for services to affected families along with multiple opportunities for possible preventative efforts and future investigations of this area.

CHAPTER 1 OVERVIEW

1.1 Introduction

Birth defects are a leading cause of stillbirth and infant mortality in the U.S. Each year, approximately 3% of all infants in the U.S. are born with a congenital defect which is recognized by age 6 (Weinhold, 2009). Those birth defects may range from a minor variant to a life threatening medical problem (Mathews, Miniño, Osterman, Strobino, & Guyer, 2011). While infant mortality from disease and accidents has decreased in the U.S. over the last century, birth defects have become the leading cause of infant mortality (Petrini et al., 2002). There are poorly understood inequalities in infant health between white and minority groups in the U.S. which appear to contribute to these numbers (Cordero, Mulinare, Berry, & Boyle, 2010; Goldmuntz, Woyciechowski, Renstrom, Lupo, & Mitchell, 2008; Shin, Kucik, & Correa, 2007). In addition to the huge emotional toll on the individuals involved, the lifetime monetary costs for the family and the community are enormous. In the U.S., birth defects have accounted for over 139,000 hospital stays a year, resulting in $2.6 billion in hospital charges (CDC, 2011a). The problem of infant mortality and morbidity due to congenital defects can be attacked from both treatment and prevention angles. Prevention is the best option, however researchers can identify a cause and effect connection for less than half of all known congenital anomalies (Schardein, 2000). Clues to avenues for prevention start with both alert clinicians and with sharing of information between locations. Tracking where and when birth defects occur and who they affect provides important clues to preventing them. Geographic and ethnic disparities in birth defect incidence need to be recognized before they can be dealt with. In addition, tracking allows for future comparison of outcomes so

that interventions can be assessed. Analysis of birth defect data can help to identify factors that increase or decrease the risks for a particular community or pinpoint environmental concerns that need to be studied.

A South Louisiana metropolitan area was chosen for this research due to both the lack of previous investigation of birth defects for this area and because the state has a poor track record for infant health. As of 2009, the infant death rate in East Baton Rouge Parish was above the national average and above the state average at 10.1 per 1000 births (March of Dimes, 2013). In addition or possibly in concert with this factor, Louisiana is ranked 49th in overall child health status and has high rates of smoking, obesity, and binge alcohol use, all risk factors for birth defects (United Health Foundation, 2011). In Louisiana in 2008, the infant mortality rate due to birth defects was 150.7 per 100,000 live births which accounted for 16.7 percent of infant deaths in the state (March of Dimes, 2013). East Baton Rouge Parish counted 156.4 per 100,000 for the same year, well above the average for the U.S. as a whole which had 135.3 per 100,000 (March of Dimes, 2013). Parishes in the Metropolitan Statistical Area include Ascension, East Baton Rouge, East Feliciana, Iberville, Livingston, Pointe Coupee, St. Helena, West Baton Rouge, and West Feliciana Parishes. Data were gathered by the Louisiana Birth Defects Monitoring Network (LBDMN) from birth certificates in the nine parish area. Children were originally identified at birth by trained coders for the Louisiana Birth Defects Monitoring Network and later gathered through electronic birth certificate data. Data were available for live births occurring between the years 2005 and 2008 in all parishes except St. Helena, which had data available for only the years 2007 and 2008.

1.2 Research Questions

Research Questions to be answered include the following: 1.What is the prevalence of birth defects individually and as a whole occurring in the Greater Baton Rouge Metropolitan Statistical Area? No previous baseline can be found for the geographic distribution of birth defects for the state of Louisiana. The metro area is a starting point for this mapping process. A baseline will enable future comparisons. 2. Where are areas with higher (hot spots) or lower (cold spots) than expected numbers of birth defects overall and what are the possible reasons for these high risk or low risk areas? There are at least two purposes for this question. First, it is important to recognize areas of increased risk for the purposes of prevention and monitoring. Secondly, areas with larger numbers of children with birth defects should also have a greater number of health care professionals within that area. Knowing where the need is greatest will allow for future facility planning which will best serve the community. 3. What are the spatial and temporal variations for the birth defects chosen for a more detailed analysis? This exploration of temporal change provides two important pieces of information. Initial patterns of peaks and troughs in birth defect rates may pinpoint possible connections between events occurring in a given year and particular birth defects if any exist. These observations can serve as a starting point for future explorations. Secondly, the years after Hurricane Katrina are known to have caused a large amount of population movement back and forth between the Baton Rouge Metropolitan area and other cities and states (Kleinpeter, 2007). There is a possibility that a locational shift in the population of children with birth defects has occurred. Knowledge of this shift is important both historically and for practical reasons.

It was not anticipated that there would be any unusual numbers of any particular birth defects in the data. Generally, alterations in expected incidence are at least anecdotally noted by physicians in any particular geographic area. This researcher could find no written indications of unusual numbers of any birth defect in the Baton Rouge MSA nor were any physicians verbally interviewed by the researcher aware of any such abnormalities. The research literature related to birth defects correlates does indicate that there is frequently clustering around concentrations of poverty, low education levels, medically underserved areas, and high infant mortality rates in general. Temporal changes in birth defect clusters were also expected due to the advent of Hurricane Katrina and the influx and the known resettling of the population during the study period (Sastry, 2009). While there were not enough years to statistically evaluate results, there is at least a baseline for the addition of future years.

1.3 Justification And Significance Of The Study

The methodology and study area are unique aspects of this dissertation. The data for birth defect rates in Louisiana had not been explored in any detail previous to 2005 when the Louisiana Department of Health and Hospitals (DHH) began to collect it by hand from hospital records through the newly formed LBDNM and in 2007, electronically from birth certificates. This dissertation is an initial exploration of that data. Another unique aspect of this dissertation is that along with the more common global methods of spatial epidemiology, a local method, geographically weighted regression (GWR) was also employed. While this is a rarely used method in the area of birth defects investigations, it may be invaluable for the purposes of this dissertation because it is exploratory in nature. GWR has the potential to reveal local variations and

relationships between birth defects and environment and also to bring to light previously unknown correlates. These variations may be starting points for additional research to identify the individual and contextual factors that explain the local differences. Chapter 2 will expand on the reasons for choosing this method. Finally, multilevel modeling was used to separate the effects of census tract variables on the outcome of individual risk for birth defects.

1.4 Organization Of The Study

This dissertation is organized into nine chapters. Chapter one contains the introduction, research questions, and justification for the research. Chapter two is a review of the literature including causes and correlates of birth defects and a discussion of geographically moderated aspects of maternal-infant health. Next is a discussion of the development of birth defects surveillance systems and their structure, current status, and availability. Following that is a description of methods for maintaining privacy in geospatial displays and how these methods are applied. Finally there is a review of the research on the categories of some specific birth defects, namely heart defects, trisomies, neural tube defects, cleft lip and palate, fetal alcohol syndrome, and hypospadias and also their known risk factors. Chapter three describes the data used in this dissertation and includes a justification for the use of both local and global methodologies which are employed to accomplish the research objectives. Chapter four presents the results of exploratory spatial analysis along with corresponding charts, tables, and illustrations for the purposes of communication and clarification. Chapter five describes factors contributing to birth defects illustrated with charts and tables of bivariate correlations. Chapter 6 explores stepwise multiple regression analysis and the search for meaningful

models to explain variances in birth defect rates. Chapter 7 is a discussion of the geographically weighted regression process and subsequent results and conclusions about this method as it is compared with stepwise regression results. Maps and charts illustrate the results. Chapter eight is the last step in the analyzing risk factors. Multilevel modeling with SAS software was used in an attempt to improve models and to separate group risk from individual risk. Chapter nine is the final chapter and attempts to bring together the results into some sort of conclusive discussion and plan for future research into the area of environmental and individual risk factors for birth defects in the Baton Rouge MSA.

CHAPTER 2 REVIEW OF RELATED LITERATURE

2.1 Contents Of The Chapter

This chapter is a comprehensive review of topics relevant to birth defects and their spatial characteristics. The history of birth defect surveillance systems, their current status, and the use of coding systems for the dissemination of information are discussed along with issues which may limit research in this area or make it more complex. Descriptions of the birth defects specifically selected for this research along with their rates, characteristics, and risk factors are provided. Finally, there is a summary of risk factors related to birth defects as a whole and for individual categories of birth defects discussed in the dissertation.

2.2 Birth Defects And Geography

Birth defects, like many other medical issues or human activities, in general, are not randomly distributed across space and time. The most obvious reasons for this are differences in birth rates. Generally these rates are moderated by age structure of the population and the cultural conditions surrounding child bearing (Weinhold, 2009). The likelihood of a particular congenital defect is related to a great number of individual, environmental, genetic, and cultural variables, thus as with any medical issue, we can find clues to etiology by using visual representations to locate areas where birth defects are overrepresented. Worldwide, there are differences in the prevalence of various birth defects related to specific genetic diseases common in a population, a variance in the frequency of births to older mothers, cultural norms related to consanguinity, and specific micronutrient deficiencies and infections related to availability of health care, food sources, and local customs (Durkin, 2002). There are a number of possible explanations

for this discrepancy. For example, in the Middle East and in North Africa the birth defect rate is high compared to the rest of the world. Some of this may be explained by the rate of consanguinity (as high as 70% in some areas) which leads to a higher than average rate of inherited metabolic disorders, and autosomal recessive traits (Saadallah & Rashed, 2007). Worldwide, birth prevalence rates for congenital rubella syndrome in infants are estimated to be between 0.6 and 4.1 per 1000 live births with a wide variation depending on the vaccination policies of the country in question (CDC, 2010). Another important correlate of birth defects is income, both that of a nation as a whole (gross national income) and that of an individual (socioeconomic status) and the surrounding community (American Public Health Association, 2006; Weinhold, 2009). Low socioeconomic status (SES) as measured by education, household income, and unemployment is found to be linked to a number of different types of birth defects. For example, Yang, Carmichael, Canfield, Song, & Shaw (2008) explored multiple congenital defects in relationship to an index which included education levels, occupation, and SES and found that some specific heart defects were associated. Wasserman, Shaw, Selvin, Gould, & Syme (1998) found connections between both individual SES and living in a low SES neighborhood with regard to neural tube defects. There do not appear to be any simple relationships between birth defects and SES, education, and employment status, but rather risk factors related to these influences are specific to certain birth defects.

Some of the geographic variation in congenital defects may be highly individual, with the combination of global and local factors producing problems for one family but not another. An example of this comes from the closely related field of infant mortality. Banerjee (2007) notes that initial research on geographic differences in infant mortality

rates showed strong relationships between socio-economic factors and infant deaths. The availability of individual data in more recent research indicates that the relationship is quite complex. Individual level factors interact with poverty rates and other aspects of socioeconomic status to present an even more varied outcome on a smaller scale. There is still much that is not known about the distribution and prevalence of birth defects because not all nations have registries. Even when registries are kept, there are differences in identification and coding.

Mapping and analyzing the distribution of affected families is an important goal, not just for prevention but also for the provision of resources to these families. Not all birth defects can be prevented; some are just statistical certainties that will happen in human reproduction. For example, spontaneous mutations and aneuploidies such as trisomy 18 and trisomy 13 are not generally predictable (Archer, Langlois, Suarez, Brender, & Shanmugam, 2007). For these children and their families interventions such as counseling, medical care, financial assistance, and genetic counseling can go a long way towards producing a healthy next pregnancy. Families need to have readily available resources that are affordable and approachable, not to mention culturally appropriate. In addition, children with special needs may be more difficult to transport and require multiple visits with health care and intervention specialists. Services should be placed strategically or be able to go to the family in need. For those congenital defects which can be prevented or at least decreased through prenatal services, knowing where the need exists allows for careful targeting of cost-effective interventions such as preconceptional care, genetic counseling, family planning, immunizations, and drug and alcohol treatment.

2.3 Surveillance Systems

Today, birth defects surveillance systems exist on both a national and on an international scale and are very active in collecting and disseminating information. This process has allowed for breakthroughs in both prevention and treatment. For example, surveillance programs have been able to document the effectiveness of folic acid supplementation for preventing neural tube defects (MMWR, 2004), and more recently to pinpoint differences in folic acid metabolism among genetic groups (Cordero et al., 2010). Widespread interest in birth defects surveillance was not generated until the Thalidomide tragedy in the early 1960's. Between 1956 and 1962, over 10,000 babies were born with oddly foreshortened limbs, hands, and feet attached to the body like the flippers of seals, missing ears, and other birth defects, less visible but often deadly (Stevens & Brynner, 2001). The cause was the drug Thalidomide, a sedative often given to pregnant women with intractable morning sickness, especially in Europe. Additional impetus for surveillance came in the form of an epidemic of German measles which caused more than 15,000 birth defects in the U.S. in 1965 and from the first infants born with genetic mutations from their parents' exposure to radioactive fallout from the bombings of both Hiroshima and Nagasaki (Stevens & Brynner, 2001). The hope of preventing more tragedies resulted in the first monitoring and reporting systems. One of the oldest is the Metropolitan Atlanta Congenital Defects Program (MACDP), created in 1967 as a result of the Thalidomide epidemic. Since its inception, MACDP has served as a resource for the development of new programs by providing training and procedures for birth defect surveillance across the U.S. and internationally (Correa-Villasenor et al., 2003).

In the U.S., the Birth Defects Prevention Act of 1998 authorized the CDC to collect, analyze, and make available data on birth defects, operate regional centers to conduct applied epidemiologic research for the prevention of birth defects, and provide the public with information on birth defects. This allowed states the support and funding needed to establish their own surveillance plans (Meaney, 2001). The actual planning and carrying out of surveillance systems in the U.S. has been a gradual process. It has been sixteen years since the act was put into place but some states are still in the beginning stages of program development or have not started programs. According to the National Birth Defects Prevention Network (National Center on Birth Defects and Developmental Disabilities, 2010), all states except Montana, Oregon, and Pennsylvania have tracking in place. Louisiana first began a task force in 1999 and began collecting data in 2005 (National Center on Birth Defects and Developmental Disabilities, 2010). Funding for tracking birth defects has been limited, however by 2011, expansion had reached 80% of all births in the state (Hicks, J. personal communication, 2/18/2011). Internationally there are programs designed to collect birth defects surveillance information on a broader scale. For example, the International Clearinghouse for Birth Defects Surveillance and Research, affiliated with the World Health Organization, brings together birth defect surveillance and research programs from around the world. The Metropolitan Atlanta Congenital Defects Program participates in this effort (Byrne, 2011). European Surveillance of Congenital Anomalies (EUROCAT) is an organization of European countries which uses surveillance to identify and ameliorate birth defects (EUROCAT, 2011). This organization covers about 29% of the European Union. Others include the Chinese Birth Defects Monitoring Program (CBDMS) and the Latin American

Collaborative Study of Congenital Malformations (LACSCM) (Bale, 2003). The sharing of data and discovery between these researchers has, and will continue to contribute to prevention and treatment of congenital defects. The World Health Organization has published an atlas of birth defects in an attempt to bring together the knowledge of different registries(figure 1) for comparison and research (WHO, 2003).

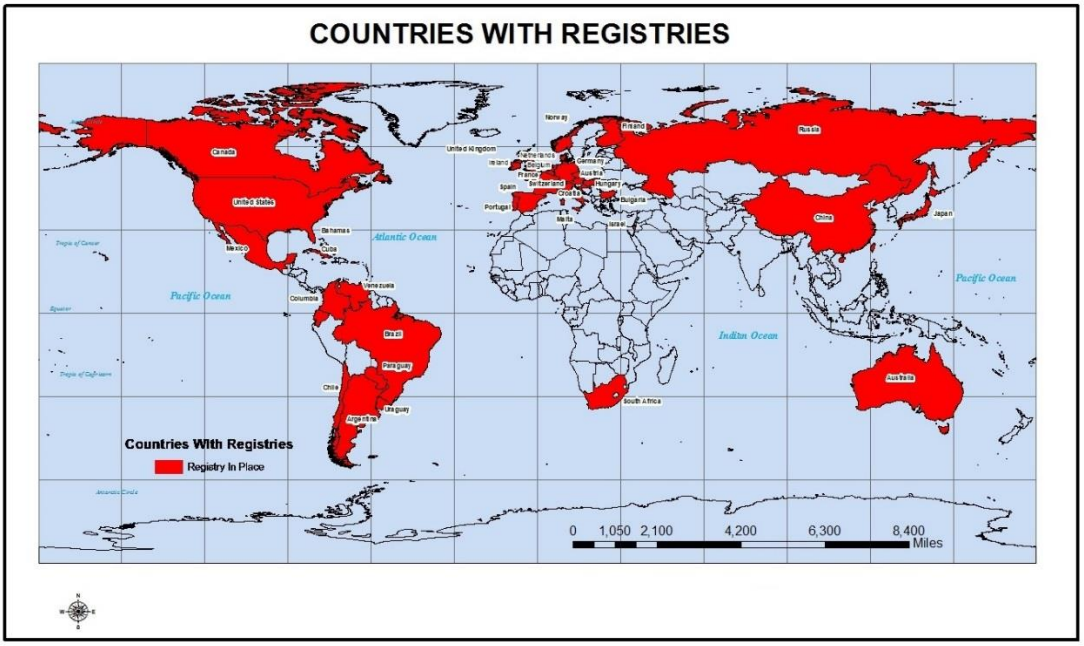

Figure 1: Nations With Active Birth Defect Registries In Place Represented in Red

While there is still much to be discovered about human birth defects, the collected research of both national and international programs has provided enough information on the most common types of birth defects to provide an estimate for average risk for different diagnoses. In addition, we have enough knowledge of etiology and variation among different age and ethnic groups to make some initial hypotheses. The interaction between baby, mother, and environmental and genetic factors provides an almost infinite number of possibilities for the exact etiology of anomalies in the fetus. Past research has indicated that approximately 20% of birth defects are the result of genetic or

chromosomal factors, 10% may arise from environmental factors, and the other 70% are unknown, or a combination of the two (Boslaugh, 2008). Even when the cause is known, sometimes the process by which the malformation occurs remains a mystery. The same teratogens can cause harm to one baby and pose no threat at all to another. For example, not all fetuses exposed to Thalidomide were injured, even when the exposure occurred during the same stage of pregnancy. In addition, the babies were born with different birth defects from the same exposure agent (Stevens & Brynner, 2001) which is indicative of the true complexity of fetal/maternal/environmental factors in the development of the human fetus.

2.4 Transient Parents And Other Research Issues

Spatial analysis of congenital anomalies involves the consideration of two separate environments, the environment of the mother prior to and during pregnancy and the environment of the fetus that the mother is carrying. The complex interaction of these two environments is also moderated by genetic susceptibility of the mother and the infant to teratogens, the amount of exposure to any influences in the environment, and the precise timing of exposure during fetal development (Holmes, 2011). An additional difficulty is the possibility that the mother has moved between pregnancy and the time that the address is recorded for the database. This is an important issue in determining exposure to teratogens. Several researchers have investigated this issue as a possible cause of misclassification (Fell, Dodds, & King, 2004; Miller, Siffel, & Correa, 2010; G. Shaw & Malcoe, 1992) Mothers who moved tended to do so in the second trimester (after primary organogenesis is complete) and to be most at risk for health and social issues (Fell et al., 2004). The women were also most likely to remain in the same county

(Miller et al., 2010). For exploration of smaller residential areas, such as census tracts, this might be a confounding issue for exposure to teratogens. In cases unrelated to a specific toxin, however, the issue of maternal mobility is not severe enough to discount the use of data as it appears that the majority of movement occurs in the same geographic area (Miller et al., 2010). Those who did move during pregnancy were likely to be younger, have an unplanned pregnancy, and more likely to be smokers, which are all risk factors for some birth defects (Miller et al., 2010). No data is currently available on address changes for the research population other than as a whole for the 2010 census. Caution regarding environmental risk assignment and a closer look at the mobility of a research population would be advisable.

Birth defects occur according to the stage of pregnancy in which something goes awry in organ or tissue formation. This is important because many processes are occurring at the same time in fetal development. For example, a teratogen affecting eye formation is also likely to affect ear and heart development as all of these organs are forming at the same time. A child exposed to German measles in the first trimester often has several anomalies including blindness, deafness, and heart defects (March of Dimes, 2011). For this reason, birth defects sometimes come in multiples in the same infant. Other reasons for multiple anomalies include the occurrence of syndromes. The use of the term 'syndrome' implies that the anomalies have a common known cause and that they form a specific diagnosis. Generally, syndromes are well researched and the outcomes for the infant or fetus and the risk of recurrence are generally known (NBDPN, 2004b). A sequence, on the other hand, is a series of anomalies which occur in a cascading fashion because of the first defect. For example, Potter sequence occurs when

there is insufficient amniotic fluid due to kidney anomalies. The lack of fluid leads to abnormal limb positioning and poor lung development so it is expected that all of these problems to occur together in a child with kidney malformation (NBDPN, 2004b). This is an important research issue for GIS mapping and analysis. According to the National Birth Defects Monitoring Program (NBDPN, 2004a), the researcher should be careful to count each anomaly separately but count the infant only one time. Which count is the focus, of course, depends on what is being investigated. International birth defects registries vary substantially in how birth defects are classified and where the data are obtained. They also vary considerably in the accuracy of the data presented. For example, conditions which vary from very mild to very severe, such as hypospadias, may or may not be recognized in their milder forms, whereas very severe conditions such as Gastroschesis, are unlikely to be missed in the recording process (WHO, 2003). This should be taken into account when using birth data. The registry used for this paper does not include miscarriages and stillborn babies, however many registries do use this data. Often the data is separated into categories to make comparisons more accurate. The difficulty with measuring anomalies in non-live births is the widely varying definition of a stillborn. Stillbirth may be assigned at 16, 20, or 28 weeks of gestation or by birth weight limits of either 500 or 1,000 grams (WHO, 2003). For the sake of choosing appropriate expected rates for birth defects, every effort was made to separate live from non-live births for comparison with data from the research area for this dissertation

2.5 Privacy

While it is best to obtain data with the most exact address possible for accuracy, it is also important to consider the privacy of a family with an affected child. The Health

Insurance Portability and Accountability act (HIPPA) laws enacted in the U.S. in 1996 made the security of health care data a legal issue under Public Law 104-191 (DHH, 2011). Statistical data in text format may be protected either by limiting access in the first place to specifically approved users, or by the elimination of personal identifiers. Under the HIPPA privacy rule, covered entities may determine that health information is not individually identifiable in either of two ways. Namely, by using statistical verification to establish de-identification or by removing certain pieces of information from each record as specified in the rule (HHS, 2011; NIH, 2011). Identifiers may include names, birth dates, hospital discharge dates, phone, fax, and e-mail addresses, unique personal account and social security numbers, fingerprint, voice print, and photographs. Removal or masking of these types of identifiers is generally considered sufficient to protect individual privacy (NIH, 2011).

The more difficult problem is how to maintain privacy in geospatial displays such as GIS maps which may not have personal identifiers but might possibly reveal the location of an individual with a medical issue. Both statistical and locational confidentiality must somehow be maintained in an age of online access to nearly everything. In addition, the researcher is obliged to balance both the privacy of the individual and the rights of the community to know about an issue directly affecting health and wellbeing. Attention to maintaining privacy in the use of geospatial data is essential due to both the universal availability of internet technology and of GIS technology. Geospatial data can be easily re-engineered to reveal the exact locations of individual data points (Curtis, Mills, Augustin, & Cockburn, 2011; Curtis, Mills, & Leitner, 2006). For example, a latitude-longitude coordinate can lead to re-identification

of an address through publicly available property records, property tax maps, etc. by simply linking the two data sets together (Curtis, Mills, & Leitner, 2006).

As a result of these privacy risks restrictions may take a couple of forms. Data may be provided to the researcher already stripped of identifiers and with requested analysis complete (Boulos, Qiang, Padget, & Rushton, 2005). Alternately, publication may be limited to aggregation units which disguise individual information at an acceptable level. For example, the U.S. National Center for Health Statistics requires that aggregation units have a population of 100,000 people (NCHS, 2004). In many cases, however, it is up to the researcher to demonstrate relationships between micro data visually while still maintaining an adequate level of confidentiality. Common techniques include the use of some form of 'masking' such as transforming original records, aggregation of data, or removal of certain reference layers. (Armstrong, Rushton, & Zimmerman, 1999). An alternate method of masking data is to use spatial manipulation of the location, which allows for a scale change or rotation of the point data on the two dimensional map surfaces, thereby preserving the appearance of clusters or other phenomena of interest while preventing the data from being re-identified (Curtis et al., 2006; Leitner & Curtis, 2004, 2006; Rushton et al., 2008). All of these methods present a balancing act between accuracy and privacy. Aggregation of data into previously defined administrative units such as census blocks, zip codes, or counties is convenient and generally prevents privacy violations, however artificial boundaries run the risk of hiding truly important phenomena better detected by point data (Meliker, Jacquez, Goovaerts, Copeland, & Yassine, 2009; Rengert & Lockwood, 2009). In the case of this dissertation, data is stripped of individual identifiers and data about income level,

education, and mobility are aggregated to census tract level, zip code, or parish groups. Any release of this document and its information will be restricted and approved by the Louisiana Department of Health and Hospitals.

2.6 Categorization

A coding and categorization plan is necessary for the aforementioned surveillance systems to not only collect and use information about birth defects but also to share that information with other systems. Characteristics of coding systems vary according to which one of the many available alternatives is used and also by the characteristics of the cases included. This is important to note when comparing data between programs. If one system includes stillborn, miscarried, and aborted infants and another only includes live born infants, the results will obviously vary considerably. In addition, a program may choose to maintain records only on structural defects or may include other health problems such as inborn errors of metabolism. All of this being equal, what system is used for coding, and who does that coding will seriously impact the results of any statistics gathered (Cunniff et al., 1994; Wang, Gabos, Sibbald, & Lowry, 2001).

Coding systems need to accommodate the objectives of the surveillance program, whether that is research, service provision, or possibly both. Specific codes are assigned to medical information, based on a standardized classification scheme. Over time, medical communities, including the World Health Organization have developed the International Classification of Diseases (ICD) in order to coordinate classification efforts and promote a standardized classification system for organizing coded data (NBDPN, 2004a). Unfortunately, this coding system is not the most useful for coding birth defects. The CDC instead adopted the system of the British Pediatric Association which had been

modified specifically for the coding of birth defects (NBDPN). This specialized 6-digit CDC code allows for more specific categorization with an extra level of detail provided by a 6th digit (Wyszynski, 2006b). Whatever the coding system or level of care with which it is applied, errors are common and should be accounted for (Callif-Daley, Huether, & Edmonds, 1995).

The categories of birth defects tracked by the CDC and the LBDMN include central nervous system disorders, eye, ear, and orofacial defects, musculoskeletal, genitourinary, and gastrointestinal disorders, chromosomal defects, and those caused by teratogens such as alcohol and drugs (NBDPN, 2004a). Within these categories, some of the most common congenital anomalies include heart defects, neural tube defects, cleft lip and palate, trisomy 21, and hypospadias. These birth defects were chosen for more specific spatial and temporal analysis due to the following factors

- Generally apparent and diagnosable at birth
- Coding well-agreed upon and unlikely to cause differences between physicians
- Common enough to have measurable frequency and not so rare that a family is likely to be in danger of a privacy violation

Descriptions and epidemiological information regarding these birth defects and other important congenital anomalies are discussed in the following sections.

2.7 Heart Defects

About 15% of infants with birth defects have a heart anomaly. In the longest follow ups about 0.9 % of all infants are diagnosed with some type of heart defect (Zierler, 1985). They are one of the most common birth defects in humans (Holmes, 2010). The heart is one of the first organs to form, even before most women are aware of

a pregnancy. It is already beating and pumping blood by the 24th day of gestation (Blackburn, 2007). The valves, chambers, and pacemakers must be laid down and put to work before much of the baby is able to form. Any disturbance in the complicated process may cause a variety of problems ranging from minor differences in the development to life threatening defects or miscarriage (Blackburn, 2007). Heart defects may be caused by genetics, environment, or a combination of both and in fact there are unexplained differences in occurrence rates between ethnic groups. One type of heart defect, teratology of fallot, is more common in African American babies and another type of heart defect, hypoplastic left heart syndrome, is significantly lower in Hispanic babies (Canfield et al., 2006). It is not known whether this is caused specifically by genetic differences or by some complex combination of factors.

Between 5% and 8% of congenital heart defects occur in concert with trisomy 21, trisomy 18, and trisomy 13. Trisomy 21 is the most common of these. There are a number of chromosomal abnormalities which cause defects in the vessels leading to the heart or in the way the blood flows between the chambers of the heart. Genetic counseling is the only way to prevent these types of heart defects. Sometimes the genetic mutations occur during fetal development and therefore cannot be prevented or predicted. In the past, a common cause of heart defects in the U.S. was rubella (German measles) in the first trimester of pregnancy. Since the advent of widespread rubella vaccination, this is now an extremely rare cause of birth defects in the U.S. Only 68 cases of rubella and 5 cases of congenital rubella syndrome were reported to the CDC for the entire U.S. between 2001 and 2005 (Averhoff et al., 2006). The virus may cause miscarriage, stillbirth, blindness, and deafness in addition to heart anomalies. Populations without

adequate vaccination programs or postnatal care which includes testing for rubella immunity may be susceptible. For this reason, women in the U.S. are routinely tested for immunity to the virus postpartally and vaccinated if they are not immune. The highest risk population in the United Stated for congenital rubella are Latin American immigrants (Averhoff et al., 2006). Continued careful attention to ongoing vaccination is necessary to prevent a new epidemic (Reef & Cochi, 2006).

There are several other known risk factors for heart defects in infants, including viral infections, especially those causing fever (Czeizel, Puho, Acs, & Banhidy, 2007), fetal exposure to alcohol (Burd, Klug, Li, Kerbeshian, & Martsolf, 2010), and some medications such as Paroxetine, and Bupropion (Alwan et al., 2010). Folic acid deficiency has been associated with a number of birth defects including heart anomalies. Recently, studies have shown that the risk of heart defects may be reduced with appropriate folic acid intake(Alwan et al., 2010). Variations in the amount of folic acid needed for protection from neural tube defects and heart defects may be due to genetically moderated differences in metabolism (Goldmuntz et al., 2008; Lupo, Mitchell, & Goldmuntz, 2011).

A particularly difficult issue in pregnancy is the treatment of chronic diseases such as diabetes and seizure disorders. Diabetes is difficult to manage during pregnancy and blood sugar may not be as well controlled as prior to pregnancy (Boinpally & Jovanovič, 2009). Uncontrolled blood sugar is a specific risk for heart defects in infants. For women with pre gestational diabetes, early prenatal care is essential as diabetes appears to cause malformations as early as the 7th week of pregnancy (American Heart Association, 2007). For women with seizure disorders, pregnancy can present a special

risk due to changes in levels of estrogen and progesterone. Changes in the levels of these hormones can make seizures more or less likely. Most importantly for heart defects in the unborn infant, seizure medications can change the way the body uses folic acid (Adab, 2006; Arpino et al., 2000).

One of the more well-known environmental teratogens which may cause heart defects is cigarette smoke. There are probably a number of reasons for its harm to a developing baby. One of the chemicals in cigarettes, Cadmium, builds up in the placenta and may compromise fetal growth. Cigarette smoke is also associated with decreased birth weight which is a risk factor in and of itself (Schardein, 2000). In addition, exposure to cigarette smoking may increase the risk of miscarriage. While the placenta may protect the fetus for a time, exposure to large amounts of tobacco smoke will eventually overwhelm the protective system (Miller, 2010). For non-inherited risk factors, prenatal care is essential for prevention. With appropriate medical advice, women can increase vitamin and folic acid intake, avoid exposure to teratogens such as unnecessary medications and environmental hazards and plan for both prenatal influenza and rubella vaccinations.

2.8 Trisomies 21, 13, And 18

Single gene and chromosomal disorders may be the result of an inherited genetic defect, a mutation which has occurred spontaneously, or a particular insult to germ cells in a fetus which leads to birth defects in the next generation (Robaire, 2010). Often, the cause is not known. One of the most common chromosomal birth defects in humans is trisomy 21, which affects about 1 in every 732 pregnancies (Sherman, Allen, Bean, & Freeman, 2007). Trisomy 21 rates vary considerably with the age of the mother. The risk

for a 20 year old mother is about 1 in 2000 but by the age of 35, the risk rises to one in 350 (NDSS, 2011). Trisomy 21 is a major cause of mental retardation and congenital heart disease (Rondal & Perera, 2006). It is most recognizable by characteristic facial and physical features (Evans-Martin, 2009). More important to the survival of the individual with trisomy 21, however, its association with congenital anomalies of the gastrointestinal tract and the heart. In addition, there are immune system dysfunctions and an increased risk of Leukemia (Korenberg et al., 1994). Trisomy 21 is usually caused by an extra copy of chromosome 21. However, in some individuals there may be mosaicism or translocation of chromosomes resulting in slightly different characteristics. In a translocation, a whole chromosome or part of a chromosome becomes attached to or interchanged with another whole chromosome. In mosaicism, an individual has more than one cell line which develops in the embryo. This may result in no obvious birth defects or in trisomy 21 with slightly different manifestations (Hall, 1988). Trisomy 21 does not result from any inherited characteristics of the parents (Yashon, 2009). Whenever a translocation is found in a child, however, it is possible that one of the parents has a translocation. If one parent has the translocation chromosome, then the physician knows the baby inherited the translocation from that parent. The parent will actually have 45 total chromosomes in each cell of their body rather than the usual 46, but since they still have only two copies of each chromosome this will not result in Trisomy 21 in the parent (Blackburn, 2007). The prevalence of infants born with Trisomy 21 does show some geographical variation, however this is generally explained by artifacts related to diagnostic coding, variation in surveillance practices, population mobility, and birth rates (Cocchi et al., 2010; Leoncini et al., 2010). The age of the

mother, availability of prenatal testing and rates of spontaneous and induced abortion are geographically variable and should be considered when comparing prevalence rates of one population to the next (Cragan et al., 1995).

Trisomy 13 and trisomy 18 are the second and third most common causes of genetic birth defects in humans (Stenson et al., 1999). These disorders result from the same process of genetic error as trisomy 21, however both of these variations are often fatal either prior to delivery or in infancy. Many infants with this disorder are miscarried. However, those who are born alive often die in the first hours to months of life (Yashon, 2009). As with Trisomy 21, these disorders may affect all of the cells in the body or only some of the cells (mosaicism) (Stenson et al., 1999). Common findings in infants with these disorders are brain, heart, and facial malformations as well as extra digits, gastrointestinal, and kidney dysfunction (Harold, 2009). For both genetic disorders the risk rises with the age of the mother. The occurrence of trisomy 13 among newborns is 1 in 5000. For trisomy 18, the occurrence rate is about 1 in 1850 (Yashon, 2009). Trisomy 18 is more common in African American babies than in Hispanic or white babies. The cause for this variation in incidence is not known (Canfield et al., 2006).

2.9 Neural Tube Defects

Neural tube defects are a group of anomalies caused by developmental problems along the central nervous system which include the brain and spinal cord, and their protective coverings (Sadler, 1998). They are among the most common congenital defects in humans (Greene, 2006). Stating an actual prevalence rate is difficult due to a number of issues. This is a group of disorders with different etiological backgrounds. The occurrence rate varies considerably in different geographic and socioeconomic settings,

and finally, the recent increase in the use of folic acid as a preventative measure for childbearing women is changing the occurrence patterns (Saul, 2006). A recent estimate is somewhere between .5 in 1000 and 1 in 1000 pregnancies (Tran et al., 2010). Figure 2 visually displays the rather dramatic effect of universal folic acid fortification in the U.S. between 1995 and 2000.

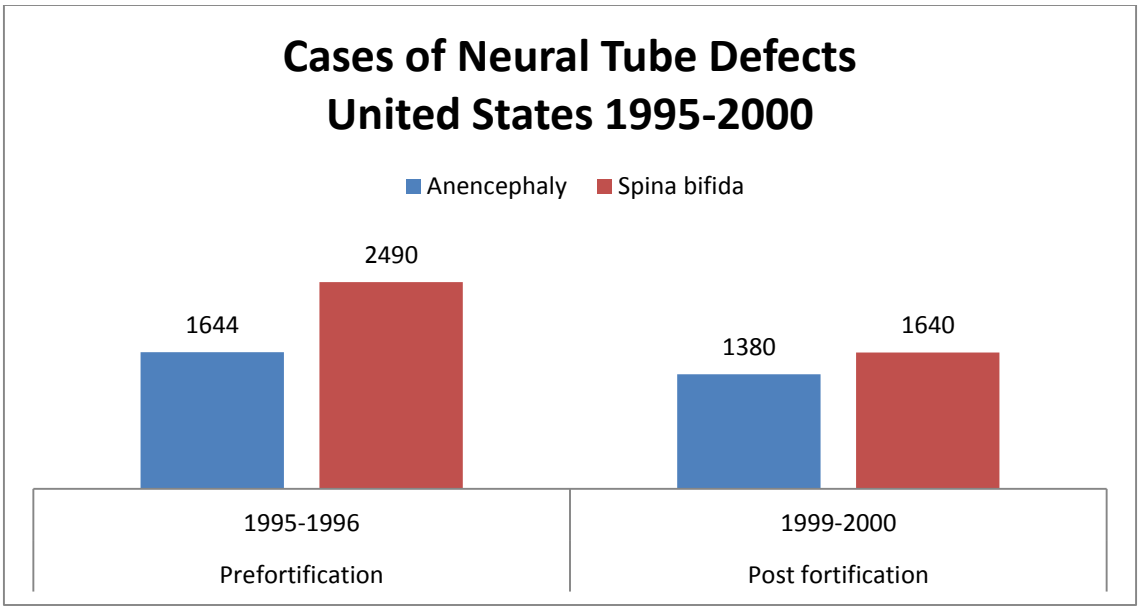

Figure 2: Number Of Births Both Live And Stillborn With Neural Tube Defects Before And After The Folic Acid Fortification Mandate In The U.S. Source: CDC (2004b)

The process of neural tube formation occurs in very early pregnancy, normally by the third and fourth weeks after conception often before the mother is even aware that she is expecting (Moore, 2006). There is considerable variation in outcome for the child depending on where the lesion occurs. To make things more complicated and confusing, each type of neural tube defect has its own name and may vary in etiology. Moore (2006) suggests a common classification scheme which includes anencephaly, spina bifida, and encephalocele. There are two rarer types mentioned by Moore (2006), craniorachiscisis and iniencephaly. Anencephaly occurs at the top of the neural tube in

the cranium which causes the malformation of all or part of the brain. Infants with this defect are either stillborn or die shortly after birth (NINDS, 2011). Neural tube defects are multifactorial in nature. Ethnic differences exist in rates, with Hispanic infants more likely to have a neural tube defect than either non-Hispanic whites or African Americans (Canfield et al., 2006). Spina Bifida generally refers to the non-closure of the lower parts of the neural tube (Moore, 2006). First year survival rates are about 90% in the U.S. (Bol, Collins, & Kirby, 2006). The amount of disability resulting is variable according to the level of the lesion and also the care available at birth. Surgery is generally required during the newborn period to place the neural tissue into the spinal canal where it will be protected from further injury (Miller & Cohen, 2006). Repair of the spinal canal is a delicate procedure with much potential morbidity, thus the availability of a skilled pediatric surgeon will have an impact on the final outcome for the child (Miller & Cohen, 2006).

Surveillance has made it possible to detect important associations which might increase the risk of neural tube defects. One of these associations is folic acid deficiency in the diet. Mandatory supplementation of some food items was put into place in the U.S. in 1996 and a corresponding drop in neural tube defects resulted (Cordero et al., 2010). It is estimated that about 70% of neural tube defects are related to folic acid deficiency. However, there are other associations as well (Wyszynski, 2006a). Obesity is a risk factor for many birth defects including neural tube defects (Hampton, 2004; Oddy, De Klerk, Miller, Payne, & Bower, 2009; Watkins, Rasmussen, Honein, Botto, & Moore, 2003). Neural tube defects are also more common in women with diabetes (Zabihi & Loeken, 2010) and in women requiring anti-seizure medications (Kelly, Edwards, Rein, Miller, &

Dreifuss, 1984). In addition, there may be a genetic predisposition to neural tube defects as there is some evidence of a genetic pattern of inheritance in families (Rasmussen, 2006), Children with neural tube defects who survive pregnancy and infancy are likely to require a large amount of expensive care due to the effect on mobility and organ systems. Education and early prenatal care are the best ways to decrease the risk.

2.10 Cleft Lip And Palate

Cleft lip and palate affect 6,800 infants annually in the U.S. (CDC, 2006).It is one of the most common birth defects worldwide with a rate of 1 to 2 per 1000 births (Bale, 2003).Clefts occur more frequently among Asians, Hispanics, and some Native American Populations. The rate in those individuals of African American descent is lower than in other ethnic groups (Canfield et al., 2006; Yu, Serrano, San Miguel, Ruest, & Svoboda, 2009). Cleft lip and palate may occur together or separately. In addition, they may be seen as an isolated birth defect or in concert with another syndrome. About 70% of the time they are isolated defects (Zucchero et al., 2004). This birth defect develops during the first weeks of pregnancy when the structures of the mouth and lips should fuse at the midline. Severity of cleft lip can range from a tiny notch in the lip to a complete opening up into the nasal area (Kubon et al., 2007). Cleft palate may affect only the soft palate or may include the hard palate. Children with cleft lip and palate are at risk of feeding problems (Owens, 2008), dental issues (Borodkin, Feigal, Beiraghi, Moller, & Hodges, 2008), ear infections (Flynn, Möller, Jönsson, & Lohmander, 2009), speech difficulties (Bedwinek, Kummer, Rice, & Grames, 2010), and self-esteem problems (De Sousa, Devare, & Ghanshani, 2009) due to speech problems and facial differences.

Both environmental and genetic factors play a role in cleft lip and palate. Sometimes the interaction of the two is complex. For example, adequate folic acid plays a part in the prevention of cleft lip and palate. However, some individuals may have a genetic difference in folate metabolism which impairs the ability to process folic acid and thus decrease the risk of this birth defect (Munger et al., 2011). Other risk factors include maternal alcohol use (Munger et al., 1996), maternal smoking (Honein et al., 2007), exposure to passive cigarette smoke (Li et al., 2010), and possibly maternal fever in early pregnancy (Shahrukh Hashmi, Gallaway, Waller, Langlois, & Hecht, 2010).

Treatments for cleft lip and palate include early assistance with feeding using specialized bottle nipples and techniques, and surgery to correct openings in the palate and clefts in the lips. Later interventions may be dental surgeries, speech therapy, and orthodontics. Treatment of cleft lip and palate varies widely in cost, depending on the severity of the problem (Wehby & Cassell, 2010).

2.11 Fetal Alcohol Syndrome

The effects of alcohol consumption on the fetus are now well known, however the association was not officially reported until the 1970s (Jones & Smith, 1975). Symptoms are variable but may include small head, deformed facial features, skeletal malformations, heart and central nervous system problems, slow development both physically and cognitively, and organ malformations (Jones, 2011). Specific diagnostic criteria were established in 2004 by The National Task Force on Fetal Alcohol Syndrome (FAS) and Fetal Alcohol Effect (CDC, 2004a). Diagnosis of fetal alcohol syndrome requires all three of the following findings: specific facial deformities of the eyes, nose, and mouth, documented growth deficits, and documented central nervous system

abnormalities (CDC, 2004a). Prevalence of this diagnosis has been shown to vary due to lack of awareness on the part of healthcare providers, differences in monitoring and reporting methods, and the population being examined (CDC, 2002). Studies by the CDC have reported FAS prevalence rates from 0.2 to 2 cases per 1000 live births (May et al., 2009). The higher prevalence rates were found among minority and impoverished groups (CDC, 2004a) and women experiencing abuse, past substance abuse treatment, heavy smoking, and mental health problems (Project CHOICES Research Group, 2002). Some infants may have what is known as alcohol related birth defects (ARBD) or alcohol related nervous system disorder (ARND) (Warren & Foudin, 2011). Babies born to mothers who use alcohol during pregnancy are more likely to be premature or sick enough to be in intensive care and the care required may be more intensive than in babies exposed to other drugs in utero (Toutain et al., 2010). The effects of alcohol on brain development may lead to substantial problems with neurobehavioral development which can cause lifelong challenges with learning and behavior (Jones, 2011). In addition, mothers who continue the use of alcohol during pregnancy are also more likely to use other substances such as amphetamines and opiates (Shor, Nulman, Kulaga, & Koren, 2010). The prevalence rate in the study area of this dissertation is unknown. However, alcohol use in the U.S. is common among the population of childbearing women (CDC, 2009). In addition, women using alcohol preconception are more likely to engage in drinking during pregnancy (Naimi, Lipscomb, Brewer, & Gilbert, 2003).

2.12 Hypospadias

Between 3 and 8 per 10,000 male babies will be born with hypospadias, a congenital defect of the penis, each year (Paulozzi, 1999). In normal fetal development

the urethra extends from the bladder to the tip of the penis in males. In hypospadias, the urethra does not develop fully and may end along the shaft, so that the urinary opening is somewhere on the underside of the penis anywhere from the tip to the scrotum or rectum (Baskin, 2004). This birth defect develops between the 6th and 16th weeks of gestation when the urogenital system is forming (Baskin, 2004). It is sometimes associated with other congenital defects. When it occurs alone, the problem is generally corrected with surgery to enable normal urination and sexual functioning in adulthood (Baskin, 2004). As with many other congenital defects, hypospadias appears to be multifactorial in nature. There is a genetic tendency as evidenced by a clustering of the diagnosis among family members in about 10% of cases (Fredell et al., 2002). Other risk factors sometimes found to be associated include maternal age greater than 35 (Carmichael, Shaw, Laurent, Olney, & Lammer, 2007), maternal obesity (Blomberg & Kallen, 2010; Carmichael et al., 2007; Porter, Faizan, Grady, & Mueller, 2005), maternal vegetarian diet (North & Golding, 2000), and maternal diabetes (Porter et al., 2005). Sharp rises in the rates of hypospadias and other birth defects resulting from endocrine disruption aroused interest in the 1960's, 70's, and 80's. Geographic distribution of these increases pointed to industrialization and exposure to chemical pollutants as a possible cause (Paulozzi, Erickson, & Jackson, 1997). Some studies have shown hypospadias to be more common in white infants (Porter et al., 2005) and less common in Hispanic infants (Carmichael et al., 2007). Hypospadias may also be more common in infants with intrauterine growth retardation, suggesting a common cause (Hussain et al., 2002). A temporal increase in rates in one geographic area would suggest external teratogens affecting the fetal endocrine system development or some sort of demographic change.

2.13 Summary Of Risk Factors

There are a variety of risk factors related to birth defects as a whole and for each individual diagnosis. A summary of these is useful both for clarity and for the development of an informative model. These can be divided into three categories, including the physical status of the mother, genetic traits in either the mother or the baby, and environmental influences. The age of the mother is an important factor for infant health at either extreme of the spectrum of the childbearing years. Mothers older than 35 are much more likely to conceive an infant with trisomy 21, 18, and 13 or other genetic defects (NDSS, 2011) or an infant with hypospadias (Porter et al., 2005). Older women are also more likely to have health conditions which rise with age including high blood pressure (Caton et al., 2009) and diabetes (Zabihi & Loeken, 2010) both of which can lead to increased risk of some birth defects. On the other hand, younger mothers are more likely to deliver an infant with Gastroschesis (Benjamin, Ethen, Van Hook, Myers, & Canfield, 2010) or to abuse drugs or smoke during pregnancy (Caetano, Ramisetty-Mikler, Floyd, & McGrath, 2006; van Gelder et al., 2010). Only In recent years have ethnic links to birth defect risk been explored. Increasingly available methods of studying genetic differences have opened up new territory for both causes and prevention. One type of heart defect, tetralogy of fallot, is more common in African American babies (Canfield et al., 2006) and Hispanic infants are more likely to have a neural tube defect than either non-Hispanic whites or African Americans (Canfield et al., 2006), possibly due to genetic variations in folic acid metabolism (Esfahani, Cogger, & Caudill, 2003; Goldmuntz et al., 2008; Lupo et al., 2011). While poverty is not a risk factor for any specific birth defect, it may co-vary with birth defects as both an individual correlate and

as a more global, neighborhood-wide risk. The reasons for this are likely to be a complex mix of inadequate prenatal care and education regarding avoidance of risk factors such as dietary problems, use of teratogenic medications, drug and alcohol exposure, and untreated health problems (Shaw, Jensvold, Wasserman, & Lammer, 1994; Wasserman et al., 1998). In addition, poverty often leads to housing in areas near industrial plants, excessive carbon monoxide from major highways (Gilboa et al., 2005), deteriorating housing with peeling lead based paint (Hu et al., 2006; Vinceti et al., 2001), and sometimes locations in rural outlying areas with little access to needed resources or medical care. Another closely related factor is the marital status of the mother. There is some evidence that childbearing by single women brings about its own risks of infant mortality. Cohabitating single parents may be more likely to give birth to premature and/or low birth weight infants. Non-cohabitating parents are at greater risk of poor birth outcomes including prematurity and low birth weight are often the result of birth defects and thus are related. In fact infants with birth defects are two to three times more likely to be premature than infants without birth defects (Rasmussen, Moore, Paulozzi, &Rhodenhiser, 2001).

CHAPTER 3 DATA AND METHODS

3.1 Contents Of The Chapter

Chapter three describes the study area, including demographic particulars, the process of obtaining the data, the data quality, and the related challenges which arose over the four year period that the data were gathered. Independent and dependent variables, the geocoding process, and the various types of software employed are also discussed. Following these descriptive aspects of the project, this chapter includes a discussion of exploratory data analysis and the various statistical methods used to analyze the data. All maps are constructed using Jenks optimal classification method for both consistency and due to this method's ability to reduce variance within classes and maximize variance between classes(Jenks, 1963).

3.2 The Study Area

The study area comprises nine parishes including Ascension, East Baton Rouge, East Feliciana, St. Helena, Iberville, Livingston, Pt. Coupee, West Baton Rouge, and West Feliciana (Figure 3). There are 151 census tracts in this metropolitan statistical area (MSA). The population is most concentrated in East Baton Rouge Parish with an estimated population of 434,000 people and least populated in West Feliciana and St. Helena Parishes with populations of 10,000 and 15,000 people, respectively. The median age for the MSA is 33.4 years, somewhat below the national average of 36.5 years. The typical education level is high school graduate and the most common occupations are education, service, healthcare, and retail. The area under study is a mixture of urban and rural settings with variable access to health care resources and pockets of high poverty levels The poverty rate in Louisiana during the study period was 17.6 percent, well

above the U.S. poverty rate of 14.3 percent (DeNavas-Walt, Procter, & Smith, 2010). Many of the rural parishes in Louisiana are considered persistent poverty areas by the U.S. Department of Agriculture (USDA). The definition of a persistent poverty area is 20 percent or more of the population below the poverty line in 1970, 1980, 1990 and 2000

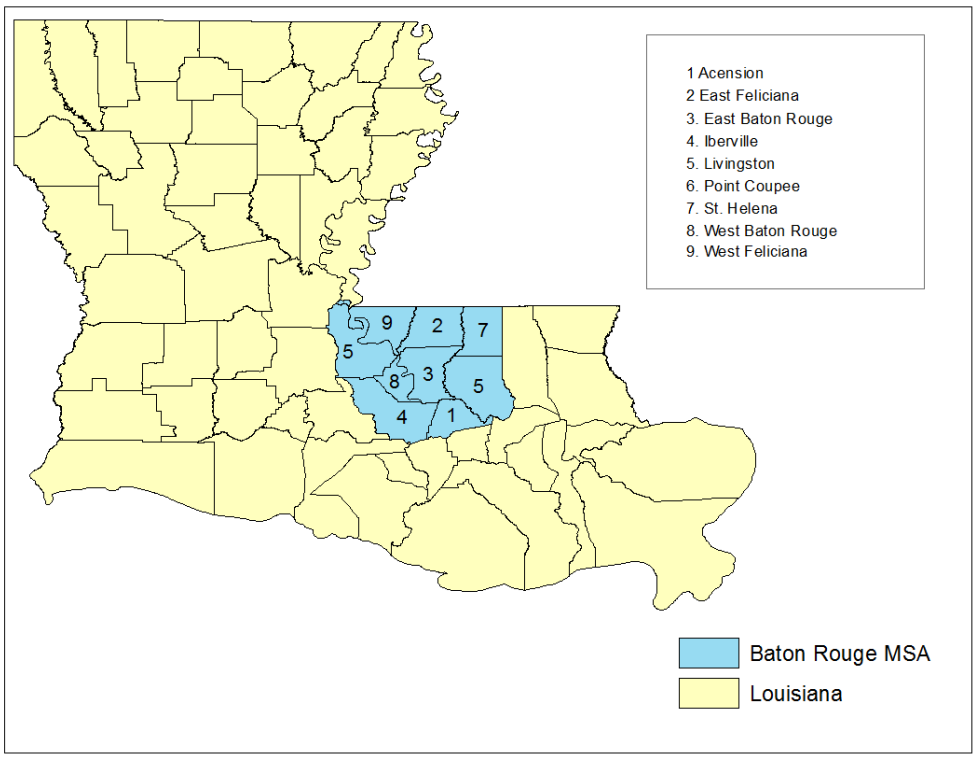

Figure 3: Louisiana With Study Area In Blue

(USDA, 2007). Most (33 out of 35) of Louisiana's rural parishes are considered high poverty areas (Figure 4). The rural parishes in the study area which fall in this category are East Feliciana, Iberville, Pointe Coupee, and St. Helena. The majority of individuals living in poverty in the nine parish area are either children under 18 or have children under 18 living with them (U.S. Census Bureau, 2011). This is important due to the fact that lower income levels increase both infant mortality and rates of specific birth defects (Weinhold, 2009).

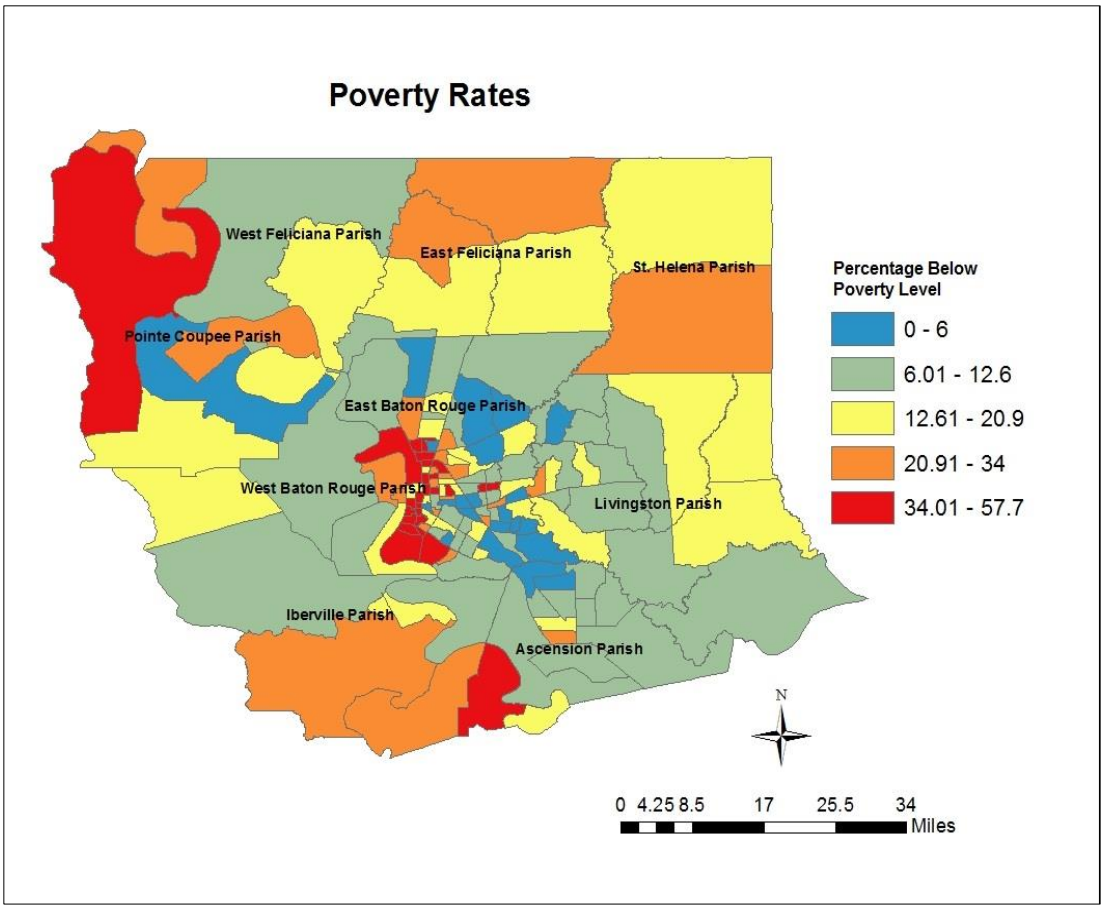

Figure 4: Percent Of People In Each Census Tract With Income Below Poverty Level

The rural/urban designation carries with it some factors which may affect the health of individuals. There is no absolute consensus on what "rural" and "urban" mean, however, the U.S. Census bureau defines these categories by population size. In 2013, the U.S Census Bureau defined an urbanized area as having 50,000 or more people, an urban cluster as having between 2500 and 50,000 people and rural as any population less than that number(U.S. Census Bureau, 2013). Health differences have been shown between rural and urban environments, possibly mediated by built environment (Wang, Wen, & Xu, 2013; Hankey, 2012) and possibly by the residential segregation which drives people to live in one or the other of these environments (Lobmayer & Wilkinson, 2002). Birth outcomes may be affected by urban environments for a complex mixture of

reasons, including poverty exposure (Britton & Shin, 2013). For these reason, the dichotomous variable "urban-rural" was added in the multilevel modeling analysis discussed in chapter 8 this research project. Figure 5 displays the spatial arrangement of urban and rural census tracts.

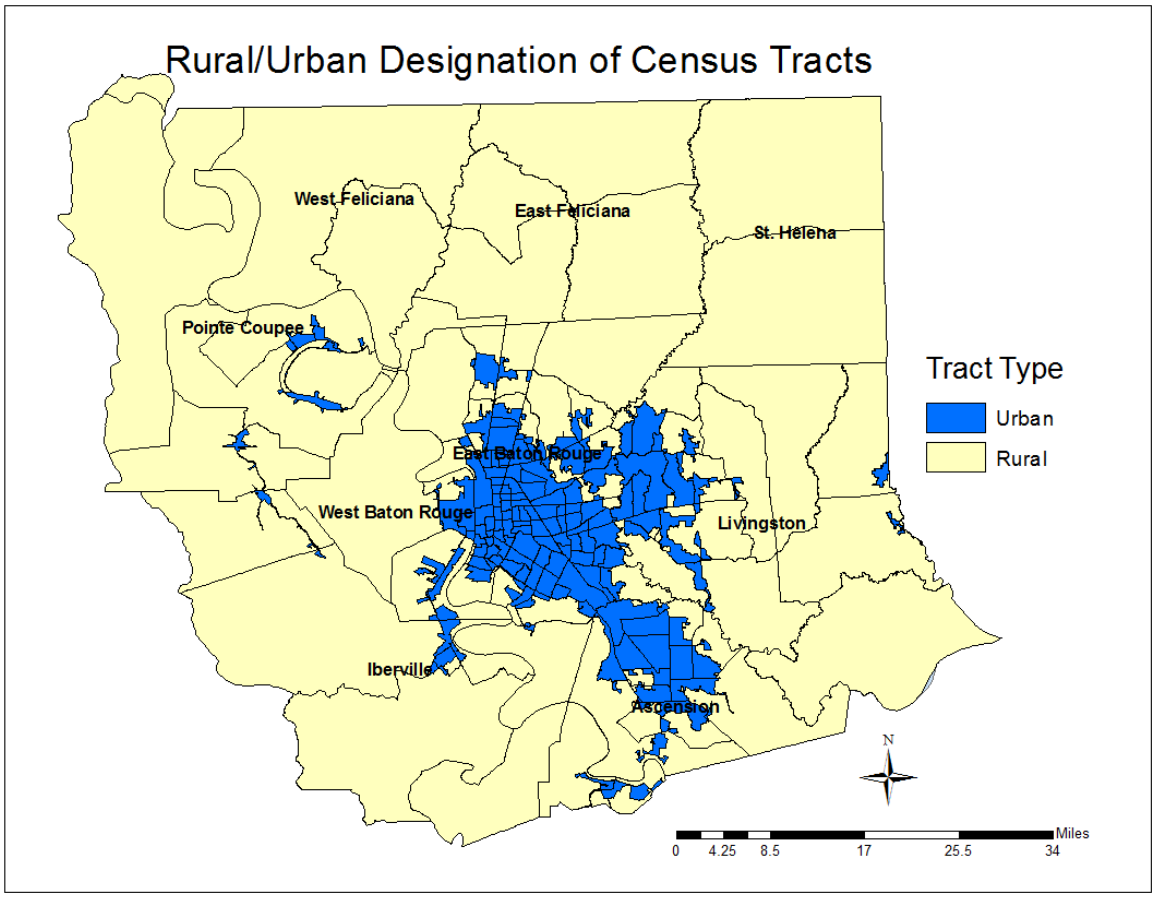

Figure 5: U.S. Census Bureau Defined Designations For Urban And Rural Census Tracts

Demographically, the MSA is about 66% white and 32% black. A small percentage are Asian and a small percentage are Hispanic or some combination of ethnicities (U.S. Census Bureau, 2011). The 2010 census included a "mixed racial category" for the first time (Saulny, 2011) and this category was included as a separate racial designation for census tract level variables. The study area has high rates of obesity, diabetes, and smoking, all of which are often reflected in the rates of birth

defects (CDC, 2011b). Infant mortality rates in Louisiana for the period of 2005-2009 were 9.4 per thousand births, which is higher than the national average of 6.6 per 1000 (The Annie E. Casey Foundation, 2010). Infant mortality rates also differ by ethnicity with non-Hispanic whites having the lowest rate at 7 per 1000 and the highest for non-Hispanic blacks at 14.7 per 1000 (Kaiser Foundation, 2011). For the period of 2005 to 2008 specifically, the MSA averaged 10.1 infant deaths per thousand births with a wide variation among the included parishes (The Annie E. Casey Foundation, 2010). Table 1 displays the parishes along with the number of infant deaths for the years 2005-2008. Parishes with fewer than 20 deaths over the 5 year period did not have rates reported and are indicated by low number event (LNE) in the rates column. Parishes with high infant death rates may also be expected to have higher birth defect rates due to the relationship between the two phenomena (March of Dimes, 2013; Petrini et al., 2004).

Table 1: Infant Mortality Rates For Parishes In The Baton Rouge MSA 2005-2008

Location	Number	Rate
Louisiana	600.80	9.40
Ascension	15.00	8.91
East Baton Rouge	67.00	10.80
East Feliciana	3.00	LNE
Iberville	4.00	8.90
Livingston	10.00	5.30
Pointe Coupee	4.00	LNE
St. Helena	2.00	LNE
West Baton Rouge	6.00	16.60
West Feliciana	2.00	LNE
Averages	12.56	10.10

*LNE is an indication that numbers were too low to calculate a meaningful rate. Data From Kids Count (2010a)

The base maps needed for the research were downloaded from the U.S. Census Bureau Tiger/line shape file library (U.S. Census Bureau, 2013). As of 2006 the nine

parish area was home to 670,000 people. During the period of 2005 to 2008 there were a total of 44,604 births recorded over the entire metropolitan area.

3.3 Case Ascertainment

The original process of gathering information about the infants born with birth defects involved sending Louisiana Department of Health and Hospitals staff to every delivery site to collect information from each chart by hand. In 2007, the state had the ability and permissions necessary to transfer this information to a computer database directly from birth certificates instead. Additionally, previously hand gathered data were entered into the database. What was eventually provided was data obtained between 2005 and 2008 from both hand collected and downloaded sources. To be included in the database, children must be live born and registered with a birth certificate in a delivery hospital in the research area. The MSA contained no birthing centers or other alternate delivery facilities at the time the data were compiled and unintentional home births were generally transferred to a hospital after delivery where a birth certificate was filed (MacDorman, Menacker, & Declercq, 2010). Louisiana is one of the ten states with the smallest number of home births, with less than 1% occurring out of a hospital setting for any reason and infants with birth defects are nearly always transferred to a hospital setting (MacDorman et al., 2010). We can be reasonably sure that our sample is close to 100% of all the births occurring in the MSA during the designated years with the exception of St. Helena Parish. St. Helena Parish data were only available for the years 2007 and 2008. Specific instructions were provided for coding birth defects into 45 meaningful categories used by the Centers for Disease Control using ICD-9 coding (CDC, 2011c). General population demographic information was collected from the 2010 census. The 2010 census tract

designation was added to each record by using the mother's residence address from the recorded information and "geocoding" this address field. Census tract level data were used for most of the data analysis due to the availability of multiple variables at this level. Independent variables include: sex of infant, race/ethnicity of mother, alcohol use by mother, percent of the census tract having less than a high school education, age of mother, smoking or non-smoking status of mother, population density of census tract where mother resides, percentage of the census tract reporting change of residence within the last 5 years, and birth density in census tract where mother resides. More detail about the independent variables is presented in section 3.3. The dependent variables are discussed in section 3.4. The base maps needed for the research were downloaded from the U.S. Census Bureau Tiger/line shape file library (U.S. Census Bureau, 2013). Table 2 below shows the breakdown per parish for the nine parish area for the period of 2005-2008.

Table 2: Number Of Births In Each Parish And The Expected Number Of Birth Defects

Parish	2005	2006	2007	2008	Total	Expected # of Birth Defects
Pointe Coupee	306	311	339	275	1231	37
St. Helena	NA	NA	129	124	253	8
East Feliciana	264	284	244	235	1027	31
West Feliciana	102	112	113	115	442	13
East Baton Rouge	5668	6306	6272	6381	24627	739
West Baton Rouge	321	348	350	332	1351	40
Livingston	1637	1871	1983	1827	7318	219
Ascension	1470	1715	1660	1689	6534	196
Iberville	443	463	428	487	1821	55
Total Births	10308	10759	11566	11472	44604	1338

3.4 Independent Variables

The independent variables used in this dissertation were gathered from the U.S. Census Bureau website (U.S. Census Bureau, 2013) and from the dataset provided by the Louisiana Birth Defects Monitoring Network (DHH, 2011). Census bureau data are only available in aggregated form in order to maintain the confidentiality of the individuals polled (U.S. Census Bureau, 2013). Table 3 displays the independent variables employed along with a description, data source, and spatial resolution.

Table 3: Independent Variables, Descriptions And Spatial Resolution

Independent Variable	Description	Data Source	Spatial Resolution
Percent Below High school Level	Percent of population over 25 with less than high school education	2010 Census	Point
Fertility Rate	Ratio of births to total population of women ages 15-50	2010 Census	Census Tract
Mobility Rate Different Parish	Percent of population moving in or out of the parish in a 5 year period	2010 Census	Census Tract
Mobility Rate Same Parish	Percent of population moving within parish in a 5 year period	2010 Census	Census Tract
Mobility Rate Abroad	Percent of population moving into the parish from within a 5 year period	2010 Census	Census Tract
Mobility Rate Different State	Percent of population moving into the parish from a different state within a 5 year period	2010 Census	Census Tract

(Table 3 Continued)

Independent Variable	Description	Data Source	Spatial Resolution
Percent Black	Mother's race as recorded on census	2010 Census	Census Tract
Percent Hispanic	Mother's race as recorded on census	2010 Census	Census Tract
Percent Asian	Mother's race as recorded on census	2010 Census	Census Tract
Percent Native American	Mother's race as recorded on census	2010 Census	Census Tract
Percent Multiracial	Mother's race as recorded on census	2010 Census	Census Tract
Age of Mother with or without birth defect at time of infant's birth	Age at Delivery	Louisiana DHH	Point
Median Age Of Female Population	Median age by census documentation	2010 Census	Census Tract
Median Age Of Male Population	Median age by census documentation	2010 Census	Census Tract
Median Age Total Population	Median age by census documentation	2010 Census	Census Tract
Poverty Rate	Percent of population below poverty rate	2010 Census	Census Tract
Year of Birth	2005, 2006, 2007, 2008	Louisiana DHH	Point
Alcohol Use	yes, no, unknown	Louisiana DHH	Point
Tobacco Use	yes, no, unknown	Louisiana DHH	Point
Rural/Urban Tract	Rural, Urban	2010 Census	Census Tract

3.5 Dependent Variables

The dependent variables include the total proportion of live born infants in the nine parish area with a birth defect diagnosis of any kind in 2005, 2006, 2007, and 2008 at the census tract level. Additional dependent variables aggregated to the census tract level and for the same four years include the number of birth defects diagnosed (assuming multiple birth defects in some children), sex of infant, and the total number of children diagnosed with hypospadias, trisomy 21, cleft lip and/or palate, heart defects, or neural tube defects. For spatial-temporal analysis, dependent variables were examined at both the census tract and the individual point data level (i.e., the address of the mother). These variables included the total proportion of live born infants with recognized birth defects for each year, the total number of birth defects recognized each year, and the total proportion of children diagnosed with hypospadias, trisomy 21, cleft lip and/or palate, heart defects, or neural tube defects for each one year period, also at the census tract level. Table 4 provides additional information about the variables and their level of analysis.

Table 4: Dependent Variables, Data Source And Spatial Resolution

Variable	Description	Data Source	Spatial Resolution
Infants born with any birth defect	Total number/rate	Louisiana DHH	Geocoded address of mother
Hypospadias	Total number/rate	Louisiana DHH	Geocoded address of mother
Trisomy 21	Total number/rate	Louisiana DHH	Geocoded address of mother
Cleft lip and/or palate	Total number/rate	Louisiana DHH	Geocoded address of mother
Heart defects	Total number/rate	Louisiana DHH	Geocoded address of mother
Neural Tube defects	Total number/rate	Louisiana DHH	Geocoded address of mother

3.6 The Geocoding Process

The initial database was created by the LBDMN and provided to the author of this dissertation. ArcGIS version 10.2 (ESRI, 2012)software provided a method of visualizing and mapping the birth defect locations. In order to make geographic locations visible, they were converted into map locations using geographic grid coordinates, in this case latitude and longitude. A previously mapped street network was used to facilitate the process of placing the addresses visually on the map surface. A list of street addresses was then converted to corresponding geographic coordinates.

While the geocoding allows for information about people and places that might otherwise be unobtainable, the process is inexact and may either inaccurately locate an address or not locate it at all (Andresen & Malleson, 2013).This inaccuracy must be taken into account in interpreting results of the subsequent analysis. There is no consensus for an accepted match rate for geocoding of addresses (Zanderbergen, 2009).The "hit rate" (the percentage measure of success) may be affected by the software employed, or the accuracy of the initial data gathering process, both of which may contribute to the inability to match an address to a geographical point on a map (Andresen & Malleson, 2013; Cayo & Talbot, 2003). Additionally, the threshold chosen for the minimum "match score" can change the match rate while not necessarily increasing accuracy (Hart & Zandbergen, 2013). Despite this lack of a consensus on match and positional accuracy rate, there is certainly agreement that both are important and possibly a source of geographic bias. For this project, the match threshold was set at 80 percent and every effort was made to check and recheck results as described below. The geocoding process was completed using ArcGIS online North American Geocode Service (ESRI, 2012)

striving for the highest possible match rate and accuracy that could be obtained with the availability of street level databases. Once the automated batch geocoding process was completed, errors were corrected and addresses re-matched for better results using a manual interactive approach. This included the use of websites, phone books, and other references such as Google Earth™ software downloaded from www.earth.google.com. Success rates and problems related to geocoding the research data are presented in section 4.1.

3.7 Software

Initial exploration of statistical relationships were completed with SPSS18 (PASW, 2009) and SAS software, Version 9.4, SAS (2014). Following the calculation of non-spatial statistics, ArcGIS version10.2 (ESRI, 2012) was used to visualize and analyze spatial patterns of birth defects in the study area. The ArcGIS software fulfilled several purposes, including storing the data, geocoding the data, visualizing the data for point pattern analysis and for aggregating the data in order to display them in the form of choropleth maps. Additionally, ArcGIS enabled the visualization of data analyzed with the three other software programs, SaTScan™ (v.9.0) and CrimeStat version 4.0 (Levine, 2013), both of which have well documented methodology and functionality and will be discussed briefly below.

3.8 SaTScan Software

SaTScan (v 9.0) (Kulldorff, 2006)was developed by Martin Kulldorff with funding from the National Cancer Institute, Centers for Disease Control and Prevention (CDC) and other agencies (Kulldorff, 2006). SaTScan is an open source software program which allows for heterogeneous populations and both spatial and temporal

analysis. The program was originally developed to analyze health event data and to detect epidemics in early stages using periodic surveillance (Kulldorff, 2006). SaTScan allows for input of several types of data files including dBase, comma delimited, or space delimited files. These are automatically converted to a format usable by the SaTScan program. The researcher can choose from one of several probability models for count data, including Poisson, Bernoulli, and Space-time permutation. A Poisson distribution refers to a discrete frequency distribution that gives the probability of an event occurring in a specific period of time. This particular model can indicate, for example, whether a cluster of birth defects is statistically likely to have occurred or is truly an unusual event (Tijms, 2012). The Bernoulli model is a discrete distribution with only two outcomes labeled as either 0 or 1 rather than a continuous distribution as with the Poisson model (Everitt & Skrondal, 2010). Unlike the previous two models offered, the space-time permutation model does not employ any background population information, rather it compares the observed cases to the expected cases in a cluster to determine the likelihood that the cluster is statistically significant. In all three models areas can be scanned for high rates, low rates, or both high and low rates of cases within the area being observed (Kulldorff, 2006). The Bernoulli model uses two different populations in comparison, in this case the control population of all births in the study area, and compares this with the population of infants diagnosed with a birth defect during the testing period. The Poisson cluster analysis method takes into account the expected number of incidents, in this case birth defects, according to the population of a given census tract (Kulldorff, 1999). The information necessary for this calculation is taken from a join between the polygons and census data information rather than by employing two different population files.

SaTScan has no built-in visualization capability and must be interfaced with a GIS program for this task. SaTScan has been used to evaluate clustering in multiple fields including forestry (Riitters & Coulston, 2005), crime control (Nakaya & Yano, 2010), environmental science (Tonini, Tuia, & Ratle, 2009), and veterinary medicine (Ward, 2001), but is especially prevalent in disease epidemiology (Hjalmars, Kulldorff, Gustafsson, & Nagarwalla, 1996; Zhan & Lin, 2003). Examples of use for birth defects include Ozdenerol, Williams, Kang, and Magsumbol (2005), Viel, Floret, and Mauny (2005) and Forand, Talbot, Druschel, and Cross (2002). This software was chosen due to its ability to look for space-time clusters while accounting for overall birthrates. As a secondary use, the Bernoulli cluster analysis routine was used for comparison against CrimeStat and ArcGIS cluster analysis methods. A limitation of this software is that it uses a circular scanning radius and may not be as accurate with clusters that are not circular in shape (Forand, Talbot, Druschel, & Cross, 2002). SaTScan is downloadable at http://www.satscan.org/.

3.9 CrimeStat Software

CrimeStat (Levine, 2013) was developed by Ned Levine and originally funded by the National Institute of Justice for law enforcement and criminal justice agencies for the purpose of tracking and mapping crime patterns. CrimeStat provides a comprehensive tool box of methods for spatial analysis. Additionally, the program works in tandem with ArcGIS and other graphical mapping programs for Windows in addition to ArcView Spatial Analyst (Smith & Bruce, 2008). The program has three main components including

1. The Spatial Description component which allows the user to analyze the spatial distribution of the data.
2. The Spatial Modeling component which allows for analysis of the spatial behavior of the dataset.
3. The Crime Travel Demand Modeling component for analyzing the behavior of serial offenders.

The spatial description component allows the user to locate the mean center and standard distance of the data and to produce a standard deviational ellipse. This module could be used to locate clusters that shift in a particular direction and/or within a time period. While useful for some purposes, this functionality was not used for this project due to the need to take into account the underlying population of births. However, CrimeStat does allow for several types of global measures of spatial autocorrelation, including Moran's *I*, Geary's *C*, and the Moran correlogram (Levine, 2006). Moran's *I* and Geary's *C* were employed for cluster analysis which allowed comparison of results produced by ArcGIS. These statistics are discussed in sections 3.9 and 3.10. The spatial modeling component provides three different types of tools to better describe and understand a dataset. Kernel density analysis, either single-variable (which produces a surface using point density) or dual-variable (which produces the surface density taking into account the density of an underlying process such as population). A third spatial modeling option is a space-time analysis routine. The space-time analysis routine examines the interaction between spatial location of the data points and time. This can be run using days, weeks, months, or years. Like SaTScan, this program has the ability to control for underlying risk (in this case, population or birth density) by using either rates of birth defects, or alternately,

using a second file with population and birth information encoded as background information. This aspect of the software is essential to answering research questions which are highly dependent on background populations. CrimeStat is downloadable at www.icpsr.umich.edu/CrimeStat/.

3.10 SAS Software

SAS (Statistical Analysis Software) was used for the statistical modeling of independent and dependent variables. This software has the capability to do multilevel logistic modeling which was required for the binomial outcomes of individual birth defects (SAS Institute, Inc., 2014) SAS is a software suite developed by SAS Institute for advanced analytics, business intelligence, data management, and predictive analyst. It can be downloaded at www.sas.com.

3.11 Exploratory Spatial Data Analysis

Multiple methods were used to explore the geographic distribution of the data using exploratory spatial data analysis (ESDA). ESDA allows for examination of clustering, dispersal or autocorrelation in the data and is an initial step before attempting to make generalizations about complex spatial patterns and relationships (Fotheringham, Brundon, & Charlton, 2000). Descriptive statistics, thematic maps, graphs, and plots provide illustration and enable the researcher to locate spatial outliers and spatial clusters (Anselin, Sridharan, & Gholston, 2007). Additionally, ESDA can be used to determine whether the planned methods of analysis are appropriate for the collected data. The process of ESDA includes simple graphical displays such as stem and leaf plots, box plots, and histograms, which give a general idea of the distribution of the data, including its center, spread, symmetry, and kurtosis (de Smith, 2007).Graphical displays may detect

problems or features of the dataset such as outliers which may be the result of error rather than an actual feature of the dataset. Thematic maps visually highlight the distribution and patterns in the data as a starting point for finding clusters and hotspots. Both SPSS and Excel were used in this dissertation to complete these tasks.

An important aspect of the data to examine in ESDA is the degree of spatial autocorrelation in the dataset. Autocorrelation indicates the presence of a spatial pattern in a mapped variable due to geographic proximity (Anselin et al., 2007). A variable can be positively or negatively spatially autocorrelated. Positive spatial autocorrelation describes patterns in which neighboring areas are more alike than areas which are farther apart. Negative spatial autocorrelation describes neighboring regions which are significantly dissimilar. Random patterns exhibit no spatial autocorrelation (Fotheringham, Brunsdon, & Charlton, 2000). The measurement of spatial autocorrelation prior to attempting statistical analysis is essential in that most inferential statistics have the assumption that the values of the observations are independent of one another. Positive spatial autocorrelation violates this assumption if the samples are taken from nearby areas (Rogerson, 2010). The issue of spatial autocorrelation makes many statistical tools and inference inappropriate for spatial analysis. A consequence of spatial autocorrelation is that the sampling variance of the statistics are underestimated for positive spatial autocorrelation and overestimated for negative spatial autocorrelation. This in turn affects confidence intervals, making them too large in the case of positive spatial dependence and too small in the case of negative spatial dependence (Haining, 2003). Spatial autocorrelation, does not necessarily indicate error in a dataset. It may also point to spatial relationships to be recognized and investigated (Anselin, 1995;

Fotheringham, 2009). Measures of spatial autocorrelation may be either global or local in nature, with the former indicating only that there may be clustering, spatial outliers, or neither somewhere in the study area, while the latter (local measure) can actually show where the clustering takes place (Anselin, 1995).

3.12 Global Methods Of Measuring Spatial Autocorrelation

Traditionally, spatial analysis had been applied globally which provided a measure of relationships which are assumed to apply across an entire study region (Fotheringham, Brundon, & Charlton, 2000). A widely used measure of global autocorrelation is Moran's *I*, developed by Patrick Moran (Moran, 1950). This spatial statistic measures values in adjacent places related to their similarity to the overall mean value. Moran's *I* is defined as:

$$I = \frac{N}{\sum i \sum jWij} \frac{\sum i \sum jWij\left(Xi - \overline{X}\right)\left(Xj - \overline{X}\right)}{\sum i\left(Xi - \overline{X}\right)^2} \quad \text{(Formula 1)}$$

Where *N* is the number of spatial units indexed by i and j; *X* is the variable of interest; $\bar{X}$ is the mean of *X*; and W_{ij} is an element of a matrix of spatial weights (Okabe & Sugihara, 2012). Spatial weights are a mathematical method of describing the integration of space and spatial relationships. There are multiple ways of doing this, including inverse distance, fixed distance, K nearest neighbors, and contiguity, among others (Rogerson & Kedron, 2012). The choice of spatial weighting methods should best suit the way that the features interact in the real world (Rogerson & Kedron, 2012). Moran's *I* was calculated using ArcGIS which offers inverse distance, inverse distance squared, fixed distance band, and zone of indifference as options. Inverse distance was employed because it is expected that the farther away a woman is from a particular

neighborhood influence, the less likely that that influence will affect the pregnancy. Additionally, census tracts are of widely varying sizes and fixed distance bands would be inappropriate in this circumstance.

An important aspect of global autocorrelation and therefore the use of Moran's *I* is the scale on which it is calculated. Spatial data is especially prone to issues related to the scale of the area under consideration. This is commonly termed the modifiable areal unit problem (MAUP) which must be taken into consideration in spatial statistical analysis (Rogerson, 2010). MAUP is a source of statistical bias which can radically affect the results of statistical hypothesis tests. This problem occurs when point-based measures of spatial phenomena are aggregated into regions. The resulting values are influenced by the choice of regional boundaries (Fotheringham, Brunsdon, & Charlton, 2002). For example, census data may be combined into census tracts, zip codes, counties, or other bounded areas but when the same statistic is applied to different sized boundaries, the results may be radically different (Griffith, Wong, & Whitfield, 2003; Rogerson, 2010). The issue of aggregation bias has occurred in other studies of birth data and is at least partially addressed by using more than one cluster analysis method for comparison (Ozdenerol et al., 2005). For this reason, Geary's *C* (Geary, 1954) was used as another global measure of spatial autocorrelation using CrimeStat software. Geary's *C* measures the similarity between pairs of regions and the resulting measurement ranges between 0 and 2 with lower numbers indicating positive spatial auto correlation and higher numbers indicating perfect negative autocorrelation (Geary, 1954).

$$C = \frac{(N-1)\sum i \sum j W ij \left(Xi - Xj\right)^2}{2W \sum i \left(Xi - \overline{X}\right)^2} \qquad \text{(Formula 2)}$$

where N is the number of polygons indexed by i and j; X is the variable of interest; $\overline{X}$ is the mean of X; W_{ij} is a matrix of spatial weights; and W is the sum of all W_{ij}.

Moran's *I* is sensitive to extreme values of X (the variable under investigation), whereas Geary's *C* is more sensitive to differences in small neighborhoods (Cliff & Ord, 1981). Both statistics were applied with birth defect rates for individual polygons to control for population differences.

While the Moran's *I* and Geary's *C* statistics can show whether the area of investigation has a pattern of values which is clustered or random, and may provide an illustration of overall clustering, they are of little use in describing relationships in any one part of the region under examination (Rogerson, 2010). A considerable amount of information about spatial non-stationarity is at risk of being lost using only a global measure. For this task, local measures of autocorrelation are necessary.

3.13 Local Methods Of Measuring Spatial Autocorrelation

Local methods as opposed to global methods are mappable, able to be represented using GIS, and inherently spatial in nature (Fotheringham & Brunsdon, 1999). Anselin (1995) and others have extended global statistics such as the Moran's *I* and Geary's *C* to depict local variations. While the global statistic provides an overall measure of spatial autocorrelation, the local Moran's *I* (LMI) relates each observation to its neighbors and assigns them to classes with a value indicating the degree of spatial autocorrelation. Only local neighbors contiguous to the target area are considered in determining the value of the statistic. LMI calculates a clustering value (here denoted as *li*) for each target area. There are four classes which may be displayed in maps and tables using Moran's *I*: insignificant clustering ($p>0.01$), significantly high values surrounded by other

significantly high values (HH; $p< 0.01$), areas with a significant lack of clustering (cold spots) surrounded by significant clusters (HL; $p<0.01$), and areas of significantly high levels of clustering (hot spots) surrounded by other areas of significant clustering (HH; $p<0.01$)(Bone, Wulder, White, Robertson, & Nelson, 2013). The Local Moran's *I* gives a score that ranges from –1 for negative spatial autocorrelation to +1 for positive spatial autocorrelation (Anselin, 1995). Local Geary's *C* ranges in value from 0 to 2 with 0 representing perfect positive spatial autocorrelation and 2 representing perfect negative spatial autocorrelation (Anselin, 1995). Local Moran's *I* and local Geary's *C* were carried out with the use of CrimeStat. ArcGIS does not offer local Geary's *C* however local Moran's *I* was calculated in ArcGIS for comparison of results from CrimeStat.

3.14 Chi-Square Tests Of Independence

Some of the data for this dissertation was categorical rather than continuous. Relationships which involved categorical data were explored using the chi-square test for independence. Chi-square also called Pearson's chi-square test or the chi-square test of association, is used to discover whether there is a relationship between two or more categorical variables by comparing the observed number of cases falling into a category to the expected number of cases falling into that category and dividing it by the expected value (Meyers, 2013). The formula for this is below where $\chi 2$ = Pearson's chi-square statistic.

$$\chi^2 = \Sigma \frac{(Observed \quad Value - Expected \quad Value)}{(Expected \quad Value)} \qquad \text{(Formula 3)}$$

Assumptions that must be met include that each cell should contain at least 5 observations. Conventionally, results are questionable when more than 20 percent of the cells contain fewer than 5 observations (Walker & Almond, 2010). Variables must be

either nominal or ordinal and that there must be two or more independent groups. This may be a problematic assumption when considering geographic regions such as census tracts or Parishes. (Fingleton (1983) and Cerioli (1997) note that spatially dependent observations require an appropriately modified chi-square statistic to take spatially autocorrelated data into account. All variables were analyzed using the chi-square test for independence except for the Parish of residence (due to obvious locational aspects). The age of the mother was divided into discrete categories to allow for large enough groups legitimize the results, as were racial categories. The number of cases falling into racial categories other than black and white was too small to legitimize the use the chi-square statistic. For this reason this variable was combined into "black", "white", and "other so that sufficient numbers of cases would fall into all three groups. Chi-square tests were used to explore differences between mothers of children with birth defects and mothers of children without birth defects on categorical variables including tobacco use, alcohol use, mother's ethnic group, sex of child, and age category.

3.15 Regression Analysis

Regression analysis is employed to estimate the quantitative functional relationships between a response variable and one or more predictor variables from the measured data. The formula for the univariate, linear, regression model is represented below where Y is the value of the dependent variable, α is the value of Y when X = 0, β is the slope of the regression line, X is the value of the independent variable, and ε is the error predicting the value of Y given the value of X (Mitchell, 2009).

$$Yi = \alpha + \beta Xi + \varepsilon_i \quad \text{(Formula 4)}$$

Linear regression is commonly used to build simple models for analyzing geographic processes. By taking a pair of variables for each point, a plot can be made showing the change in Y for each change in X. The idea behind this method of analysis is to find the line that best fits through the data points (Seber & Lee, 2012). Ordinary least squares regression (OLS) is one method of finding this "best fit". OLS minimizes the squared distance of the points from the regression line as they are measured parallel to the y-axis. The distances of the points from the line are squared and summed. The line with the smallest sum of the squared distances is considered the best fit (Seber & Lee, 2012). While this is a starting point for determining relationships in geographic space, it fails to take into account some important issues. Many geographic relationships are not linear and in fact may display a distance decay (the slope of the line begins to drop sharply as the data points get farther away from the y-axis)(Fotheringham et al., 2002). Additionally, regression analysis is a global procedure thus applied to the entire site under study and with spatial data it is desirable to determine locally moderated relationships. For example, if clustering of birth defects is occurring more at one location than at another location given an equivalent percentage of births, it is highly probable that there are different underlying processes in each place. Finally, analysis of spatially distributed data presents a number of problems for classical statistics. Regression analysis assumes that events and their attribute values are independent of each other, that is, not spatially autocorrelated (Rogerson, 2010). Spatial data are inherently autocorrelated as their locational aspects as well as their attributes are influential. Ignoring this spatial autocorrelation results in either statistical problems related to the structure of the data, or difficulty with interpretation and bias which may lead to incorrect

results (Richardson, 1997). Classical regression models are most valid when the residuals have no meaningful spatial pattern which is often not the case with spatial data (Anselin, 1990; Richardson, 1997). The residuals may be dealt with by examining the cause of the model's misspecification to reveal missing variables or regional differences which need to be assessed (Haining, 2003).

Other issues may occur if the data are not normally distributed. Inferential tests may be invalid in this case leading to the need to transform the dependent variable into a more normal distribution or to use nonparametric statistics (Salkind, 2006). Non-parametric statistics work around the problem of non-normal distributions by "ranking" the data prior to performing correlations. Neither the dependent not the independent variables are normally distributed for the census data used in this study. For this reason, the significance of correlations are computed using a Spearman's Rank Order Correlation. This test is non-parametric and does not require normally distributed data.

3.16 Geographically Weighted Regression

Geographically weighted regression (GWR) is a method specifically designed to investigate non-stationary contextual relationships over space. Birth defects are often related to the local environment and therefore can be considered spatially varying. Tobler's observation that "Everything is related to everything else, but near things are more related than distant things" is applicable here (Tobler, 1970). It was hoped that the use of this technique would improve the results of linear regression analysis. The GWR allows parameters be estimated anywhere in the study area for a dependent variable and a set of one or more independent variables. In GWR as opposed to linear regression, the model coefficients are allowed to vary regionally and each location has its own

regression model rather than a single global model for the whole study area (Fotheringham, Brunsdon, et al., 2000). Additionally, data points closest to the point of interest are geographically weighted so that they have more influence than observations which are further away. This is accomplished with the use of a spatial kernel corresponding to each data point (Fotheringham et al., 2002). ArcGIS provides options for the use of the GWR which allow variation in bandwidth around the spatial kernel. The bandwidth controls the amount of distance decay so that smaller bandwidths produce a rougher surface than larger bandwidths. The smaller bandwidth will cause the points closest to the point of interest to have more effect on parameter estimates (Fotheringham et al., 2002). However, the arbitrary nature of the process of selecting a bandwidth may result in misleading or inaccurate maps. A very small bandwidth may produce "noise" that is not particularly useful or important, while a very large bandwidth may smooth out important information so that it is missed altogether (Carlos, Xun, Sargent, Tanski, & Berke, 2010). Fortunately, ArcGIS allows alternate methods of determining the kernel function, including the Akaike Information Criterion (AIC) and a fixed bandwidth method in which the number of neighbors or the bandwidth is predetermined. AIC is an objective way to come up with a model fit. It represents a tradeoff between the number of parameters added and the amount of error entering the equation (Brunsdon, Fotheringham, & Charlton, 1996). If the bandwidth can be estimated based on what is known about a phenomenon then a fixed bandwidth makes sense, however, if no theoretical basis exists, an adaptive bandwidth employing the AIC offers a method for choosing the most useful bandwidth (Brunsdon, Fotheringham, & Charlton, 1998). The

formula for the AIC is below where L_m is the maximized log-likelihood and M is the number of parameters in the model (Everitt & Skrondal, 2010).

$$AIC = -2L_m + 2_M \quad \text{(Formula 5)}$$

The bandwidth with the smallest AIC is considered to be the "optimal" choice(Everitt & Skrondal, 2010). Additionally, mapping the resulting regression values allows the researcher to see where the model is performing well and where it is not a good fit (Mitchell, 2009). For this dissertation the process started with bivariate correlation then global regression analysis. Those results were examined and then compared to geographically weighted regression results. ArcGIS 10.2 software contains a tool for calculating the GWR which was employed for this project.

3.17 Multilevel Modeling

Bivariate regression and stepwise linear regression, may provide information about simple relationships between variables within census tracts and for individual mothers and infants, however this leaves the interpretation of these relationships open to what may be referred to as the "ecological fallacy". The ecological fallacy is the process of deducing individual behavior from aggregated data (Waller, 2004). At the basic level, multilevel analysis is similar to ordinary regression. However, in standard regression analysis the regression intercept and the regression coefficients are both "fixed". Only the residuals are random. In contrast, in multilevel modeling the outcome variable is modeled as with coefficients designated as either "random" or "fixed". The fixed variable has but one value which is applied to the level one variable (in this case, the individual mother) regardless of the level two variable. A random effect is allowed to vary between the level two variables (Wang, Fisher, & Xie, 2011). It is informative to

have knowledge of variables affecting individuals and those affecting entire census tracts. However, without the ability to model the interaction between the two, the relationship between the individual's neighborhood risk level and individual risk of birth defects is left unexamined. Multilevel models can account for the interaction between individual and environment. As such, they are employed in this dissertation to further explain differences in birth defect rates which are not explicated by either individual or neighborhood variables alone.

CHAPTER 4 EXPLORATORY SPATIAL ANALYSIS

4.1 Contents Of The Chapter

Chapter 4 will describe the data analysis in detail, including the quality of the data collected, challenges which arose with the geocoding process, and the characteristics of the dataset. Descriptive statistics for the complete data set are provided, relationships between variables, spatial distributions, cluster analysis, and temporal patterns are described. Both charts and maps are used to illustrate the characteristics of the data and the results of analysis. The majority of the maps employed the Jenks classification method for consistency and also to produce the most accurate representation of the data (Jenks, 1963). ArcGIS was allowed to calculate the ideal number of categories for the choropleth maps. For Figure 6 and Figure 7 on page 69, there were only three categories and these were set manually by the author when designing the maps.

4.2 Data Quality Of Collected Data

The available variables were coded with the ICD-9-CM coding system (DHH, 2011). The data included all of the infants born in the nine parish area between 2005 and 2008, both those with and those without birth defects. Thus the total number of cases provided was 44,604. Due to the effects of Hurricane Katrina on transiency and communication, tracking of birth defects may not have been as accurate in 2005 and 2006 as for the years following that time. Additionally, no data were available for St. Helena Parish during those two years. Since rates and clusters were of the most interest in this case and birth rates were low in that parish, this was not a significant issue. The geocoding process was successful for 94% newborns with recorded birth defects and 92% of infants without recorded birth defects. A total of 44,604 live births were recorded in

the nine parish area between January 2005 and December 2008. Of those deliveries, 1,118 (2.5 percent) were reported to have at least one birth defect at delivery. Problems with geocoding were generally due to post office boxes being recorded rather than addresses. Geocoding results were better for urban areas than for rural areas. This is a well-known issue (Cayo & Talbot, 2003;Zimmerman & Jie, 2010). Hay, Kypri, Whigham, & Langley (2009) suggest a number of reasons for this difference in accuracy, including less specific rural addresses, with rural delivery routes and post office boxes often used instead of street addresses, more frequent use of colloquial place names, larger interpolation errors due to longer street segments (in the case of the U.S.), and less accurate roadway reference data. Choices for dealing with this issue may include hand geocoding addresses, excluding non-geocoded data, or using less accurate addresses (Goldberg, 2008;Zimmerman, 2008). Excluding non-geocoded data can affect spatial analysis by reducing statistical power or possibly creating selection or geographic bias (Vach, 1997; Wey, Griesse, Kightlinger, & Wimberly, 2009). The database used for this study contained eight cases with no address at all or a partial address, and 2,188 had only a post office box. Among these births not geocoded, thirty-five had heart defects, two had cleft lip and/or palate, one had trisomy 21, two had neural tube defects, nine were diagnosed with hypospadias, and twenty-six had other types of birth defects. The decision was made to omit these from spatial analysis since locations could not be obtained. However, addresses which could not be geocoded were still taken into account in statistical analysis which did not include mapping, such as descriptive statistics and non-spatial regression analysis. The highest geocoding rates were in Ascension, East Baton Rouge, Livingston and West Baton Rouge Parishes. These are the parishes considered

non-rural thus these superior geocoding rates are not surprising. Table 5 shows the variation in successful geocoding rates and Table 6 displays the variation in geocoding of specific types of birth defects. Differences in match rates will need to be taken into account in interpreting results of the analysis.

Table 5: Absolute Number Of Deliveries And Percent Of Deliveries Successfully Geocoded By Parish With And Without Birth Defects

Parish	Number of Deliveries	Match Rate All Deliveries	Match Rate with Birth Defects	Match Rate without Birth Defects
Ascension	6,534	91.3	91.5	91.2
East Baton Rouge	24,627	96.2	96.1	96.4
East Feliciana	1,027	70.8	71.4	70.3
Iberville	1,821	91.2	93.7	88.7
Livingston	7,318	93.4	87.3	99.6
Pointe Coupee	1,231	77.9	86.2	69.6
St. Helena	253	46.6	40.0	53.2
West Baton Rouge	1,351	85.1	85.7	84.5
West Feliciana	442	55.7	66.6	44.9
All Parishes	44,604	92.6	93.0	92.2

Table 6: Percent Of Birth Defects Successfully Geocoded By Parish And Type of Birth Defect

Parish	**Hypospadias**	**Trisomy 21**	**Cleft Lip/ Palate**	**Heart Defects**	**Neural Tube Defects**
Ascension	94.73	91.66	100.00	98.38	100.00
East Baton Rouge	99.84	96.77	100.00	98.28	100.00

(Table 6 Continued)

Parish	Hypospadias	Trisomy 21	Cleft lip/Palate	Heart Defects	Neural Tube Defects
East Feliciana	66.66	100	100.00	86.66	50.00
Iberville	75.00	100	100.00	100.00	No Cases
Livingston	86.95	76.92	88.23	100.00	100.00
Pointe Coupee	66.66	No Cases	No Cases	85.32	100.00
St. Helena	No Cases	No Cases	No Cases	No Cases	No Cases
West Baton Rouge	75.00	No Cases	66.66	88.23	50.00
West Feliciana	100.00	No Cases	No Cases	50.00	No Cases

Tables 7 and 8 give descriptive statistics for independent and dependent variables across census tracts. The minimum for all of the variables is zero due to both the infrequency of some of the dependent variables and also because the Baton Rouge Metropolitan Airport has its own census tract. There are no homes actually located within that tract. An additional aspect of the data is that no category of birth defects was normally distributed throughout the census tracts, this violates the assumptions of many of the statistical tests which were used for analyzing the data. A Shapiro-Wilks test ($p>.05$) (Razali & Wah, 2011; Shapiro & Wilk, 1964) and a visual inspection of histograms, Q-Q plots, and box plots were used to test this aspect of both the independent and dependent variables. The Q-Q plots are not included here, however Tables 9 and 10 display the salient characteristics of the dataset. Sex of infant, year of birth, alcohol use, and tobacco use are not included in these tables because they are employed as categorical variables.

Table 7: Descriptive Statistics Of Independent Variables

Independent Variable	Mean	SD	Median	Minimum	Maximum
Percent Below High School Level	15.52	9.07	15.39	0	39.07
Fertility Rate	14.7	4.16	7.34	0	27.4
Population Density/Sq. Mile	1166.89	1181.88	540.9	12.5	3233.7
Mobility Rate Different Parish	5.4	0.014	5.4	5.4	5.4
Mobility Rate Same Parish	1.34	4.22	0	0	29
Mobility Rate Abroad	0.337	0.95	0.013	0.011	8.5
Mobility Rate Different State	0.381	1.10	0	0	7
Percent White	50.35	28.62	53.14	3.22	95.36
Percent Black	44.61	28.81	43.8	2.389	95.56
Percent Hispanic	0.1	0.684	0	2.13	9
Percent Asian	1.28	1.6	0.578	0.476	7.36
Percent Native American	0.25	0.12	0.27	0.386	0.53
Multiracial	1.12	0.31	1.13	0.912	1.18
Age of Mother (with or without birth defect at time of infant's birth)	26.30	5.82	26.00	12.00	57.00
Median Age of Female Population	35.36	5.12	34.60	0	46.10
Median Age of Male Population	32.40	4.85	32.80	0	42.4
Poverty Rate	13.32	9.19	10.56	0	41.92

Table 8: Descriptive Statistics Of Dependent Variables

Independent Variables	Total	SD	Median	Minimum	Maximum
All Defects	1130	3.92	9	0	28
Hypospadias	122	1.16	1	0	4
Trisomy 21	60	0.71	0	0	3
Cleft Lip and/or Palate	77	0.84	0	0	4
Heart Defects	525	3	5	0	12
Neural Tube Defects	25	0.52	1	0	3

Table 9: Normality Tests Of Independent Variables

Independent Variables	Skewness	SE	Shapiro-Wilk Significance
Percent Below High School Level	0.39	0.19	0.00
Fertility Rate	12.28	0.19	0.00
Mobility Rate Different Parish	3.69	0.19	0.00
Mobility Rate Same Parish	1.51	0.19	0.00
Mobility Rate Abroad	5.61	0.19	0.00
Mobility Rate Different State	2.92	0.19	0.00
Percent White	-0.12	0.19	0.00
Percent Black	0.16	0.19	0.00
Percent Hispanic	0.98	0.19	0.00
Percent Asian	2.1	0.19	0.00
Percent Native American	0.12	0.19	0.00
Percent Multiracial	-0.5	0.19	0.00
Age of Mother	0.436	0.12	0.00
Median age of Female population	-4.1	0.19	0.00
Poverty Rate	0.91	0.19	0.00

Table 10: Normality Tests Of Dependent Variables

Dependent Variables	Total	Skewness	SE	Shapiro-Wilk Significance
All Defects	1130	0.16	0.47	0.00
Hypospadias	25	8.66	0.09	0.00
Trisomy 21	525	0.58	0.06	0.00
Cleft Lip and Palate	122	1.28	0.07	0.00
Heart Defects	60	1.31	0.05	0.00
Neural Tube Defects	77	1.25	0.02	0.00

4.3 Sociodemographic Characteristics Of Mothers Individually And By Census Tract Population

Sociodemographic variables are known to be related to birth outcomes and as such, birth defects. Taken as population variables, they are surrogates for what cannot be known about the individual mothers and as individual variables, might lead the way to preventative interventions. This section encompasses what is known with regard to the Age ranges of mothers at time of delivery, education levels, birth rates, population densities, mobility rates, ethnic distributions, and poverty rates for census tracts are discussed in detail below. These discussions are augmented with maps and charts for clarification and illustration.

4.3.1 Age Ranges Of Mothers At Time Of Delivery

The age structure of the population was expected to influence the birth rates in each census tract, and the number and types of birth defects that occurred there. For this reason, the age distribution of the female population was examined at the individual level when available, and at the census tract or parish level otherwise. Mothers of all infants (with and without birth defects) ranged from 12 to 57 years of age with an average age of 26. It was not known whether each mother had more than one child at a time (multiple births) or more than one during the time period studied, therefore some mothers may be counted more than once in the dataset. Not surprisingly, the age range was not normally distributed, as younger women are more likely to become pregnant. For this reason, median age was used as an indicator rather than average age. There was one extreme outlier at the higher end of the age range where a mother was recorded to be 57 years of age. There is no way to assess whether this is truly the case, or an error in recording.

This mother had a healthy child and removal of this case did not change the mean age at birth of 26.3 years. As such, it was left in the database. Age varied somewhat according to ethnic group with black mothers being the youngest on average and Chinese mothers having the oldest average age at time of delivery. Some ethnic groups contained a very small number of individuals including, Japanese (7), Hawaiians (3), and Islanders (1). These categories were regrouped as "other". Table 11 illustrates this variation in age ranges from lowest median age to highest. Figure 6 illustrates the median age distribution of the female population in the study area. Younger women are more likely to bear children, thus it is expected that birth rates will be higher in those census tracts with a lower median age. These numbers include females both under and over childbearing age, however it should still be an indication of the childbearing population. A younger population indicates the likelihood that more children live there and also that more women of childbearing age reside there. Median age of the mothers in the study was extracted from the dataset at the parish level for the two largest racial groups of mothers (white and black) separately. White mothers in the northern parishes had a younger median age than those in the central and southern parishes (Figure 7). Black mothers, as indicated in Table 10, were younger in median age than white women in all 9 parishes but were especially young in West Feliciana Parish with a median age of only 22 years (Figure 8).

Table 11: Mean Age Of Mothers At Birth By Ethnicity

Ethnicity	Median Age
Median Age All Groups	26
Black	24

(Table 11 Continued)

Ethnicity	Median Age
Multiracial	25
Native American	26
White	27
Other	29
Vietnamese	30
Chinese	31

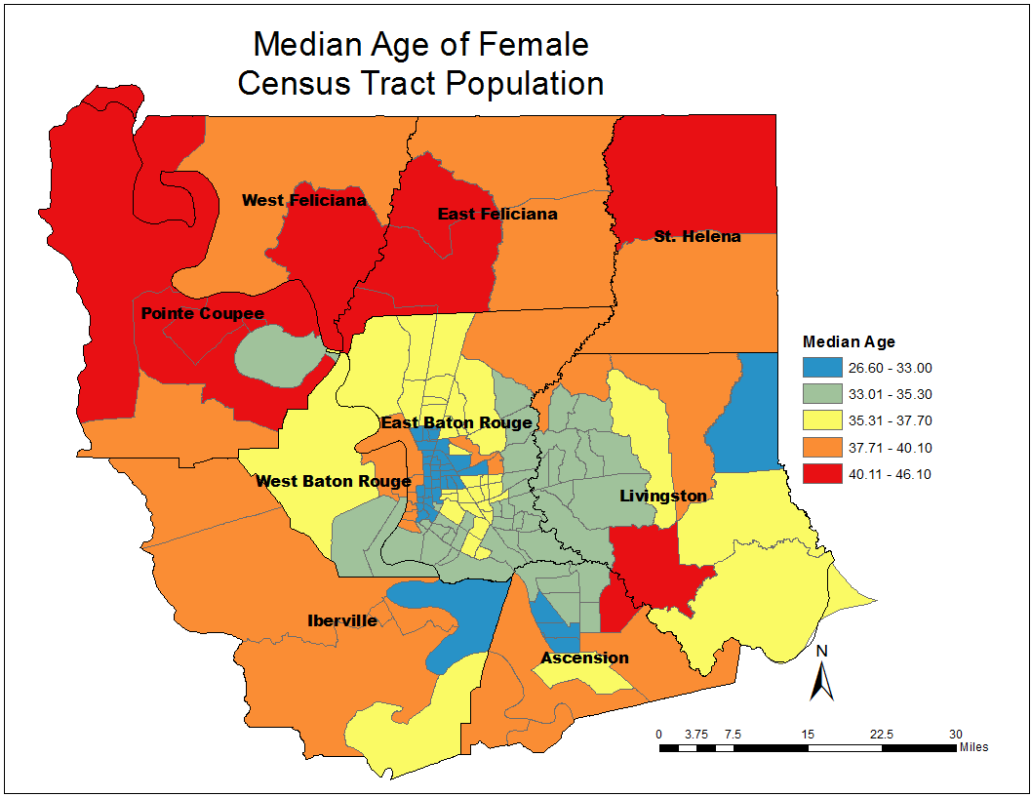

Figure 6: Median Age Of Females By Census Tract

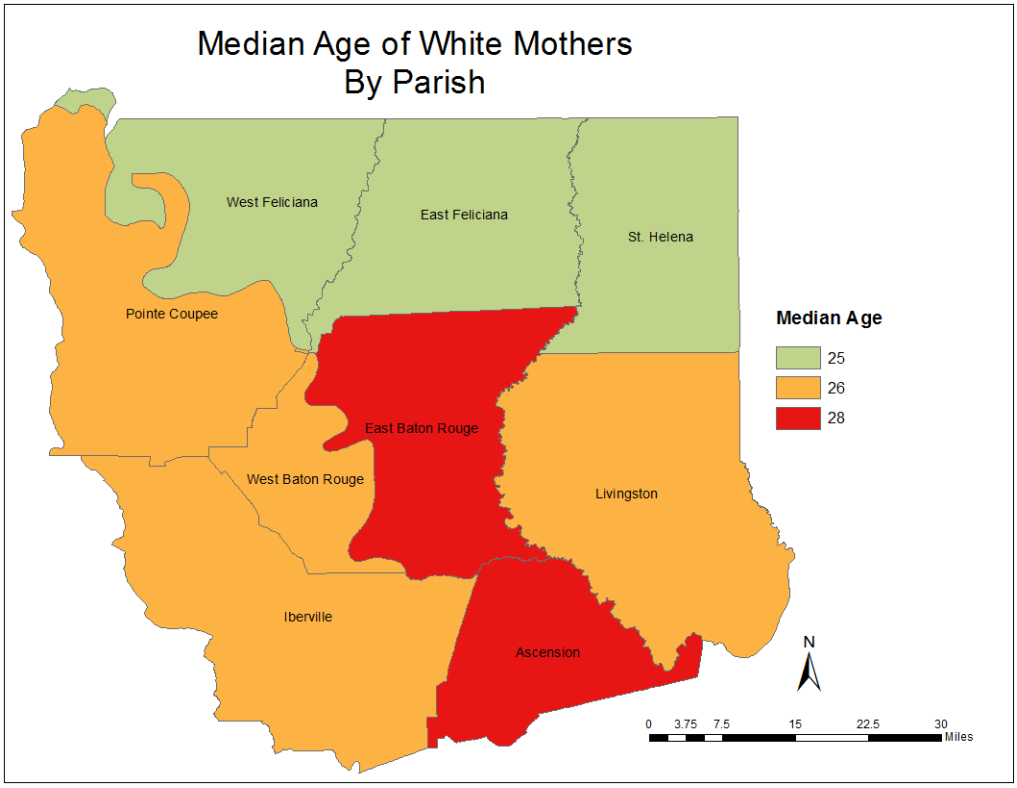

Figure 7: Median Age Of White Mothers At Time Of Delivery By Parish

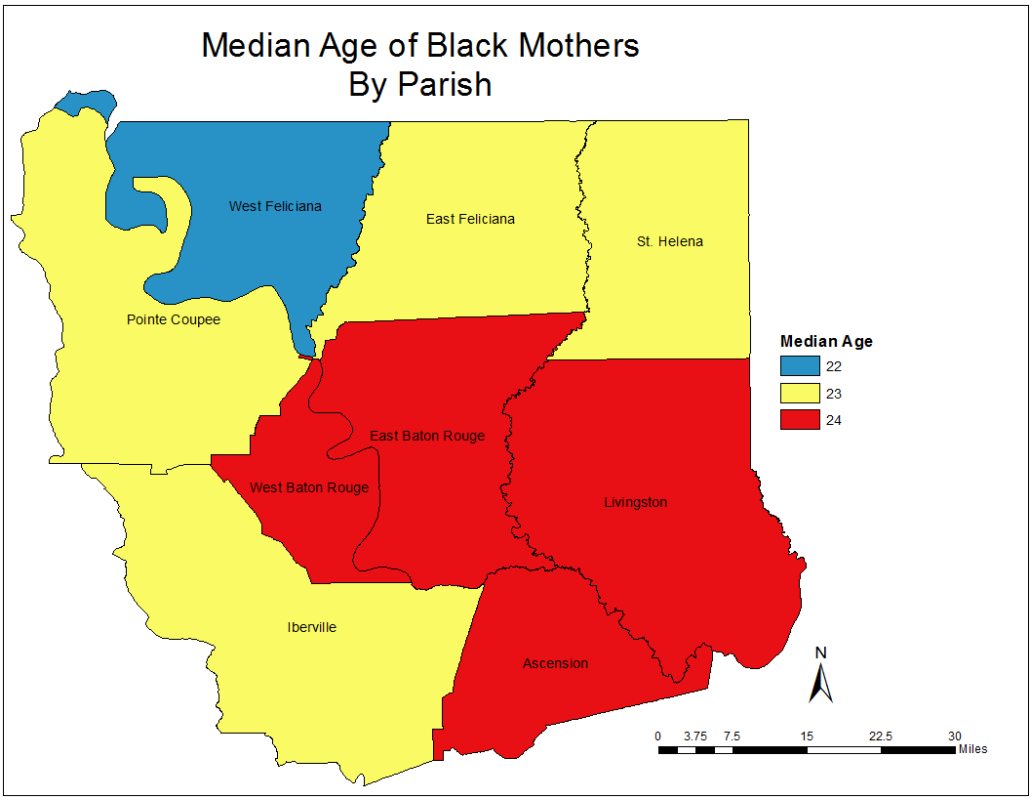

Figure 8: Median Age Of Black Mothers At Time Of Delivery By Parish

4.3.2 Education Levels By Census Tracts

Education levels for the purposes of this research were measured by percent of individuals in a census tract over age 25 with no high school diploma. The percent of adult individuals over 25 in the U.S. with at least a high school diploma is 85.2% as of 2005 (U.S. Census Bureau, 2011). This means that on average, 14.8% of the adult population over the age of 25 do not have a high school diploma. In comparison, the average percentage of individuals over 25 with less than a high school education in the study area was 15.52%. The census areas ranged from a minimum of 1.1% with less than a high school diploma to a maximum of 39.07% with less than a high school diploma. This discounts the census tract containing the Baton Rouge Airport where there is no population. The Census Bureau displayed no value for education level in that census tract and it was omitted from any rate calculations. Figure 9 displays a broad spatial variation in education levels among the census tracts with areas of higher education levels interspersed among areas with lower education levels.

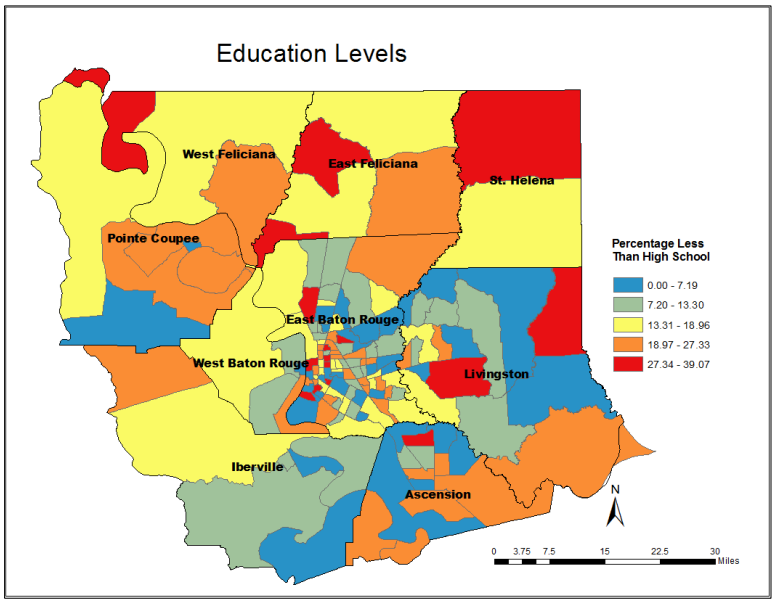

Figure 9: Percentage Of Adult Population Over 25 With Education Level Below High School

In general the southeastern parishes have the most census tracts with above average percentages of people having at least a high school diploma. Figure 9 illustrates the spatial distribution of education levels.

4.3.3 Birth Rates By Census Tracts

Two ways of describing birth rates are used depending on the purpose of the information. Either crude birth rate or fertility rate may be used. The fertility rate indicates the number of births per 1000 women per year, ages 15-49. Crude birth rate is the number of births per 1000 people regardless of sex or age (CDC, 2012). The fertility rate(Figure 10) was explored in this dissertation due to its relationship to poverty and infant health, Reasons for this link are not fully understood (Merrick, 2002). Crude birth rates are also represented in the choropleth maps for the purposes of comparison (Figure 11). Crude birth rates are skewed by the number of women of child bearing age who happen to be living in a particular area. This is of some importance for planning services to meet the needs of the local population demographic. Additionally, census data can only provide information for a large number of households, not for individual households, which would likely be more meaningful in the case of infant birth defects and mortality. Nevertheless, of interest was that the fertility rate was highest in the central parts of East Baton Rouge Parish (Figure 10). However, there was no significant relationship between census tract poverty levels and fertility levels in this dataset. The average fertility rate for the entire MSA was 60.71 per 1000 women ages 15 to 49. This was lower than the U.S. fertility rate of 69 per 1000 women in 2009 (CDC, 2012).

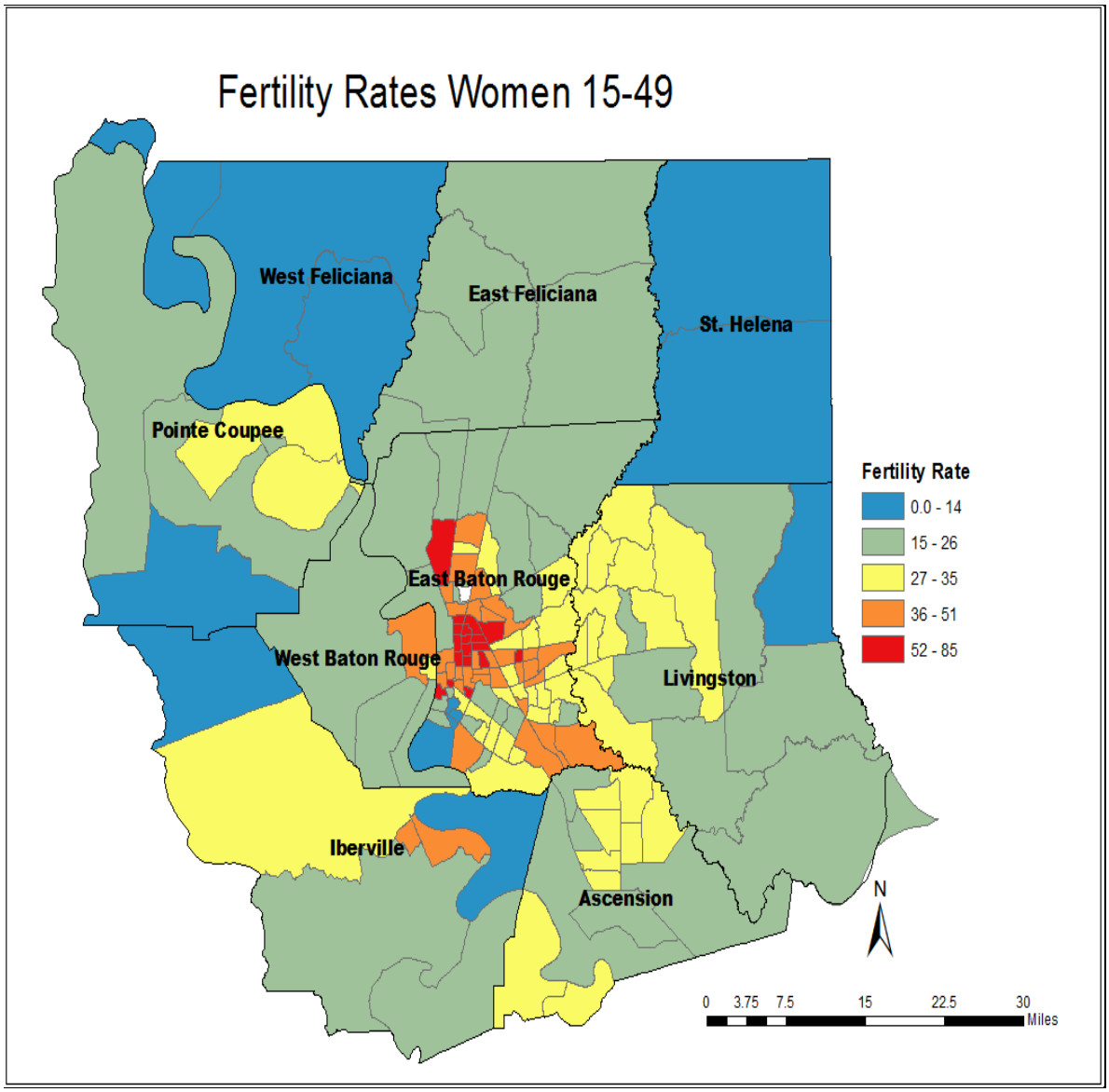

Figure 10: Fertility Rates For Women Ages 15-49

The crude birth rate for the MSA was 15.37 per 1000 people, higher than the nation as a whole at 13.90 per 1000 in 2009 (CDC, 2012). There was a very broad range for crude birth rates among the census tracts, ranging from 0 (northern Pointe Coupee Parish) to 27.41 in one census tract of urban East Baton Rouge Parish. Overall, crude birth rates were widely variable but display a definite pattern of higher rates in urbanized areas and lower rates in more rural parishes (Figure 11).

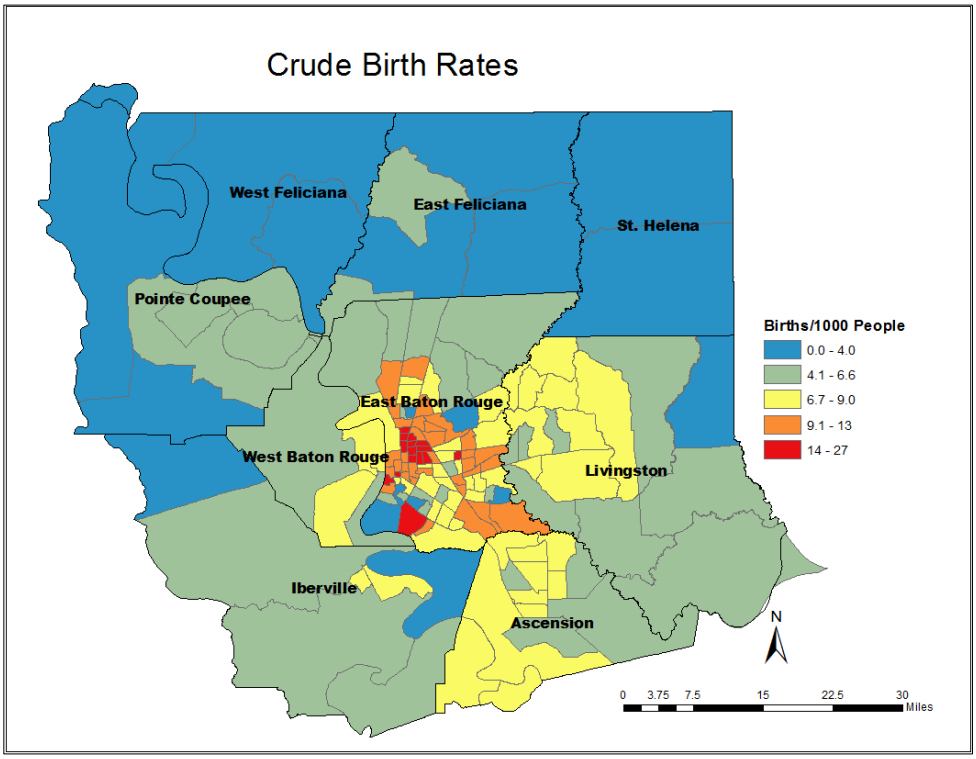

Figure 11: Crude Birth Rates Calculated As Total Births Per 1000 People

4.3.4 Population By Census Tracts

The population of the Baton Rouge Metropolitan Area as of 2010 numbered 802,484 with Baton Rouge as the largest and most populous city in the MSA. Overall population density was 184.5 persons per square mile. Racial and ethnic patterns are reviewed here due to associations between the ethnicity of a neighborhood or census tract and health disparities (Reichman, Hamilton, Hummer, & Padilla, 2008).

The white population is concentrated in the southeast part of the metro area and makes up 60.9% of the total population (see Figure 12). The black population is focused more towards the northwestern part of the area and makes up 35% of the population (see Figure 13). These are the two largest ethnic groups. The Asian population (approximately 1%) and the Hispanic population (approximately 3%) make up most of

the rest of the residents of the MSA (U.S. Census Bureau, 2011). The Asian and Hispanic populations are represented in Figures 14 and 15. The black and white populations are widely spread across the MSA, whereas the Asian and Hispanic residents are more tightly clustered in the southern part of the MSA. The multiracial population rate, new to the 2010 census, is exhibited in Figure 16. While the proportions of the population who were listed as multiracial are very small, areas of concentration are still apparent. What is known about individuals who choose this designation is that they tend to be younger on average than the rest of the populace and that Native Americans, Hawaiians, and Pacific islanders are more likely to report that they are multiracial(Saulny, 2011).

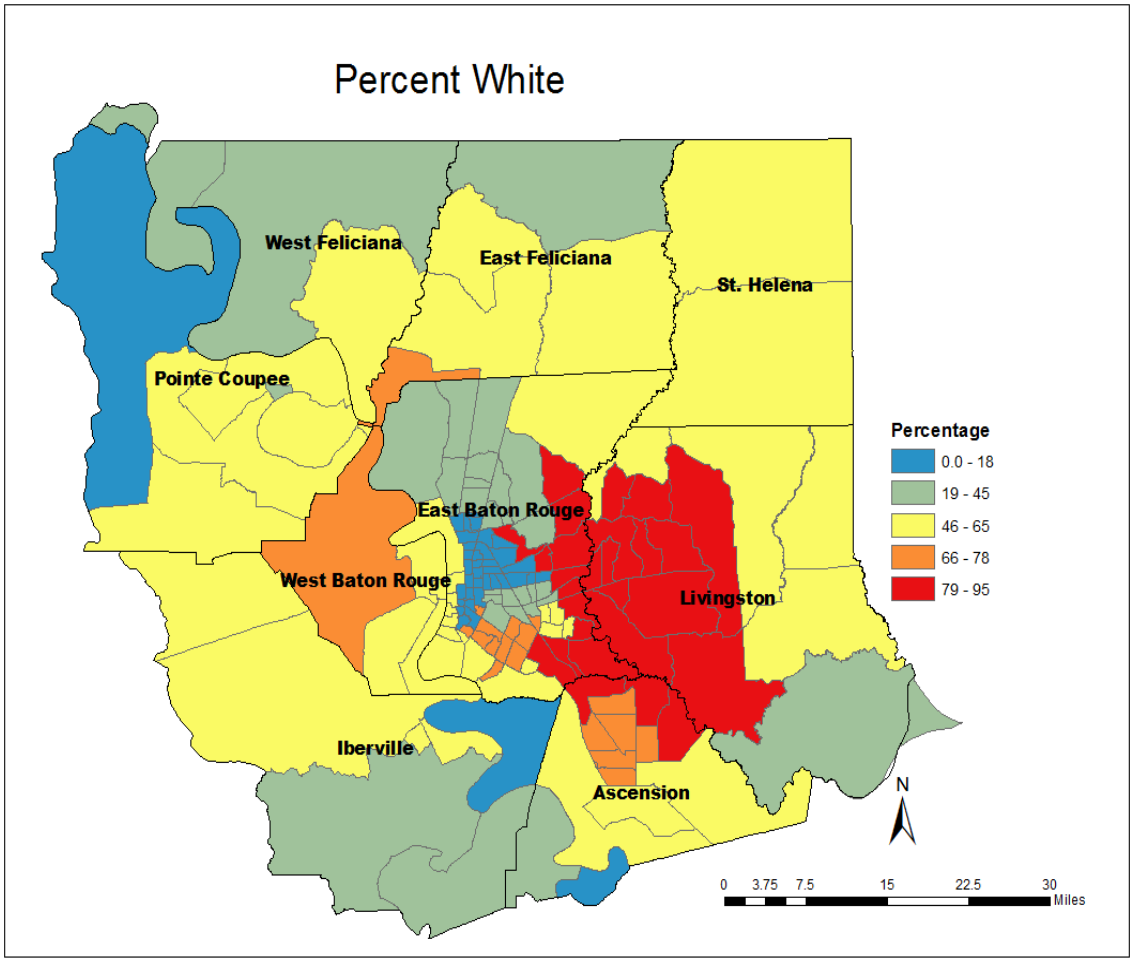

Figure 12: Percent White By Census Tract (2005-2008)

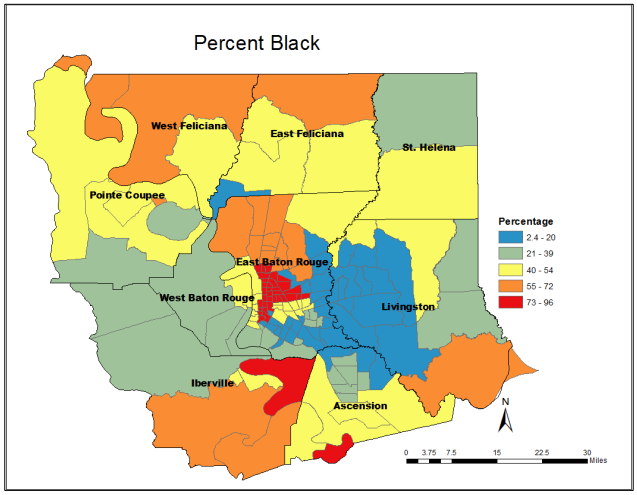

Figure 13: Percent Black By Census Tract (2005-2008)

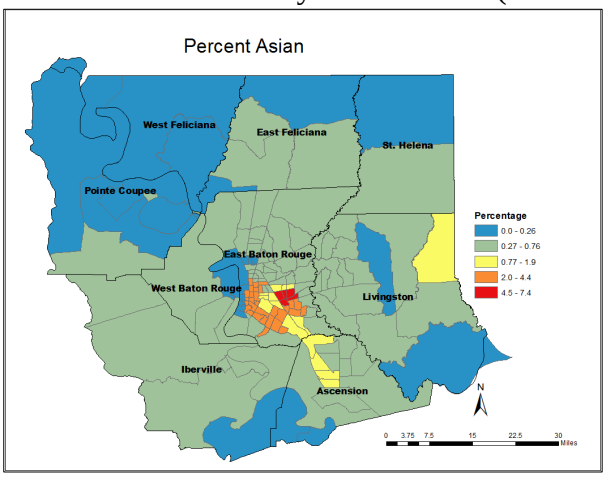

Figure 14: Percent Asian By Census Tract (2005-2008)

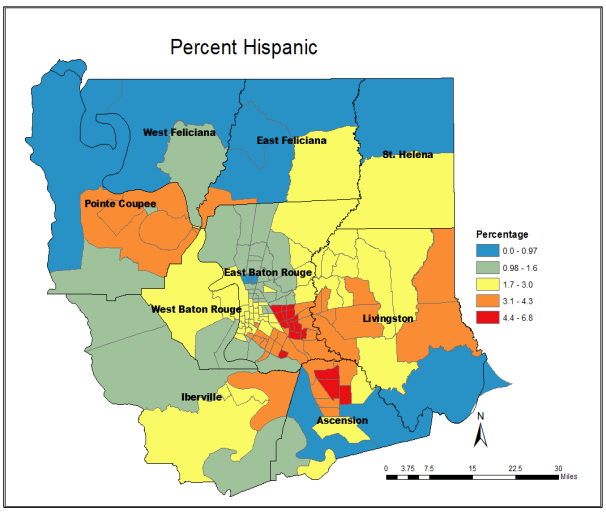

Figure 15: Percent Hispanic By Census Tract (2005-2008)

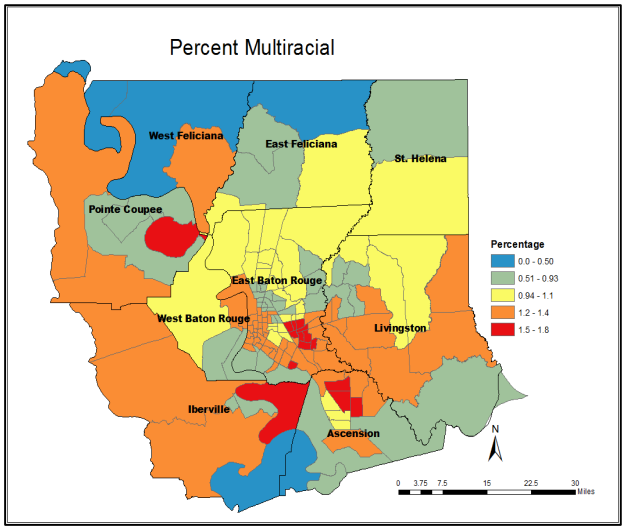

Figure 16: Percent Multiracial By Census Tract (2005-2008)

4.3.5 Birth Defect Rates By Census Tract

The breakdown of types of birth defects was very close to the expected rates. More specifically, there were 122 (.02% of male infants) diagnosed with hypospadias, 60 (.01%) had Trisomy 21, 44 (.01%) had cleft lip and/or palate, 523 (.07%) had heart defects, and 25 (.005%) had a neural tube defect. Table 12 demonstrates the different types of birth defects chosen for analysis and the expected and actual totals in the study area. Only heart defects and hypospadias exceeded the expected percentage.

Table 12: Expected And Actual Birth Defect Rates

	Actual	Percentage of Total Deliveries	Expected Total	Expected Percentage
Birth Defects Total	1,123	2.5	1,323	3
Hypospadias	122	0.003 (male)	67	0.001
Trisomy 21	60	0.13	57	0.13
Cleft Lip/Palate	76	0.17	88	0.20
Heart Defect	525	1.20	396	0.90
Neural Tube Defect	25	0.06	22	0.05

A set of choropleth maps provide a visual illustration of the pattern and distribution of birth defects. Figure 17 demonstrates the birth defect rates in total. While the expected average is 3% of all live births, some of these are not diagnosed until after the newborn period. There is no absolute answer as to what percentage are recognized immediately after birth. This was taken into consideration, however, in choosing birth defects easily diagnosed in the newborn period. The average birth defect rate for the research area was 2.5%. There is wide variation with some areas having extremely low rates and some extremely high rates. These outliers did not appear to be the result of error and were left in the dataset. Hypospadias rates (Figure 18) were higher than the expected .001 percent of male babies. Rates ranged from 0 to 1.28 % of live births and rates were variable. In contrast to hypospadias rates, trisomy 21 rates (Figure 19) show an obvious visual pattern of concentration in the southeastern portion of the region. Overall rates were as expected at 0.13% of live births.

Heart defects were the most common birth defect. It was expected that 0.9% of the infants born between 2005 and 2008 would have a diagnosed heart defect at birth. The rate was actually higher than expected at 1.2% over the four year period. Figure 20 demonstrates the distribution in rates however, there are uniformly higher percentages in the eastern part of the MSA in Livingston Parish.

Cleft lip and palate cases (Figure 21) and neural tube defect cases (Figure 22) are not as easily demonstrated visually due to low numbers of cases in each census tract. Cleft lip and palate rates for the four year period were slightly below the expected rate of 0.20 percent of live births. There are a few census tracts, however with higher than expected rates and a general trend towards increasing rates in the southern edge of the

metropolitan statistical area. Neural tube defects were found to be virtually as expected at 0.05 percent of live births (Figure 22). There were only 25 over the entire four year period and no census tracts had rates above 0.06 percent of live births during that time.

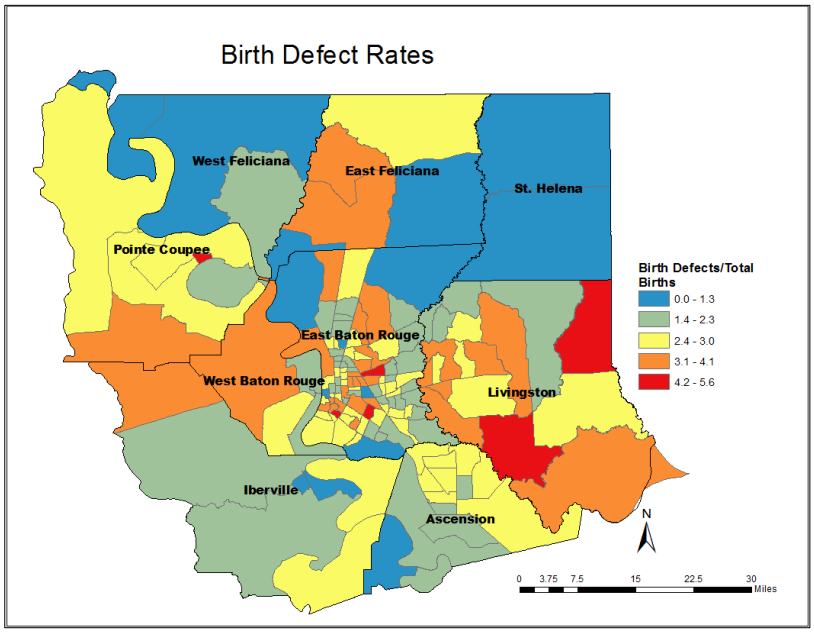

Figure 17 : Birth Defect Rates By Census Tract (2005-2008)

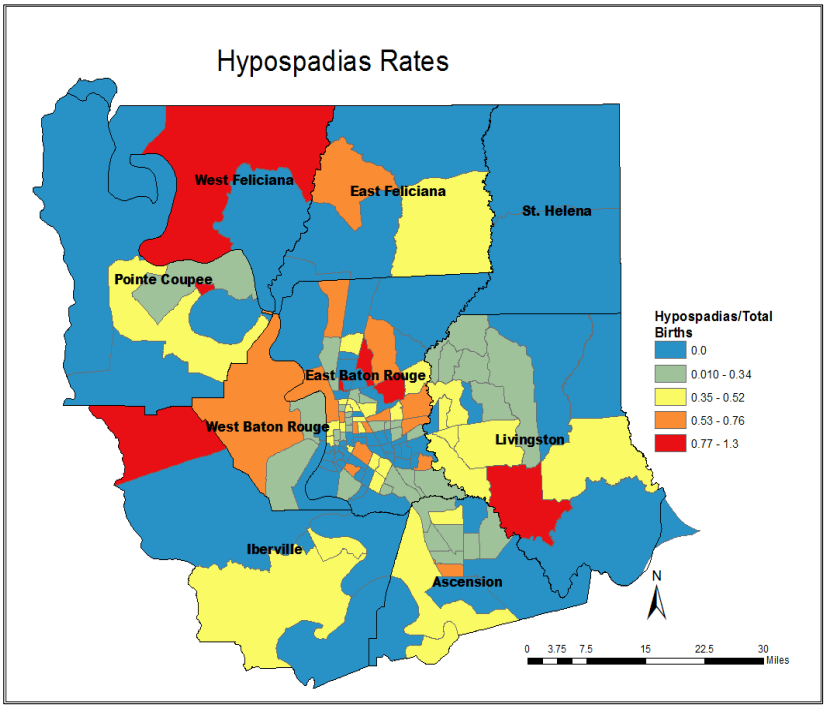

Figure 18: Hypospadias Rates By Census Tract (2005-2008)

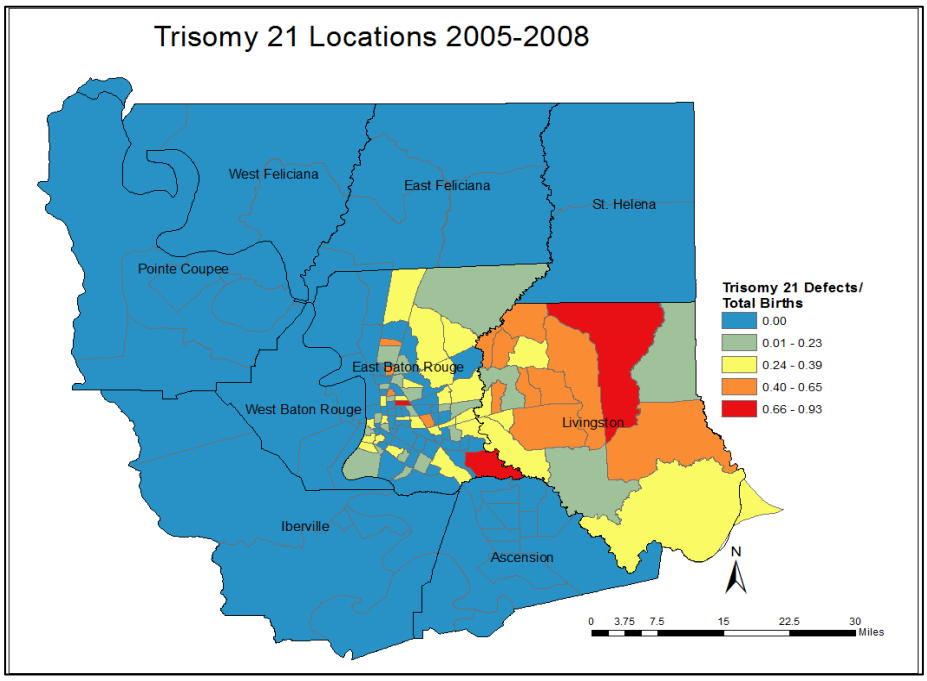

Figure 19 : Trisomy 21 Rates By Census Tract (2005-2008)

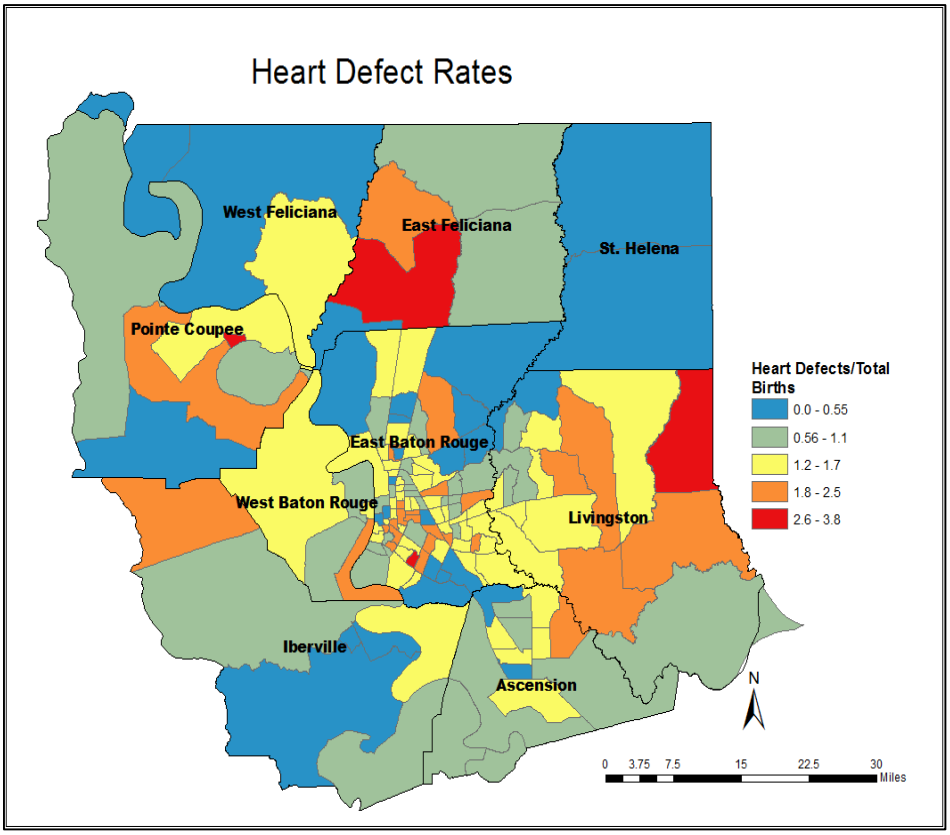

Figure 20: Heart Defect Rates By Census Tract (2005-2008)

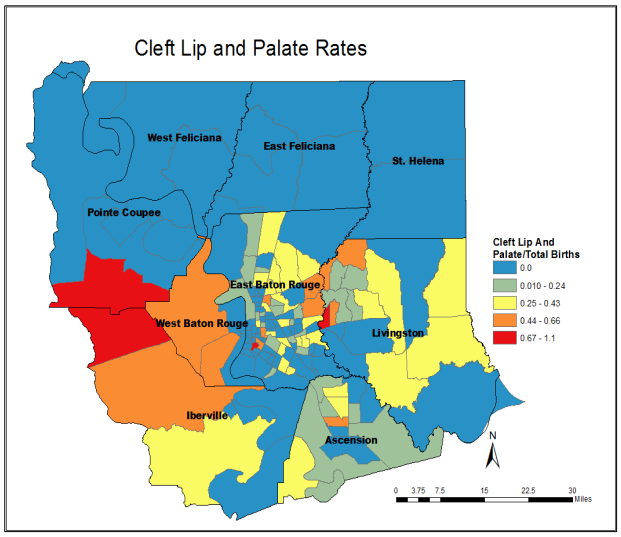

Figure 21: Cleft lip And Palate Rates By Census Tract (2005-2008)

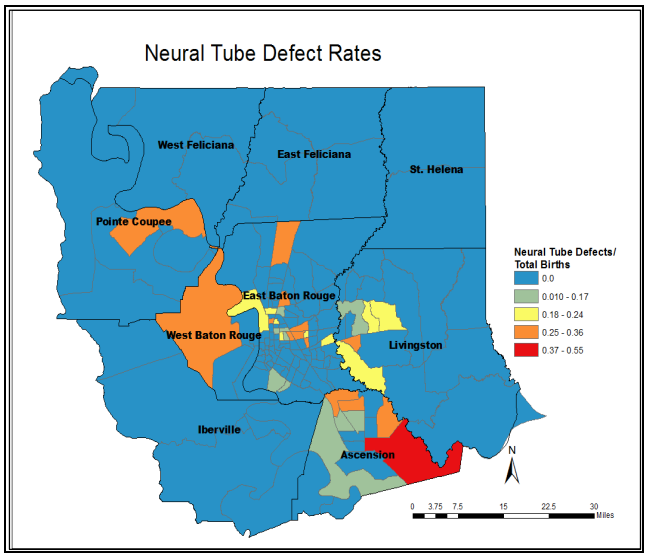

Figure 22 : Neural Tube Defects By Census Tract (2005-2008)

4.3.6 Geographic Mobility By Census Tracts

Geographic mobility was assessed using U.S. census data to determine movement within the same parish, movement between parishes within the same state, movement between states and into the study area from out of the U.S. from 2005-2008. The 2010 U.S. Census Bureau respondents were asked whether all individuals over the age of five years had lived in the same house or apartment for the preceding five years. This data

pertained to the years 2005 to 2010(U.S. Census Bureau, 2012). This was an important issue since the location of a mother during a pregnancy may have developmental effects on the fetus. Additionally, mobility rates are often related to poverty, younger age, tobacco use, and single parent status(Fell et al., 2004) Overall geographic mobility rates in the MSA are represented in Table 13. The most mobile census tracts were surrounding Louisiana State University and Southern University possibly due to the student population of part time residents. The highest level of mobility was within the same parish with an average rate of 9.84% of the population (Figure 23). This was followed by movement within the same state with an average rate of 3.53% (Figure 24), from a different state (1.96%) (Figure 25), and finally from abroad (0.34%) (Figure 26). This is a low geographic mobility rate compared to the national average. Nationally, an average of 35.4 percent of respondents reported that they had not been in the same location for the previous five years (U.S. Census Bureau, 2012).

Table 13: Geographic Mobility Rates

Distance	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Different Country	0.00	8.50	0.34	0.94
Within State	0.00	30.60	3.53	3.96
Different State	0.00	16.20	1.96	2.01
Same Parish	0.00	43.50	9.84	6.72

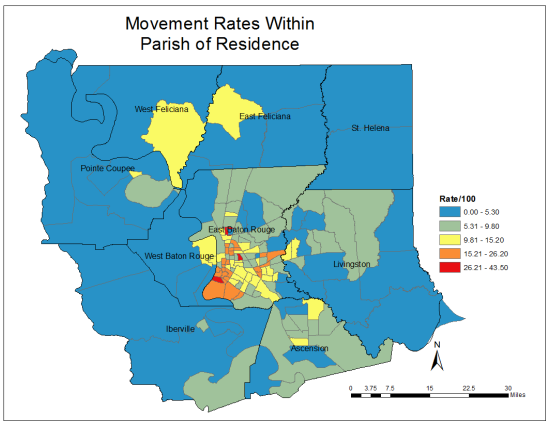

Figure 23 : Number of Individuals Per 100 Reporting Parish Change Of Residence In the Last 5 Years (2010 Census).

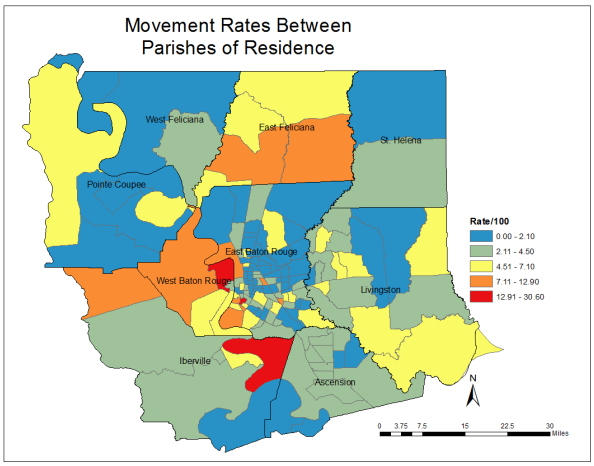

Figure 24: Number Of Individuals Per 100 Reporting Between Parish Change Of Residence In The Last 5 Years (2010 Census).

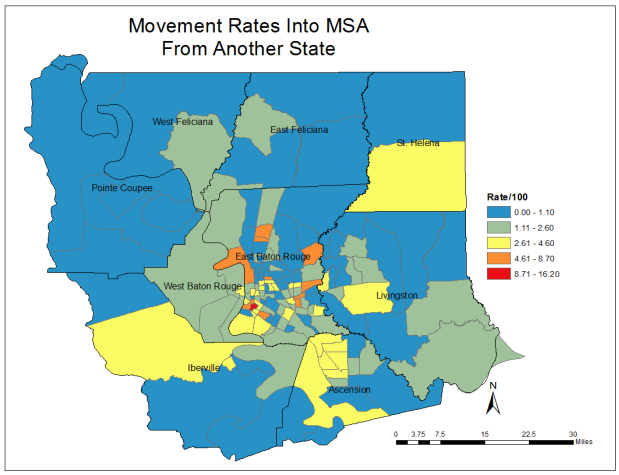

Figure 25: Number of Individuals Per 100 Reporting Movement Into MSA From Another State In The Last 5 Years (2010 Census).

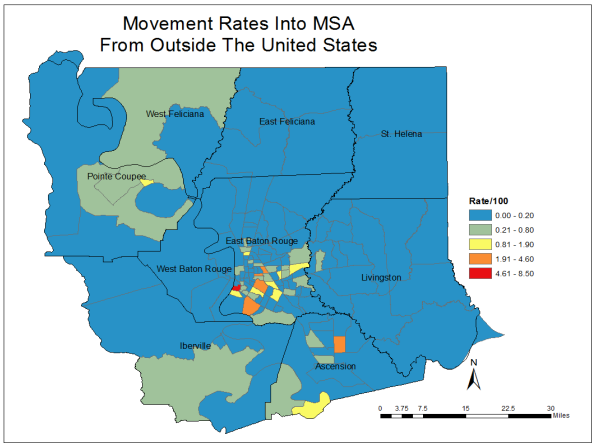

Figure 26: Number Of Individuals Per 100 Reporting Movement Into MSA From Another Country In The Last 5 Years (2010 Census).

4.4 Tobacco And Alcohol Use Per Parish

Alcohol and tobacco use were observed for patterns due to their relationship to birth defects and infant mortality (Paul, Mackley, Locke, Stefano, & Kroelinger, 2009; Suarez et al., 2011). Fetal alcohol syndrome was recorded in four infants of mothers using alcohol. Tobacco use was reported by 2,958 (6.6%) of the mothers while only 118 (0.26%) reported alcohol use during pregnancy and only four of those had reported birth defects. Tobacco use was much more commonly reported and 74 of those infants had birth defects. The birth defect rate for mothers reporting tobacco use was 2.5%, which was the same as the MSA population as a whole. Of those infants with anomalies whose mother's had reported tobacco use, 33 had heart defects, 7 had hypospadias, 3 had cleft lip and/or palate, and the rest had other defects. Tobacco use percentages varied somewhat between parishes with Livingston Parish reporting the highest rate at 11.2% of mothers and East Baton Rouge parish reporting the lowest use at 5.1%. 79 mothers reported both alcohol and tobacco use with four of those having birth defects. Figure 27 demonstrates the variation in rates of use of both substances. It is apparent that tobacco use is much more common than alcohol use among the mothers in this database.

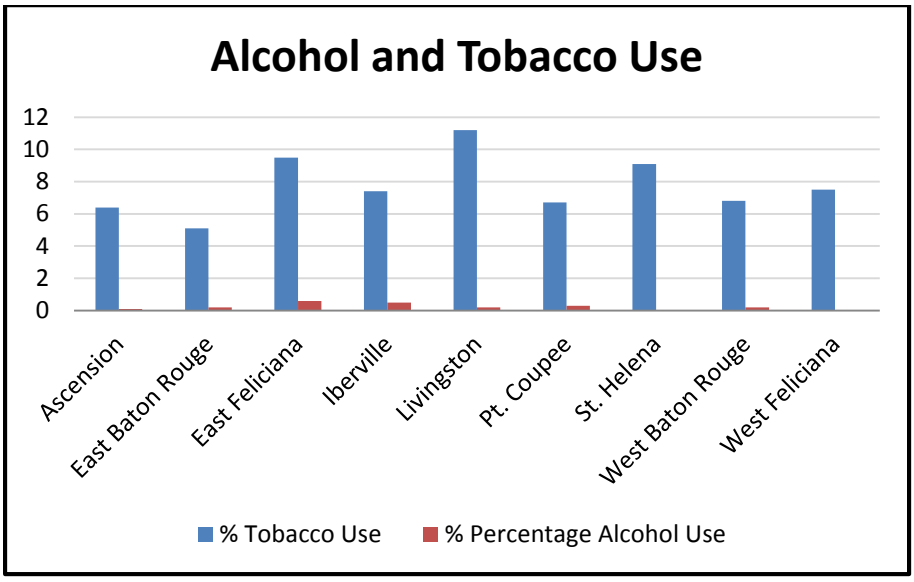

Figure 27: Alcohol And Tobacco Use Percentages Among Parishes

4.5 Spatial Distribution Of Birth Defect Locations From 2005-2008

Figure 28 shows the individual residential locations of all births recorded during the years 2005-2008. The spatial pattern can be visually compared with the distribution of all birth defects (Figure 29) recorded during the years of the study, including those categories of birth defects not examined individually. Figures 30-34 exhibit individual point locations of infants born with the five different types of birth defects chosen for closer examination. Heart defects are the most numerous and show some evidence of clustering on the eastern edge of Livingston parish and in one census tract in Pointe Coupee Parish (Figure 30). Hypospadias (Figure 31) is most apparent in East Baton Rouge and Ascension Parishes. The rarer birth defects, cleft lip and palate defects(Figure 32) and neural tube defects(Figure 33), are sparse or absent altogether in the less populated areas and trisomy 21 cases are heavily clustered in the central part of Baton Rouge and into the Southeastern edge of the MSA(Figure 34).

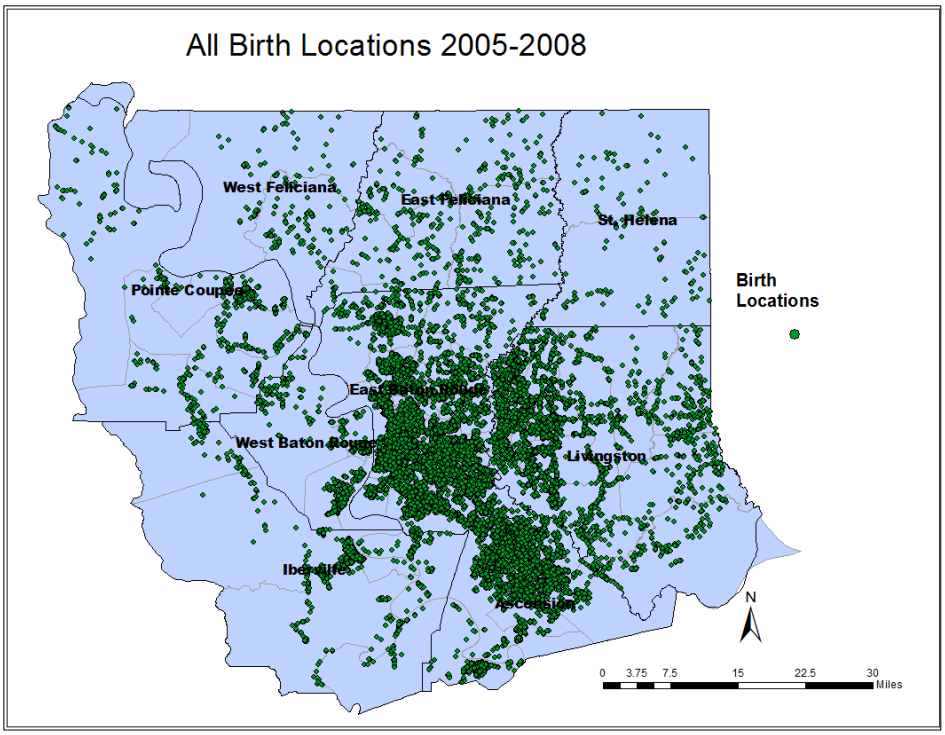

Figure 28: Individual Birth Locations
For All Four Years 2005-2008

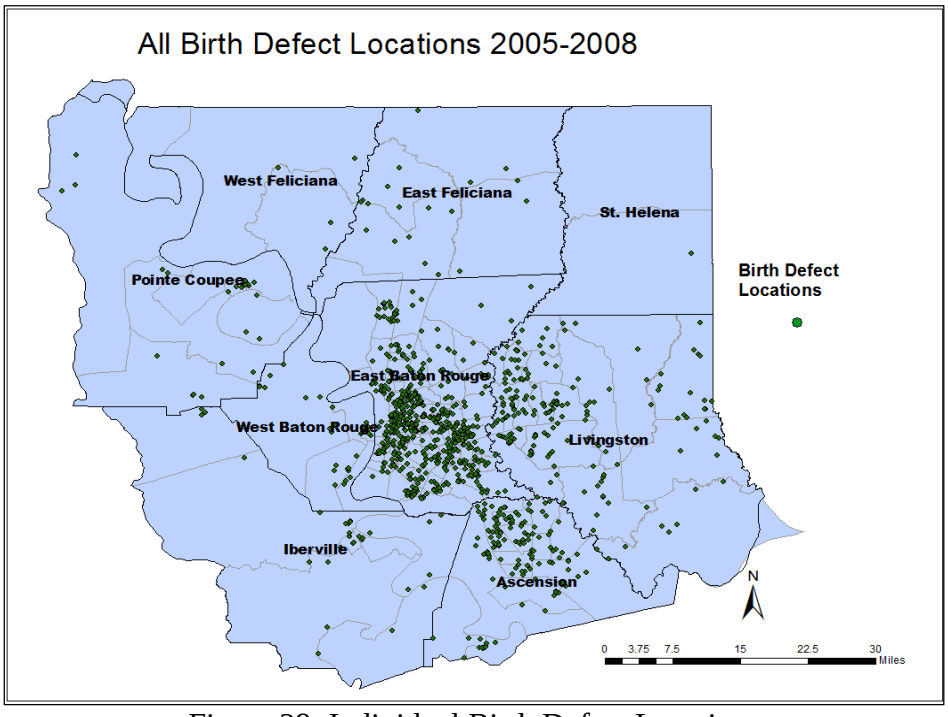

Figure 29: Individual Birth Defect Locations
For All Four Years 2005-2008

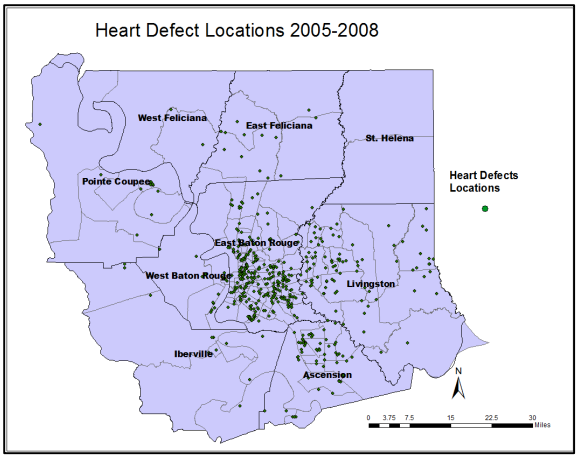

Figure 30: Individual Heart Defect Locations
For All Four Years 2005-2008

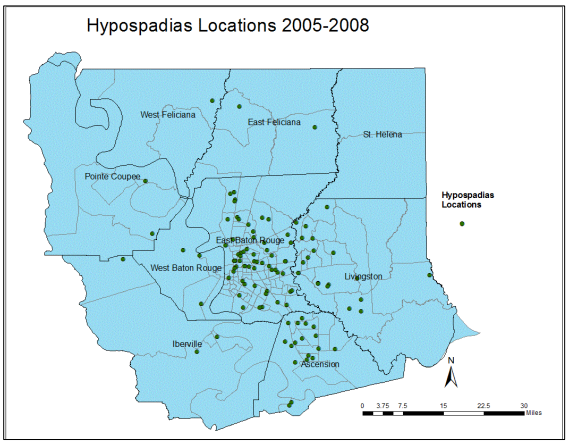

Figure 31: Individual Hypospadias Defect Locations
For All Four Years 2005-2008

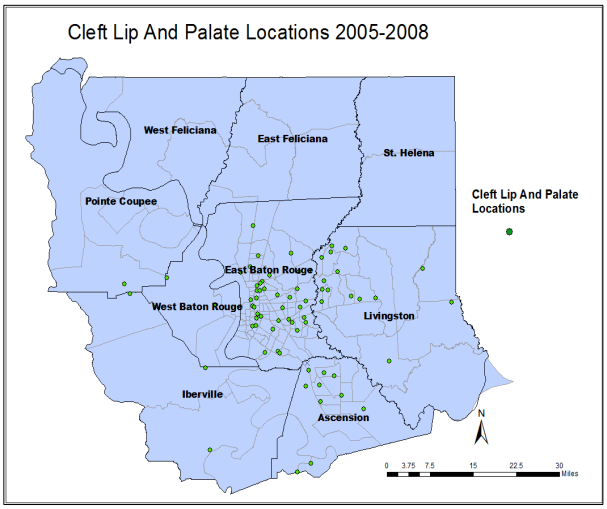

Figure 32: Individual Cleft Lip and Plate Defect Locations
For All Four Years 2005-2008

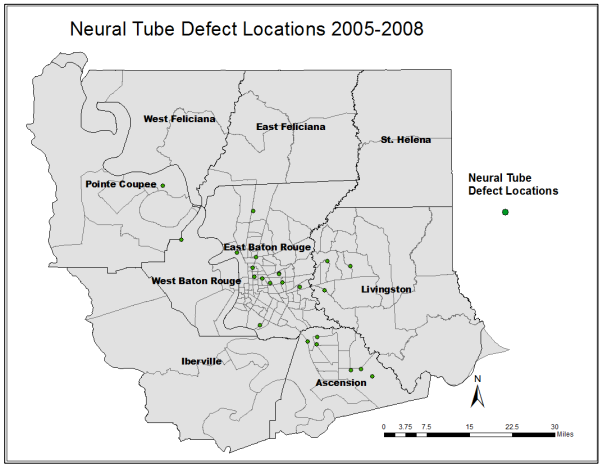

Figure 33 : Individual Neural Tube Defect Locations
For All Four Years 2005-2008

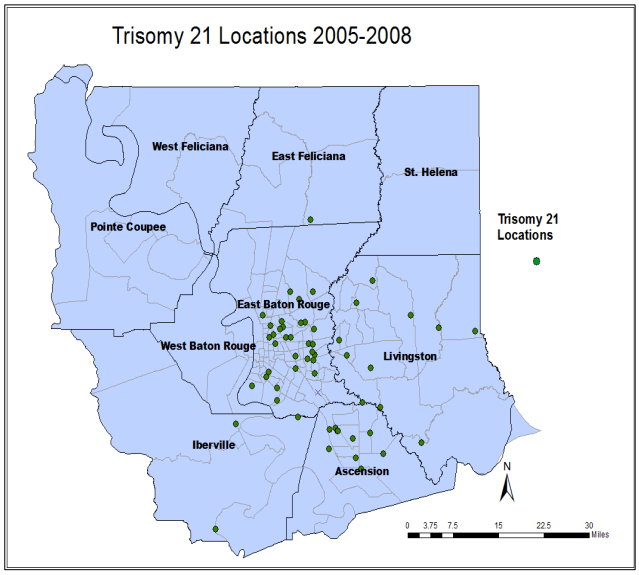

Figure 34: Individual Trisomy 21 Locations
For All Four Years 2005-2008

4.6 Temporal Variations Of Birth Defect Locations By Year From 2005-2008

Temporal variations for the four years of the study were compared for incidence of birth defects overall and for each specific birth defect. In general, locational patterns are similar from year to year. This seems to indicate that precipitating factors did not change much over the four year period. Table 14 displays the total amounts of all births by parish. The number of births grew by 2.7 percent from 2005 to 2006 as compared to

0.1 to 0.2 percent for each year after that. This change in total births is especially apparent in Figure 35. This large jump in births may have been due to the population influx after Hurricane Katrina. While the spatial locations of birth defects are visually similar from one year to the next, the total numbers of individual types of birth defects were not as stable from year to year. Heart Defects jumped dramatically in 2006 at a rate similar to the overall increase in deliveries. This can be seen by comparing Figures 35 and 36. Hypospadias cases shown in Figure 37, on the other hand, stayed about the same in 2006 but climbed rather dramatically in 2007 and fell off only slightly in 2008. Cleft lip and palate (Figure 38), neural tube defects (Figure 39), and trisomy 21 cases (Figure 40) closely followed the increases and decreases in overall births between 2005 and 2008.

Table 14: Total Number Of Births Per Parish Per Year From 2005-2008

Birth Year	1	2	3	4	5	6	7	8	9	Total
2005	1470	5668	264	443	1637	306	*0	321	102	10211
2006	1715	6306	284	463	1871	311	*0	348	112	11410
2007	1660	6272	244	428	1983	339	129	350	113	11518
2008	1689	6381	235	487	1827	275	124	332	115	11465
Total	6534	24627	1027	1821	7318	1231	253	1351	442	44604

*No data available 1= Ascension, 2= East Baton Rouge, 3= East Feliciana, 4= Iberville, 5= Livingston, 6=Pt. Coupee, 7= St Helena, 8=West Baton Rouge, 9=West Feliciana

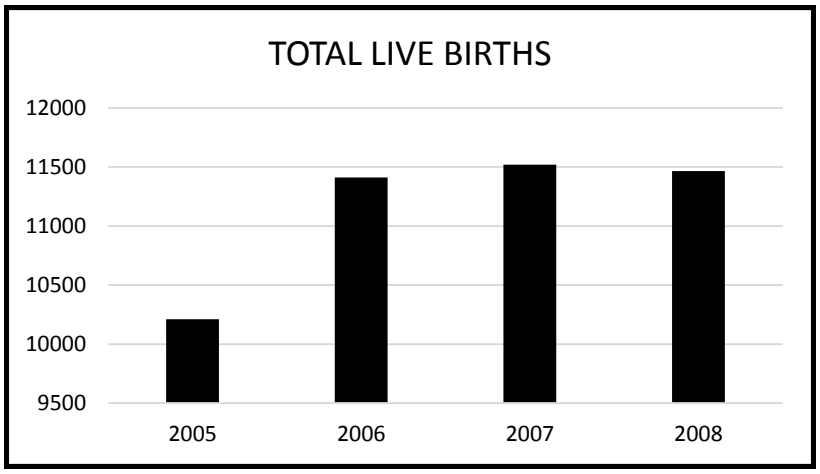

Figure 35: Total Live Births By Year 2005-2008

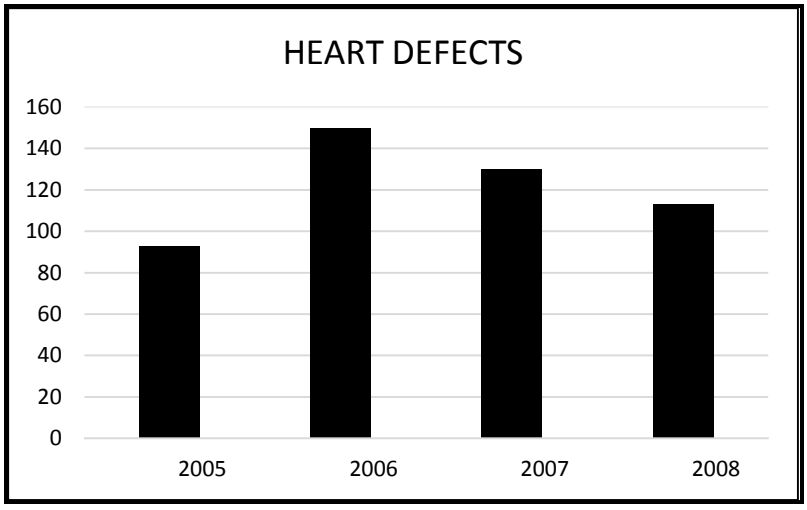

Figure 36: Total Heart Defects By Year 2005-2008

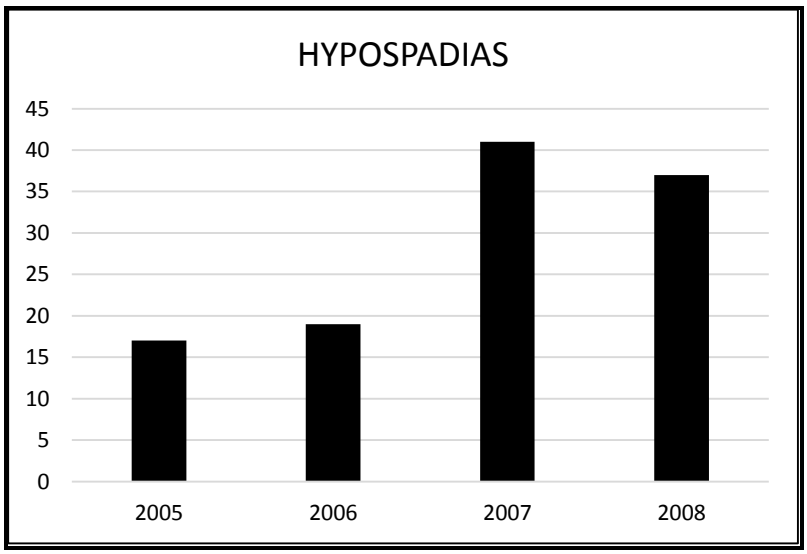

Figure 37: Total Hypospadias Defects By Year 2005-2008

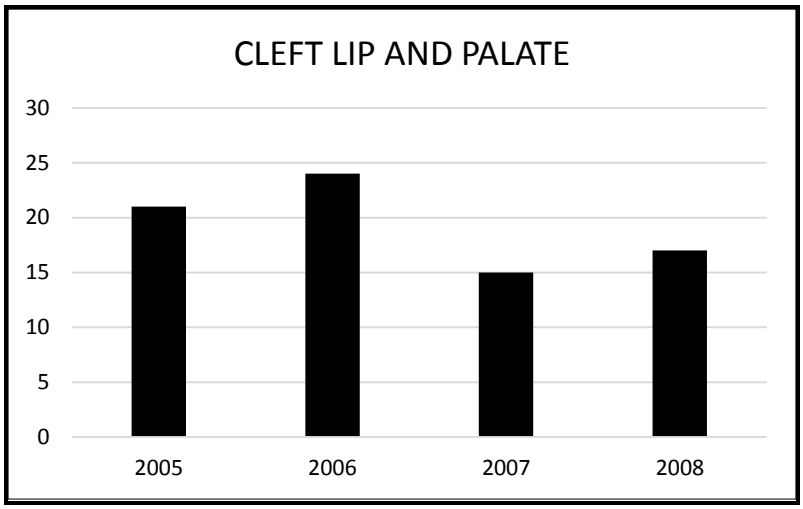

Figure 38: Total Cleft Lip and Palate Defects By Year 2005-2005

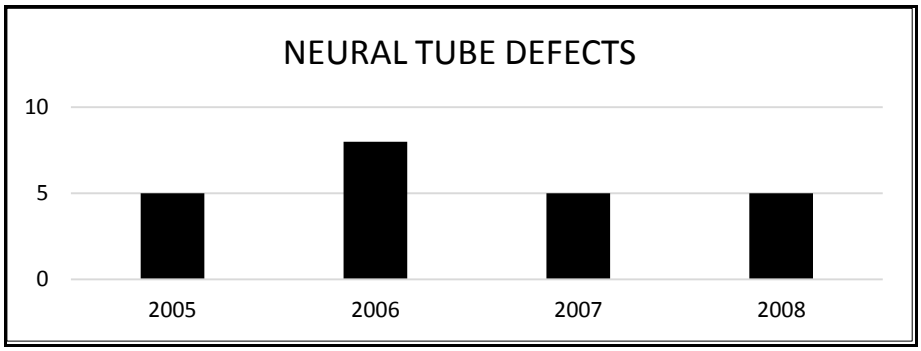

Figure 39: Total Neural Tube Defects By Year 2005-2008

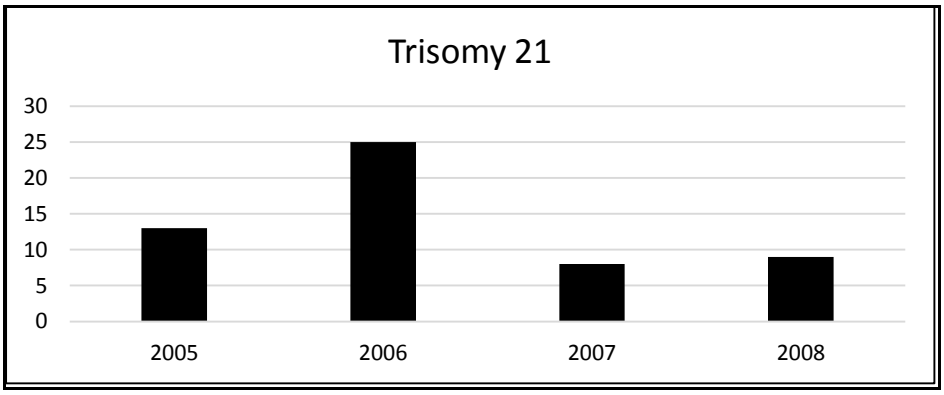

Figure 40: Total Trisomy 21 Defects By Year 2005-2008

4.7 Relationships Between Tobacco Use, Alcohol Use And Birth Defects

A goal of this research was to discover relationships between behavioral, and environmental variables and birth defects. Some of these variables are categorical in nature and do not meet the assumptions of regression analysis. In this section those

variables will be described in terms of the statistical analysis performed and the results of that analysis will be discussed. There were some expectations as to the relationships between these variables and various types of birth defects based on the review of the literature. These expected relationships are clarified in Table 15. Categorical variables of interest included tobacco use, alcohol use, and racial/ ethnic group. All of these have been shown to be predictors of various types of birth defects and were important to explore.

Table 15: Expected Relationships Between Categorical Variables And Birth Defects

Variable	Type of Birth Defect	Expected Statistical Relationship
Alcohol Use Reported	Heart/Cleft Lip and Palate	Positive
Tobacco Use Reported	Heart/Cleft Lip and Palate	Positive
White	Hypospadias	Positive
Black	Heart	Positive
Hispanic	Heart/Cleft Lip and Palate	Positive
Asian	Cleft Lip and Palate	Positive
Native American	Cleft Lip and Palate	Positive
Multiracial	None Known	None Known
Age Category	Trisomy 21/All/Heart Defects	Positive

While these variables were examined as rates when comparing census tracts, the additional information related to *individual* mothers and babies was desired. For tobacco use, a 3x2 matrix was constructed with "Tobacco use", "No Tobacco use", "Unknown" as independent variables and "Birth Defect" or "No Birth Defect" as dependent variables. The same matrix was constructed for each individual type of birth defect. A Chi-Square test of independence was chosen as a method of analysis. For the category of all birth defects, there was no significant difference between mothers of children with birth

defects and mothers of children without birth defects related to mother's tobacco use. Tobacco use was significantly related to heart defects, $\chi 2$ (2, N= 44604) = 6.98, p = .03 α= 0.05. Tobacco use is a known risk factor for heart defects in newborns, therefore this result was not unexpected (Schardein, 2000). As shown in Table 16, there were no other significant relationships between tobacco use and any other types of birth defects or birth defects as a whole. The expected relationship between tobacco use and cleft lip and palate was not significant (Honein, 2007).

Table 16: Results Of Chi-square Test Between Tobacco Use And Birth Defects

Birth Defect	Pearson chi-square	df	*p*
All	3.31	2	0.19
Hypospadias	1.05	2	0.59
Trisomy 21	1.21	2	0.52
Cleft Lip and Palate	1.44	2	0.49
Heart Defects	6.98	2	0.03*
Neural Tube Defect	1.96	2	0.37
* $p<.05$			

Similar to tobacco use, alcohol use was explored using a 3x2 matrix constructed with "No alcohol use, "alcohol use" and "unknown". Alcohol use was very infrequently reported in this dataset. In fact, only 118 out to the 44,604(0.26%) women reported any alcohol use. Use of alcohol was related to heart defects, $\chi 2$ (2, N= 44604) = 5.34, p = 0.07 α= 0.10. As with tobacco use, this was not a surprising result due to the known relationship between heart defects in infants and prenatal alcohol use(Burd et al., 2010). No other significant relationships were found between alcohol and birth defects as a whole or any category of birth defects. Table 17 describes these results.

Table 17: Results Of Chi-square Test Between Alcohol Use And Birth Defects

Birth Defect	Pearson chi-square	df	*p*
All	2.1	2	0.36
Hypospadias	1.1	2	0.59
Trisomy 21	0.51	2	0.51
Cleft Lip and Palate	1.44	2	0.89
Heart Defects	5.34	2	0.07*
Neural Tube Defect	0.21	2	0.89

* $p<.05$

Ethnicity was reported as one of nine different categories in the dataset, including multiracial, white, black, Native American, Chinese, Japanese, Hawaiian, Filipino, Vietnamese, Hispanic and islanders. Many of these categories are uncommon in the Baton Rouge MSA and had none or very few individuals who fell into them. Additionally, the chi-square test of independence requires that a minimum number of cases fall into each group in order to validate the results. A decision was made to divide

the groups into "white", "black", and "other" as those are the largest ethnic groups in the MSA. This is with the exception of the "Hispanic" category. "Hispanic" is a designation that indicates a rather large group of nationalities described by the U.S. Census Bureau as a person of Cuban, Mexican, Puerto Rican, South, or Central American or other Spanish culture regardless of any other categories that person might choose (U.S. Census Bureau, 2011). This group was made into an individual category for two reasons. First, individuals who choose this category on health care or census surveys are known to have distinct health disparities despite the broad inclusion of nationalities (CDC, 2004b). Additionally, this grouping falls at the intersection of genetics and cultural identification and as such, does not fit into any other collection of categories. To deal with this issue, "Hispanic" was tested with its own statistical analyses.

For race/ethnicity, the resulting matrix was 3x2 for birth defects as a whole and for each category of birth defects. Race/ethnicity was significantly related to birth defects as a whole χ^2 (2, N=44604) =5.96, p=.05 α= 0.05, hypospadias χ^2 (2, N=44604) =4.70, p=.09 α= 0.10, trisomy 21 χ^2 (2, N=44604) =5.40, p=.07 α= 0.10, and heart defects χ^2 (2, N=44604) =5.20, p=.07 α= 0.10 (Table 18). This was expected for a number of reasons including the fact that race/ethnicity moderated many characteristics of pregnant women, including age at delivery, health habits, genetic makeup, location of home and access to healthcare. There were no relationships found between any individual birth defects and racial category or for birth defects as a whole and Hispanic ethnicity (Table 19). Some birth defects, including neural tube defects and heart defects, are more common in Hispanic infants (Nembhard, Salemi, Tao, Loscalzo, & Hauser, 2010; Prue, Hamner, & Flores, 2010) but these relationships were not statistically significant in this sample.

Table 18: Results Of Chi-Square Test Between Racial Category And Birth Defects

Birth Defect	Pearson chi-square	df	*p*
All	5.9	2	0.05*
Hypospadias	4.7	2	0.09*
Trisomy 21	5.4	2	0.07*
Cleft Lip and Palate	3.8	2	0.15
Heart Defects	5.2	2	0.07*
Neural Tube Defect	0.42	2	0.81

Table 19: Results Of Chi-square Test Between Hispanic Ethnicity And Birth Defects

Birth Defect	Pearson Chi-Square	df	*p*
All	0.77	2	0.77
Hypospadias	3.03	2	0.22
Trisomy 21	0.19	2	0.91
Cleft Lip and Palate	2.22	2	0.33
Heart Defects	1.33	2	0.51
Neural Tube Defect	1.32	2	0.51

4.8 Age Category Of Mother In Relationship To Infant Birth Defects

Age at delivery is an important factor in the incidence of birth defects and as such, was explored in as many ways as possible in this research, including as a geographical

variable (median age of women in mother's census tract, as a continuous variable using multivariate regression analysis, and as a categorical/ordinal variable with a chi-square test of independence) For the sake of maintaining consistency with regard to level of measurement, age is discussed here as a categorical variable and then in Section 4.15 and 4.16 as a continuous variable. Age will be described in terms of its relationship to birth defects as a whole and in relationship to individual types of birth defects. Results of chi-square tests for all birth defect categories discussed are presented in Table 20.

No specific guideline could be found in the literature with regard to dividing mothers' ages into categories. For simplification, the age ranges of mothers were categorized into seven categories of five year intervals. These intervals were; "12-16" "17-21" "22-26" "27-31" 32-36 "37-42" and "older than 42". A 7x2 matrix was formed and a chi-square test was employed to look for significant relationships. As expected, some categories of birth defects as well as birth defects as a collective were related to age group. The relationship between age and birth defects as a whole was significant, χ^2 (6, N=44604) =20.84, p=0.00 α= 0.01. Also expected was the apparent escalation in risk associated with increasing age. Table 21 illustrates the increasing percentages of mothers whose infants have birth defects climbing gradually with age. Age was also significantly related to trisomy 21 diagnosis, $\chi 2$ (6, N=44604) = 62.17, p<.000, α= 0.001 as were heart defects $\chi 2$ (2, N= 44604) = 17.49, p = .01, α= 0.01. Tables 22 and 23 display these relationships. It should be remembered that many infants with trisomy 21 have heart defects as well, so this relationship is also expected. Some infants had more than one birth defect, especially if the diagnosis was trisomy 21. Hypospadias, cleft lip and palate and neural tube defect were unrelated to maternal age.

Table 20: Results Of Chi-Square Test Between Age Category And Birth Defects

Birth Defect	Pearson chi-square	df	*p*
All	20.84	6	*0.00
Hypospadias	7.28	6	0.29
Trisomy 21	62.17	6	*0.00
Cleft Lip and Palate	6.32	6	0.38
Heart Defects	17.49	6	*0.01
Neural Tube Defect	6.52	6	0.37
* $p < .05$			

Table 21: Birth Defect Percentages By Age Group

Age Group	Birth Defect Present	
	No	yes
12-16	97.8%	2.2%
17-21	97.5%	2.5%
22-26	97.7%	2.3%
27-31	97.6%	2.4%
32-36	97.1%	2.9%
37-41	96.3%	3.7%
42 and up	96.2%	3.8%

Table 22: Trisomy 21 Percentages By Age Group

Age Group	Trisomy 21	
	No	Yes
12-16	99.9%	0.1%
17-21	99.9%	0.1%
22-26	99.9%	0.1%
27-31	99.9%	0.1%
32-36	99.7%	0.3%
37-41	99.5%	0.5%
42 and up	99.0%	1.0%

Table 23: Heart Defect Percentages By Age Group

Age Group	Heart Defect	
	No	Yes
12-16	98.9%	1.1%
17-21	98.9%	1.1%
22-26	98.9%	1.1%
27-31	98.9%	1.1%
32-36	98.7%	1.3%
37-41	98.2%	1.8%
42 and up	97.2%	2.8%

4.9 Global Spatial Clustering Of Birth Defects

A key element of geography as a research orientation is the search for spatial patterns. As such, the spatial locations were an important part of the investigation of birth defects and their underlying causative factors in this dissertation. The goal was to first look for spatial clustering and then to explore any potential environmental risks. The process included first looking for global clustering and then local clustering in order to identify where the clusters were located and to look for the possible associations that might explain them. In this section, the processes used for investigating global clustering are described followed by the results of global clustering analyses.

For the examination of spatial distribution, two indices of spatial autocorrelation were employed, Moran's *I* and Geary's *C.* Both of these are global measures. The difference between them is that Geary's C compares deviations in intensities of each observation location with one another rather than the cross-product of deviations from the mean (Levine, 2007). For this reason, Geary's C is more sensitive to differences in smaller areas than Moran's I (Geary, 1954). CrimeStat was the only program with the capability to employ Geary's *C*. Both of these tests were used to explore birth defects as a whole and each individual birth defect in terms of its spatial distribution across the MSA with a null hypothesis that the spatial autocorrelation of the birth defect in question was zero. It was expected that clustering would exist due to the spatial separation of different racial/ethnic groups, the possible exposure to unknown, environmental toxins, and to the effects of education and poverty which varies among census tracts. Additionally, median age of both white and black mothers appears to be higher in some parts of the MSA than in others. Areas of high poverty and low education levels are more dispersed, however,

and thus may not exert an effect on cluster analysis tests. Finally, there is some evidence that residential mobility exerts an influence on birth outcomes due to the fact that geographically mobile families are more likely to be smokers and less likely to plan a pregnancy leading to poorer prenatal care opportunities(Miller et al., 2010). Moves among this population are most common within the same parish, thus the expected relationship would be between birth defects and geographic mobility within a parish-wide distance. As indicated by the literature on this topic, movement within a small geographic area is the most common and this held true for this population as well.

To control for differing numbers of live births in each census tract, rates were calculated by dividing the number of live births in that census tract during the time period by the number of infants born with a birth defect over that same time period. ArcGIS software was used to calculate the global Moran's *I* statistic. Inverse distance was chosen for the conceptualization of spatial weights rather than fixed distance due to varying sizes of the census tracts. Moran's *I* with ArcGIS found no global autocorrelation for rates of any individual birth defects nor for birth defects as a whole (Table 24). This was an unexpected result. In contrast, Moran's *I* with CrimeStat found clustering for birth defects as a whole as well as for heart defects. The results of analysis of global clustering using the Geary's *C* statistic with CrimeStat were in line with the second set of Moran's *I* statistics. Geary's *C* was significant for birth defects as a whole, neural tube defects and also heart defects. For Moran's *I* a zero value indicates a random (non-significant) spatial pattern. -1 is a strong dispersion and + 1 a strong positive autocorrelation. With this in mind, Table 24 displaying the results of ArcGIS software shows very little indication of global correlation of any of the birth defects examined. Table 25 provides

the results of global Moran's *I* done with CrimeStat software, and Table 26 contains the results of Geary's *C* statistic performed with CrimeStat.

Table 24: Results of Global Autocorrelation Tests
Moran's I Calculated With ArcGIS

Variable	Moran's Index	Z-Score	P-value	Result
All	0	0.07	0.94	Random
Hypospadias	-0.01	-0.39	0.69	Random
Trisomy 21	-0.01	-0.35	0.72	Random
Cleft Palate	-0.01	-0.2	0.84	Random
Heart Defect	-0.01	0.41	0.68	Random
Neural Tube Defects	0	0.78	0.43	Random

Table 25: Results Of Global Autocorrelation Tests
Moran's I Calculated With CrimeStat

Variable	Moran's Index	Z-Score	P-value	Result
All	0.02	2.35	0.01	Clustered
Hypospadias	0	0.98	n.s.	Random
Trisomy 21	0	0.89	n.s.	Random
Cleft Palate	0	0.86	n.s.	Random
Heart Defect	0.02	2.19	0.5	Clustered
Neural Tube Defects	0	0.98	n.s.	Random

*n.s. indicates that the result was not statistically significant

Table 26: Results Of Global Autocorrelation Tests
Geary's C Calculated With CrimeStat

Defect	Z	C	P-value	Result
All	-1.89	0.89	<0.05	Clustered
Hypospadias	0.07	1	n.s.	Random
Trisomy 21	0.51	1.02	n.s.	Random
Cleft Lip and Palate	0.64	1.03	n.s.	Random
Heart Defect	-1.83	0.89	<0.05	Clustered
Neural Tube Defects	-2.08	0.88	<0.05	Clustered

*n.s. indicates that the result was not statistically significant

4.10 Local Clustering Of Birth Defects

Following the global clustering tests, locations for the clusters detected by the Geary's *C* statistic, and Moran's *I* with CrimeStat were examined using both local Moran's *I* with ArcGIS software and the spatial scan statistic using SaTScan. The expectation was that local clusters might be found for all birth defects, heart defects, and neural tube defects. Most likely locations where local clustering might be discovered

were determined by the initial maps made with geocoded point data. Both hot spots (census tracts with high birth defect rates next to other census tracts with high birth defect rates), and cold spots (an area of very low birth defect rates next to other areas of very low birth defect rates) are displayed if they were statistically significant. The weighting function was set for inverse distance. As stated previously, this was a way to take into account the drastically differing sizes of census tracts.

Both Global Moran's *I* and Geary's *C* executed with CrimeStat found significant clustering for birth defects as a group. It was expected that there would also be significant local clustering also. Figure 41 demonstrates the result of local Moran's *I* performed with ArcGIS. Hot spots were found in several small clusters in central East Baton Rouge Parish. These tracts are densely populated and both crude birth rates and fertility rates are high here, however since these are rates which take population into account, the clusters are unexplained. Two cold spots are also apparent. One cluster encompasses St. Helena Parish and the other is on the northern edge of East Baton Rouge Parish. Since two years of data are missing from St. Helena Parish, the explanation for that cold spot could be missing data. As for the other cold spot, there are no immediately apparent explanations. The small hot spots in central East Baton Rouge Parish are in an area with both high fertility and high crude birth rates. The birth defect rates in these tracts are all close to 4 percent or over 4 percent of all births. This is significantly higher than the 2.5 percent average for the rest of the MSA.

Heart defect rates showed a similar pattern of clustering in central East Baton Rouge Parish. There are two additional statistically significant clusters located in East Feliciana Parish and in Livingston Parish. This pattern is shown in Figure 42.

Additionally a statistically significant cold spot again was shown in St. Helena Parish and also in the northeastern corner of East Baton Rouge Parish

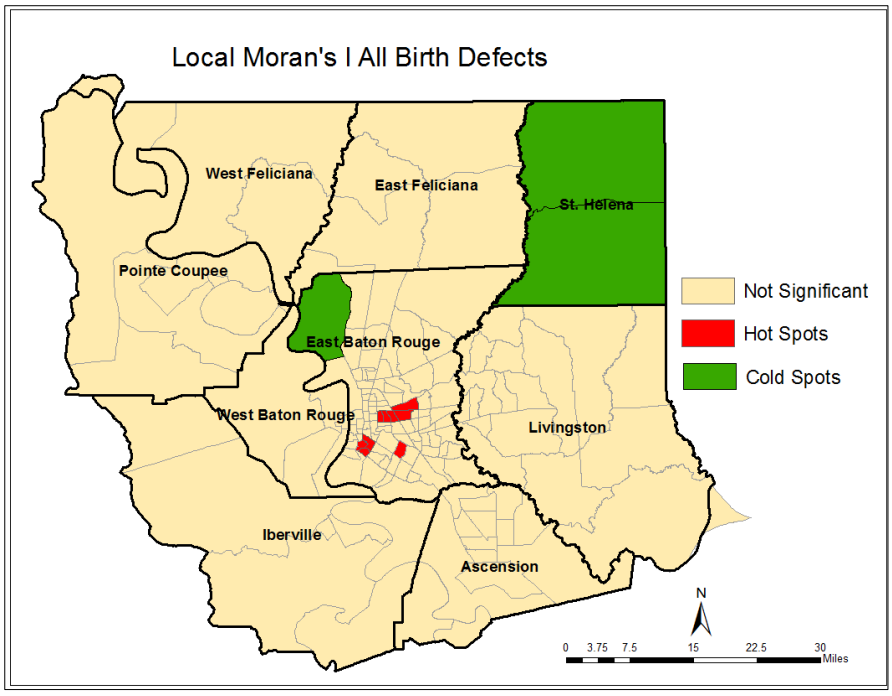

Figure 41: Local Moran's I For All Birth Defects Using ArcGIS

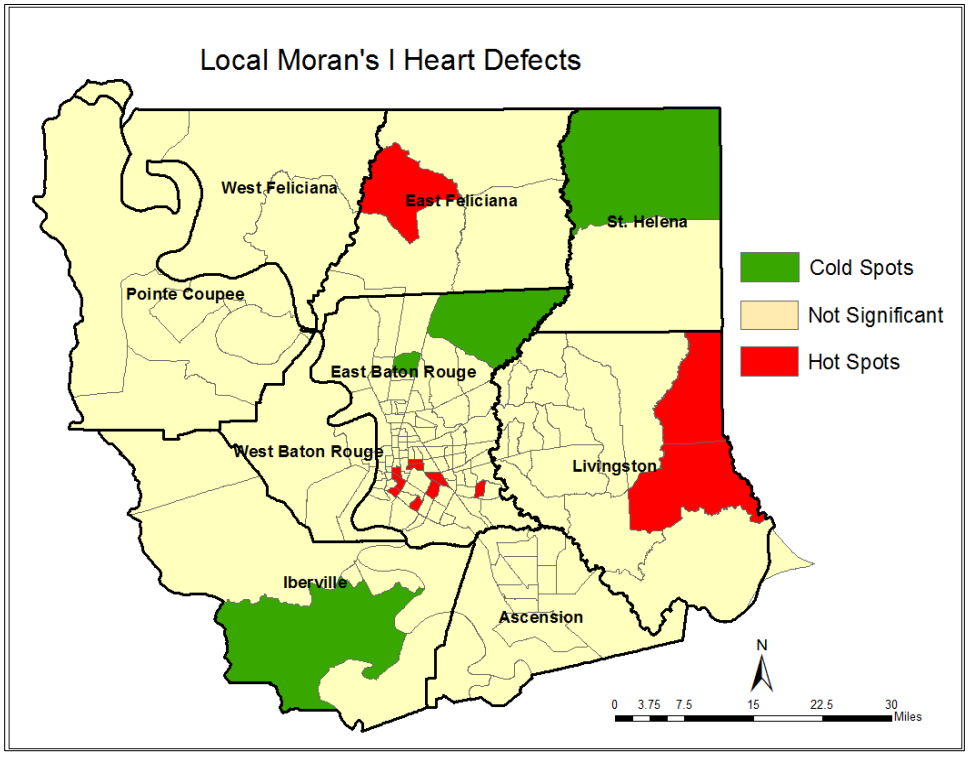

Figure 42: Local Moran's I For Heart Defects Using ArcGIS

Local Moran's *I* indicated two statistically significant clusters of neural tube defects in the central part of East Baton Rouge Parish similar in location to birth defects as a whole and heart defects (Figure 43). This location emerged as an area of concern repeatedly. Neural tube defects were very rare in the dataset, therefore caution should be taken with interpreting rates.

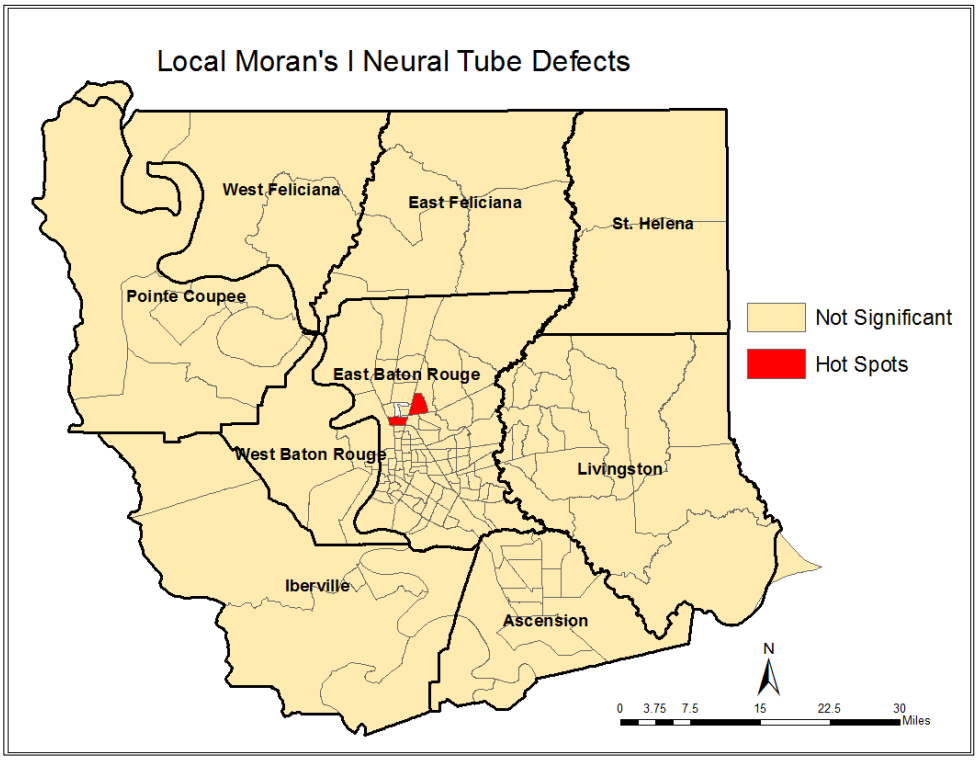

Figure 43: Local Moran's I For Neural Tube Using ArcGIS

As expected, no hot spots were found for hypospadias or trisomy 21, however despite the fact that Global Moran's *I* did not find anything significant for cleft lip and palate cases, ArcGIS located a large statistically significant hotspot of cleft lip and palate cases in Iberville Parish and another on the divide between Livingston Parish and East Baton Rouge Parish (Figure 44). There were a small number of cleft lip and palate cases in the database also and in fact, only three between Pointe Coupee and Iberville Parish

where the cluster location appears on the western edge of the MSA. As with neural tube defects, this result should be received with caution.

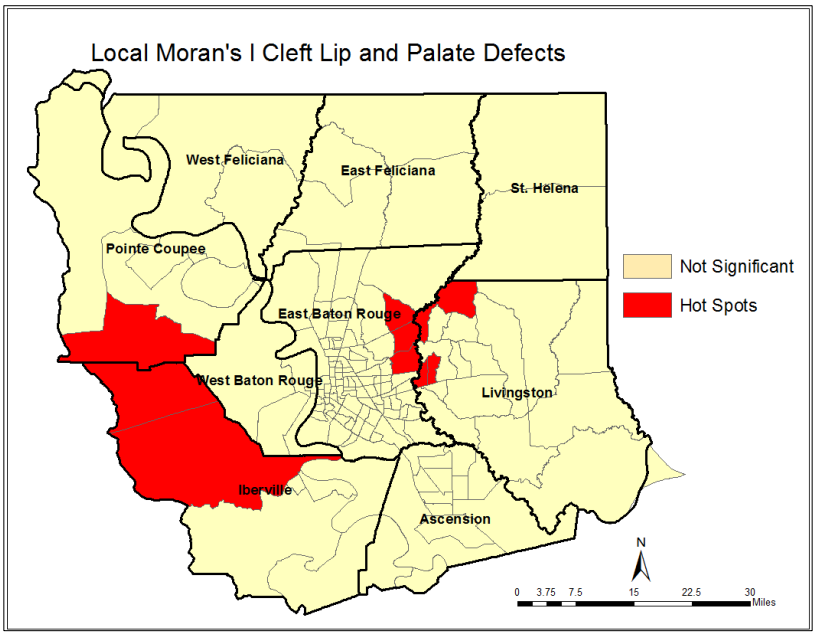

Figure 44: Local Moran's I For Cleft Lip And Palate Using ArcGIS

In order to further validate any clusters found by Arc GIS and CrimeStat, SaTScan was also employed for local cluster analysis using the Bernoulli model due to the ability of this software to take the underlying population at risk into account and its use of an alternate method of finding hot spots. The analyses were carried out using 999 Monte Carlo replications to test for significance, and allowing for overlapping clusters at different maximum spatial cluster sizes based on the percent of the population at risk. The spatial scan statistic is known to be sensitive to parameter choices. A range of maximum spatial cluster sizes, as suggested by Chen, Naito, Lengerich, MacEachren (2008) were investigated including 1, 1.5, 2, 5, 7, 10, 20, and 30% of the population at risk. All six of the dependent variables were tested for clustering at all eight parameters for population at risk. The expectation was that clusters would be found for the same

birth defects in similar locations, however since SaTScan uses a different method of finding clusters, it was also possible that the results might differ somewhat. There were significant heart defect clusters discovered at parameter sizes of 5 percent and 7 percent of the population at risk. At 5 percent one significant cluster was found ($p<.05$) with a relative risk of 3.29 (Figure 45). At 7 percent SaTScan found one cluster ($p<.05$) with a relative risk of 2.01(Figure 46). These areas of increased risk for heart defects are persistent, if slightly different in size and orientation, across the different software types and cluster analysis methods. For the categories of all birth defects, hypospadias, cleft lip and palate, or neural tube defects, the spatial scan statistic found no significant clusters. Overall areas of concern across all cluster analysis modalities were located in central East Baton Rouge Parish with regard to all birth defects, and in Livingston Parish specifically for heart defects.

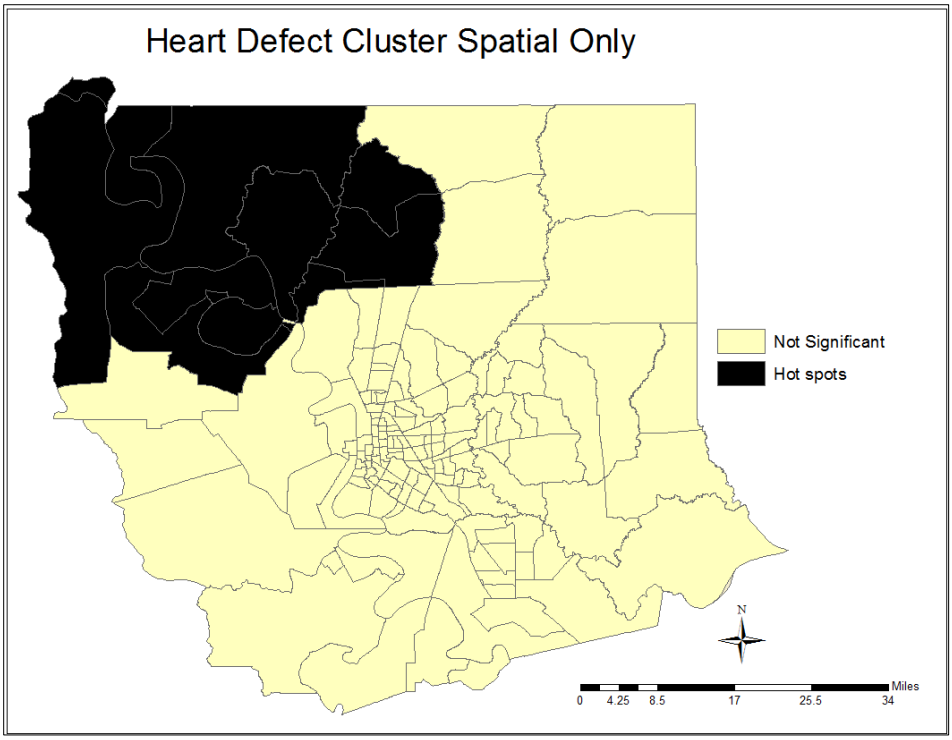

Figure 45: Spatial Cluster of Heart Defects Using SaTScan
At A Parameter Size Of 5% Of Population At Risk

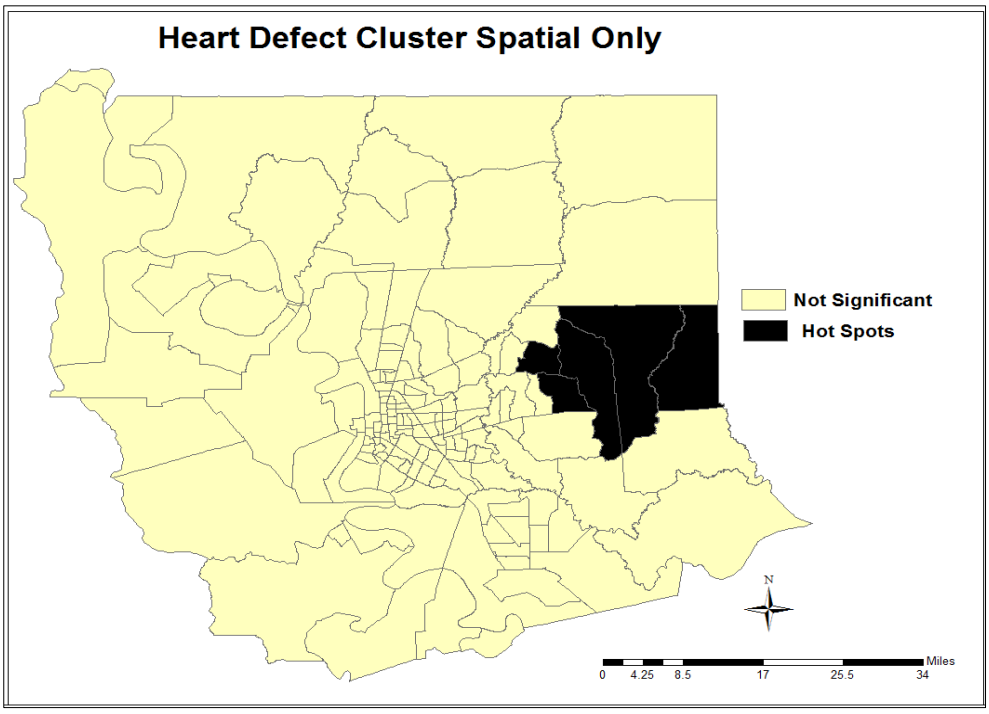

Figure 46: Spatial Cluster of Heart Defects Using SaTScan
At A Parameter Size Of 7% Of Population At Risk

CHAPTER 5 FACTORS CONTRIBUTING TO BIRTH DEFECTS

This chapter will describe expected relationships between variables along with the rationale for these expectations. Bivariate correlations are described and tables provided to assist with visualization. One aspect of this project was to try to determine some of the contributing factors that may have led to the clusters or temporal changes in birth defects between 2005 and 2008 in the Baton Rouge MSA. An initial step was to employ bivariate correlations for the purpose of assessing the linear relationships between each dependent variable and the multiple independent variables at the census tract level.

5.1 Expected Relationships

By exploring previous literature on relationships between the available independent variables and their effects on the incidence of birth defect rates, some initial expectations could be gleaned. Table 27 summarizes these anticipated relationships.

Table 27: Expected Relationships Between Continuous Variables And Birth Defect Types

Variable	Type of Birth Defect	Expected Statistical Relationship
Percent Below High School Level	All/Heart	Positive
Fertility Rate	All	Positive
Mobility Rate Variables	None	None
Race/Ethnicity Variables	All/Heart/Cleft/Neural Tube	Positive
Age Variables	All/Heart/Trisomy 21	Positive
Poverty Rate	All/Heart/Cleft/Neural Tube	Positive

Initially, bivariate correlation analysis was attempted using Spearman's rho due to inability to meet the assumption of normally distributed data. Birth defect rates as a whole and individual birth defects were analyzed for significant relationships as an initial step in choosing model components for multivariate regression analysis. While all of the independent variables were initially chosen from the previous research and were expected to be related to birth defects in some fashion, exploration of spatial relationships gave clues to which ones might have the most impact for the Baton Rouge MSA. Birth defect rates as a whole were significantly correlated with percentage of Asian individuals residing in the census tract, r (150) = -.17, $p < .05$, two tailed. Asian census respondents are quite clustered in residential location as can be appreciated in Figure 14 on page 77. In other words, the areas populated by this group have significantly low rates of birth defects (Figure 47).

For heart defects, significant correlations were found for geographic mobility rates within the same parish, r (150) = + .25, $p<.01$, two tailed, and also the percent of individuals in the census tract who were of Asian ancestry, r (150) = + .32, $p < .01$, two tailed, or of multiracial ancestry, r (150) = + .27, $p<.01$, two tailed. Additionally, heart defects were related to median age total r (150) = .18, $p < .05$, median age male r (150) = .19, $p < .05$, and median age female r (150) = .18, $p < .01$. For heart defect then, significantly mobile, older populations and those with Asian or multiracial census respondents were significantly more likely to have high rates of heart defects (Figure 48). Asian mothers were seen to have the oldest median age at delivery so this is not surprising. Additionally, chi-square tests of independence shown on page 110 in table 19, displayed a relationship between age and heart defects. As stated earlier, little is

known about the multiracial category and the possible explanation for this relationship is open to more investigation. More mobile populations, on the other hand, have characteristics which increase the risk of birth defects, including higher rates of poverty and tobacco use (Fell et al, 2004).

Hypospadias rates evidenced only two significant relationships with the independent variables (Figure 49). As with heart defect rates, there was a significant relationship to geographic mobility within the same parish r (150) = + .32, $p < .05$. Additionally, hypospadias was the only birth defect correlated with fertility rates r (150) = .27, $p < .01$. High fertility rates are sometimes associated with poverty and poor birth outcomes, however in this dissertation that particular relationship was not significant. There were no other relationships apparent for hypospadias rates. Hypospadias is sometimes genetic but also related to maternal age over 35 (Carmichael, Shaw, Laurent, Olney, & Lammer, 2007), maternal obesity(Blomberg & Kallen, 2010; Carmichael et al., 2007; Porter, Faizan, Grady, & Mueller, 2005) and possibly local exposure to environmental toxins (Paulozzi, Erickson, & Jackson, 1997). The data available for this dissertation did not include individual or census tract obesity rates or information on environmental exposure to toxins.

Cleft lip and palate rates were significantly related only to percentage of Native Americans in the census tract, r (150) = + .34, $p < .01$, two tailed (Figure 50). This was the lone significant relationship for cleft lip and palate defects. Native American ancestry is known to increase the risk of cleft lip and palate defects and this result was not unexpected (Vieira, 2002). As noted previously, small numbers of cleft lip and palate cases may have artificially inflated census tract rates, however this relationship was also

significant in the categorical data analysis for individual cases which lends credibility to the result (Figure 51).

Trisomy 21 was significantly *negatively* related to all age categories; median age total r (150) = -.21, $p < .01$, median age male r (150) = -.21, $p < .05$, and median age female r (150) = -.23, $p < .01$(Figure 51). This was not the expected direction of this relationship. Categorical analysis revealed the expected risk in trisomy 21 diagnosis with the increasing age of the mother. The focus does shift here, however from individual risk to risk related to mothers residential location. Even though trisomy 21 is more likely in infants of older mothers, more young mothers actually give birth, and thus numerically there are more trisomy 21 affected infants born to young mothers. Also of interest, was a correlation between higher levels of education in a census tract and increased trisomy 21 rates. Trisomy 21 rates were negatively related to percent of individuals over 25 in the census tract with education level below high school level, r (150) = -.19, $p < .05$. An initial possibility is that older, more educated individuals give birth later in life and have a greater likelihood of having a child with trisomy 21, but this contradicts the finding of lower median age in census tracts with higher rates of trisomy 21. This finding may be worth exploring further. Finally, percent of individuals reporting Native American ancestry, r (150) = .17, $p < .05$ was also correlated with trisomy 21. There is no connection found in the research literature to explain this on an individual risk level. In summary, trisomy 21 was found to be statistically more common among census tracts

with younger median age, higher education levels, and higher percentage of Native Americans.

No significant relationships could be found for found for neural tube defects. Possibly the extremely small number of these limited the ability of the analysis to find any relationships. Figures 47-52 provide comprehensive tables of each dependent variable in relationship to all the independent variables. While none of the relationships between the variables were particularly strong, some were significant.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	birth defect rate	1.000																	
2	percent below Poverty	-.095	1.000																
3	percent below High	-.092	.770**	1.000															
4	same parish	.150	-.132	-.002	1.000														
5	different parish	.158	.075	.055	-.042	1.000													
6	different state	.108	.048	.001	.258**	.183*	1.000												
7	abroad	.064	-.076	-.068	.266**	.051	.071	1.000											
8	Fertility Rate	-.116	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	-.041	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	-.037	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	.177*	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	.093	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	.058	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	.152	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.121	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.136	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.148	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	.041	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 47: Bivariate Correlations All Birth Defects *p ≤.05. **p≤ .01

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Heart Defects	1.000																	
2	Percent Below Poverty	-.137	1.000																
3	Percent Below High	-.051	.770**	1.000															
4	same parish	.253**	-.132	-.002	1.000														
5	different parish	.087	.075	.055	-.042	1.000													
6	different state	.018	.048	.001	.258**	.183*	1.000												
7	abroad	.071	-.076	-.068	.266**	.051	.071	1.000											
8	Fertility Rate	.030	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	-.067	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	-.020	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	.319**	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	.143	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	.180*	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	.271**	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.205*	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.207*	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.192*	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	.054	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 48: Bivariate Correlations Heart Defect *p ≤.05. **p≤ .01

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Hypospadias	1.000																	
2	percent below poverty	-.049	1.000																
3	percent below high	-.067	.770**	1.000															
4	same parish	-.038	-.132	-.002	1.000														
5	different parish	-.200*	.075	.055	-.042	1.000													
6	different state	-.072	.048	.001	.258**	.183*	1.000												
7	abroad	.058	-.076	-.068	.266**	.051	.071	1.000											
8	Fertility Rate	.275**	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	.031	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	.140	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	.019	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	.041	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	-.049	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	-.086	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.175*	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.157	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.166*	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	-.034	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 49:Bivariate Correlations Hypospadias *p ≤.05. **p≤ .01

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	cleft palate rate	1.000																	
2	percent below poverty	-.101	1.000																
3	percent below high school	-.155	.770**	1.000															
4	same parish	-.148	-.132	-.002	1.000														
5	different parish	-.066	.075	.055	-.042	1.000													
6	different state	.032	.048	.001	.258**	.183*	1.000												
7	abroad	-.079	-.076	-.068	.266**	.051	.071	1.000											
8	fertility Rate	-.043	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	-.168*	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	.342**	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	.158	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	-.007	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	.056	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	.111	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.030	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.007	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.039	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	.158	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 50: Bivariate Correlations Cleft Lip/Palate *p ≤.05. **p≤ .01

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Trisomy 21	1.000																	
2	Percent Below Poverty	-.158	1.000																
3	Percent Below High	-.193*	.770**	1.000															
4	same parish	.064	-.132	-.002	1.000														
5	different parish	-.034	.075	.055	-.042	1.000													
6	different state	-.045	.048	.001	.258**	.183*	1.000												
7	abroad	-.077	-.076	-.068	.266**	.051	.071	1.000											
8	Fertility Rate	-.071	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	-.077	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	.173*	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	.078	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	.012	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	.082	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	.090	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.201*	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.168*	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.187*	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	.075	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 51: Bivariate Correlations Trisomy 21 *p ≤.05. **p≤ .01

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	neural tube defect rate	1.000																	
2	percent below poverty	-.127	1.000																
3	percent below high school	-.021	.770**	1.000															
4	same parish	-.126	-.132	-.002	1.000														
5	different parish	-.031	.075	.055	-.042	1.000													
6	different state	.030	.048	.001	.258**	.183*	1.000												
7	abroad	-.029	-.076	-.068	.266**	.051	.071	1.000											
8	fertility rate	.158	-.048	.065	.385**	-.326**	-.003	-.044	1.000										
9	black percent	.072	.057	.159	.262**	-.214**	-.085	.061	.303**	1.000									
10	native american	.025	-.175*	-.173*	-.151	-.093	.049	-.163*	-.019	-.425**	1.000								
11	asian percent	-.001	-.120	-.059	.316**	-.015	.292**	.025	.219**	-.236**	.277**	1.000							
12	hawaiian percent	.024	-.109	-.054	.341**	.014	.121	.181*	.196*	-.248**	.002	.385**	1.000						
13	hispanic percent	-.008	-.038	-.025	.056	.095	.206*	.088	.020	-.570**	.246**	.597**	.555**	1.000					
14	multiracial percent	-.100	-.080	-.029	.173*	.139	.275**	-.070	.011	-.380**	.293**	.675**	.440**	.707**	1.000				
15	median age total	-.152	.118	.008	-.373**	.104	-.115	.039	-.394**	-.247**	.056	-.435**	-.114	.004	-.101	1.000			
16	median age male	-.153	.113	-.026	-.356**	.110	-.087	.029	-.371**	-.329**	.100	-.423**	-.070	.040	-.059	.937**	1.000		
17	median age female	-.150	.083	-.013	-.300**	.056	-.087	.059	-.353**	-.209*	.061	-.402**	-.080	.015	-.062	.947**	.932**	1.000	
18	white percent	-.082	-.054	-.157	-.280**	.233**	.066	-.067	-.332**	-.992**	.397**	.178*	.230**	.510**	.331**	.256**	.342**	.215**	1.000

Figure 52: Bivariate Correlations Neural Tube Defects *p ≤.05. **p≤ .01

CHAPTER 6 STEPWISE MULTIPLE REGRESSION RESULTS

In this chapter, multicollinearity was explored with a resulting decrease in the variables employed for analysis. This is followed by a stepwise multiple regression procedure and a discussion of the results of this attempt. Charts of the resulting models are presented for clarification and illustration.

A potential issue involving data in multiple linear regression is multicollinearity. It was anticipated that some or most of the variables in this research were not independent of one another. The goal was to avoid any excessive multicollinearity which might make it difficult to tell which independent variables were actually having an effect on the dependent variable in question (Webster, 2013). This issue was addressed by using SPSS software to test for this problem prior to proceeding with stepwise multiple regression analysis. Variance inflation factors did reveal concerns about Collinearity with regard to percentage of white and black individuals within the census tract in question and median age male, median age female, and median age overall. As a result, these variables were entered in individual trials on SPSS and resulting models compared. No resulting models were altered by replacing correlated variables, so only one of the variables, "percent black", was used in the final analysis. "Median age" was reduced to "median age female" only and the other two age variables were removed. Table 28 displays variance inflation factors for all of the independent variables

The results of the stepwise linear regression analysis for birth defects as a whole indicated that two predictors explained 25% of the variance (R^2=.25, F (2,148) =5.08, $p<.05$). Geographic mobility between parishes significantly predicted birth defects (β = .17, $p<.05$), as did percent of population residentially mobile within the same parish

($\beta = .17$, $p<.05$). These were the only predictors for birth defects as a group (Figure 53). Stepwise regression analysis for heart defect rates did not produce a multivariate model. As shown in Figure 54, only the percentage of multiracial individuals in a census tract was predictive of heart defect rates ($R^2=.06$, $F(1,149)=8$, $p<.01$). Comparing the spatial characteristics of the multiracial population and the spatial aspects of Heart defect rates does indicate some similarity in location but the actual mechanism for this correlation is not clear.

Table 28: Variance Inflation Factors
For Independent Variables

Variable	VIF
white percent	26.96
median age female	262.26
black percent	23.37
native american	1.73
asian percent	2.78
hawaiian percent	1.70
hispanic percent	3.93
multiracial percent	3.94
median age total	1016.79
median age male	314.21
same parish	1.88
different parish	1.48
different state	1.57
abroad	1.27
Poverty Rate	2.10
Percent Below High School	1.24

Table 29 provides an overview of the results of bivariate correlations between each type of birth defect and independent variables.

Table 29: Significant Bivariate Correlations Between Independent and Dependent Variables

All Birth Defects		
Variables	Coefficient	*p*
Percent Asian	-0.17	0.05
Heart Defects		
Same Parish	0.25	0.01
Percent Asian	0.32	0.01
Percent Multiracial	0.27	0.01
Median Age Total	0.18	0.05
Median Age Male	0.19	0.05
Median Age Female	0.18	0.05
Hypospadias		
Same Parish	0.32	0.05
Fertility Rate	0.27	0.01
Cleft Lip/Palate		
Percent Native American	0.34	0.01
Trisomy 21		
Median Age Total	-0.21	0.01
Median Age Male	-0.21	0.05
Median Age Female	-0.23	0.01
Percent Below High School	-0.19	0.05
Percent Native American	0.17	0.05

Figure 55 displays the results of the stepwise regression analysis for cleft lip and palate rates. This defect also failed to produce a multivariate model and had a single significant predictor, percent Native American, which explained 10% of the variance (R^2=.10, F (1,149) =16.73, p<.01). Trisomy 21 rates were best predicted by higher percentage of people with education beyond high school and younger median age (Figure 56). These two predictors in tandem explained 32 % of the variance (R^2=.32, F (2,147) =8.14, p<.01). The two predictive variables were median age female (β = -.23, p<.01) and Percent below high school (β = -.20, p<.01). Hypospadias was weakly predicted by a combination of three variables (R^2=.13, F (3) =7.04, p<.00). These were increased fertility rates (β = .27, p<.01), percent Native American (β = .20, p<.05) and percentage of Hispanics in the census tract (β = -.16, p<.05) as displayed in Figure 57. The stepwise regression models for neural tube defect produced no models (Figure 58). This was not unexpected since bivariate correlations did not result in any significant relationships. Overall the models were very weak though significant and some birth defects were unable to be modeled at all with the variables available.

Variable	**Model 1**				**Model 2**			
Dependent Variable: Birth Defect Rates	*B*	*SE B*	*β*	*t*	*B*	*SE*	*β*	*t*
Percent Below Poverty								
Percent Below High School								
Same parish					0.02	.010	0.17	2.25
Different parish	0.04	0.02	0.18	2.25	0.04	.019	0.17	2.22
Different state								
Abroad								
Black percent								
Native american								
Asian percent								
Hawaiian percent								
Hispanic percent								
Multiracial percent								
Median age total								
Median age female								
R^2	0.18**[a]				0.25**[b]			
F	5.08				4.46			
a. Predictors: Different Parish								
b. Predictors: Different parish, Same Parish								
** $p \leq .01$								

Figure 53: Stepwise Regression Model Birth Defects Overall

Variable	Model 1			
Dependent Variable: Heart Defect Rates	B	SE B	β	t
Percent Below Poverty				
Percent Below High School				
Same parish				
Different parish				
Different state				
Abroad				
Black percent				
Native american				
Asian percent				
Hawaiian percent				
Hispanic percent				
Multiracial percent	0.49	168.00	0.24	2.96
Median age total				
Median age female				
R2	.056*			
F	8.76			
a. Predictors: Multiracial				
* $p \leq .05$				

Figure 54: Stepwise Regression Model, Heart Defects

Variable	Model 1			
Dependent Variable: Cleft Lip and Palate Rates	*B*	*SE B*	*β*	*t*
Percent Below Poverty				
Percent Below High School				
Same parish				
Different parish				
Different state				
Abroad				
White percent				
Native american	2.20	0.54	0.32	0.55
Asian percent				
Hawaiian percent				
Hispanic percent				
Multiracial percent				
Median age total				
Median age female				
R2	0.101**			
F	16.73			
a. Predictors: Native American				

Figure 55: Stepwise Regression Model, Cleft Lip And Palate

Variable	Model 2			
Dependent Variable: Trisomy 21	*B*	*SE B*	*β*	*t*
Percent Below Poverty				
Percent Below High School	-0.20	0.00	-0.20	-2.57
Same parish				
Different parish				
Different state				
Abroad				
Black percent				
Native american				
Asian percent				
Hawaiian percent				
Hispanic percent				
Multiracial percent				
Median age total				
Median age female	-0.20	0.00	-0.23	-2.93
R2	.32**			
F	8.15			
a. Predictors: Median Age Female, Percent Below High School				
** $p \leq .01$				

Figure 56: Stepwise Regression Models, Trisomy 21

Variable	Model 1				Variable	Model 2				Variable	Model 3			
Dependent Variable: Hypospadias Rates	*B*	*SE B*	*β*	*t*	Dependent Variable: Hypospadias Rates	*B*	*SE B*	*β*	*t*	Dependent Variable: Hypospadias Rates	*B*	*SE B*	*β*	*t*
Percent Below Poverty					Percent Below Poverty					Percent Below Poverty				
Percent Below High School					Percent Below High School					Percent Below High School				
Same parish					Same parish					Same parish				
Different parish					Different parish					Different parish				
Different state					Different state					Different state				
Fertility Rate	0.27	0.01	0.27	3.42	Fertility Rate	0.02	0.01	0.28	3.58	Fertility Rate	0.02	0.01	0.27	3.60
Abroad					Abroad					Abroad				
Black percent					Black percent					Black percent				
Native american					Native american	1.52	0.72	0.16	2.11	Native american	1.88	0.73	0.21	2.57
Asian percent					Asian percent					Asian percent				
Hawaiian percent					Hawaiian percent					Hawaiian percent				
Hispanic percent					Hispanic percent					Hispanic percent	-0.11	0.05	0.21	2.57
Multiracial percent					Multiracial percent					Multiracial percent				
Median age female					Median age female					Median age female				
R2	0.073***				R2	0.10***				R2	0.126***			
F	11.71				F	5.70				Fertility Rate	7.04			
a. Predictors: Fertility Rate					a. Predictors: Fertility Rate, Native American					a. Predictors: Fertility Rate, Native American, Hispanic Percent				
**p<.05 **p<.01 ***p<.00*														

Figure 57: Stepwise Regression Models Hypospadias

CHAPTER 7 GEOGRAPHICALLY WEIGHTED REGRESSION MODELS

This chapter will describe the application of geographically weighted regression in an attempt to improve the regression models and explore the possibility of non-stationary relationships between independent and dependent variables. The geographically weighted regression procedure is described for each dependent variable. This is followed by an assessment of autocorrelation of the residuals for each resulting model along with maps for visual assessment. Charts are used to compare the results of stepwise regression models and geographically weighted regression models and problems with this method are discussed.

The next step in the research process was to determine whether relationships between variables were non-stationary, one way to do this was to employ geographically weighted regression. The ArcGIS geographically weighted regression function was applied to the data using adaptive kernel type and the AICc bandwidth method. Following this procedure, residuals were checked for spatial autocorrelation using global Moran's *I*. Spatial autocorrelation in the residuals invalidates the use of GWR. This assumption is important as heteroscedasticity can lead to inefficient least-squares estimators and as a result, misleading statistical inference (Leung, Mei, & Zhang, 2000). The independent variables which were shown to be significant predictors for each dependent variable were entered into the GWR models and compared with the multiple regression results.

For overall birth defect rate, geographically weighted regression did show some local variation, with R^2 improving from 0.18 for traditional regression analysis to 0.35 using GWR demonstrating that relationships were non-stationary. The model was most

valid in rural areas and least valid in south central areas of the MSA. Figure 58 illustrates the findings. Heart defect rate predictions were also improved with GWR. R^2 increased from 0.06 for traditional regression analysis to 0.27 for GWR. This was a rather dramatic jump even though the relationships still appear to be very weak. Figure 59 demonstrates where the relationships are most valid. The model held up well in the southeastern part of the MSA in Livingston and Ascension Parish and also in parts of West Feliciana Parish. It performed especially poorly in central East Baton Rouge Parish. Notable is the fact that heart defects were most numerous in areas where the model was more successful. For trisomy 21, GWR could not be employed due to significant autocorrelation of the residuals. Applying GWR to hypospadias relationships also produced negligible change. The model, shown in Figure 60, while weak, produced the best results in rural areas, especially St. Helena Parish. There were very few births or birth defects in that parish, however. Figure 61 displays the results for cleft lip and palate. As with the other categories of birth defects results were weak. There were no informative patterns to the distribution of results. Table 30 shows the comparison between the stepwise regression models and the geographically weighted regression models. Maps are displayed for GWR results showing the local variations in R^2. While GWR did improve some models, showing the non-stationary aspects of these relationships, the models are far from successful in terms of explaining the relationships between birth defects and the independent variables employed. This lack of success may be due to the way that GWR conceptualizes the spatial aspects of the variables. Methodological problems may arise due to the straight-line measurement of distance. In the Baton Rouge metropolitan area, the Mississippi river curves around the city and local

communities and forms a 2,300 foot gap between housing areas. This may explain why the GWR models were more successful in rural and outlying areas not bisected by the Mississippi River.

Table 30: Geographically Weighted Regression Results

	Original R^2	GWR R^2	Moran' s *I*	*P*(Moran's *I*)
All Birth Defects	0.18	0.35	0.00	0.37
Heart Defects	0.06	0.27	0.01	0.16
Hypospadias	0.13	0.18	-.01	0.86
Cleft Lift and Palate	0.10	0.28	0.00	0.75
Trisomy 21	0.32	0.05	0.02	0.03*

**P<.05*

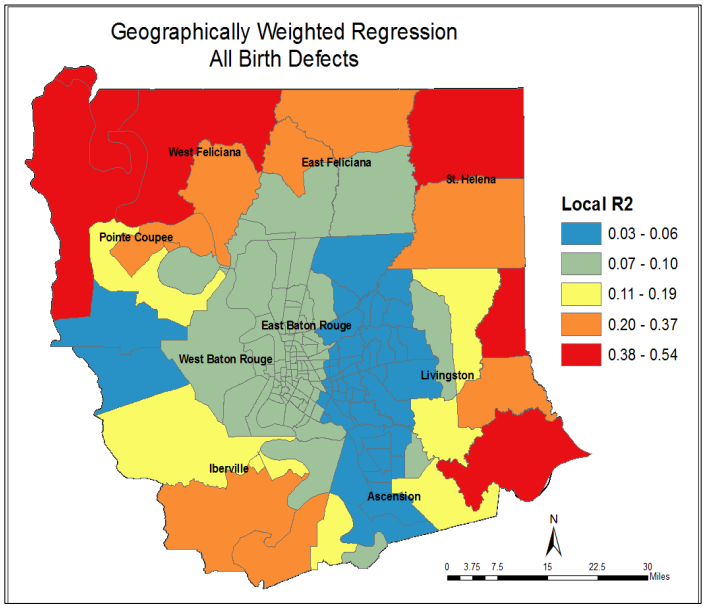

Figure 58: Geographically Weighted Regression All Birth Defects

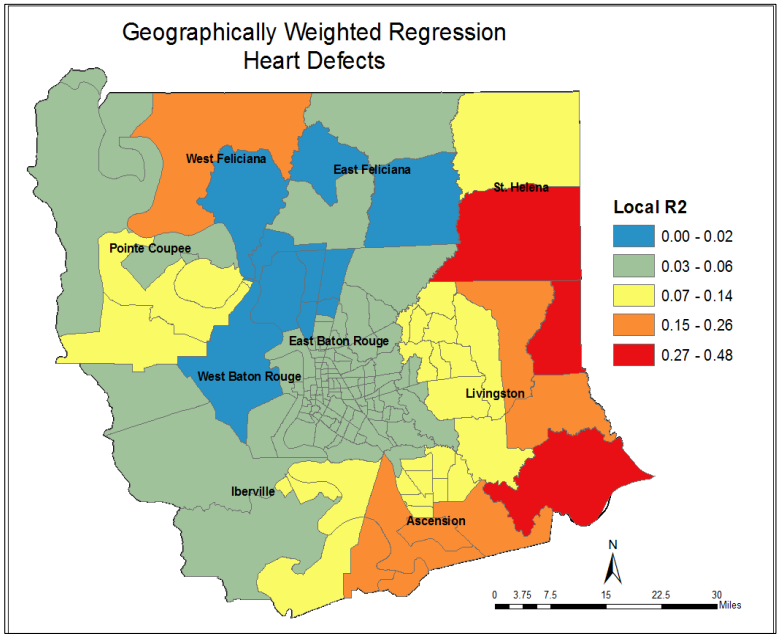

Figure 59: Geographically Weighted Regression Heart Defects

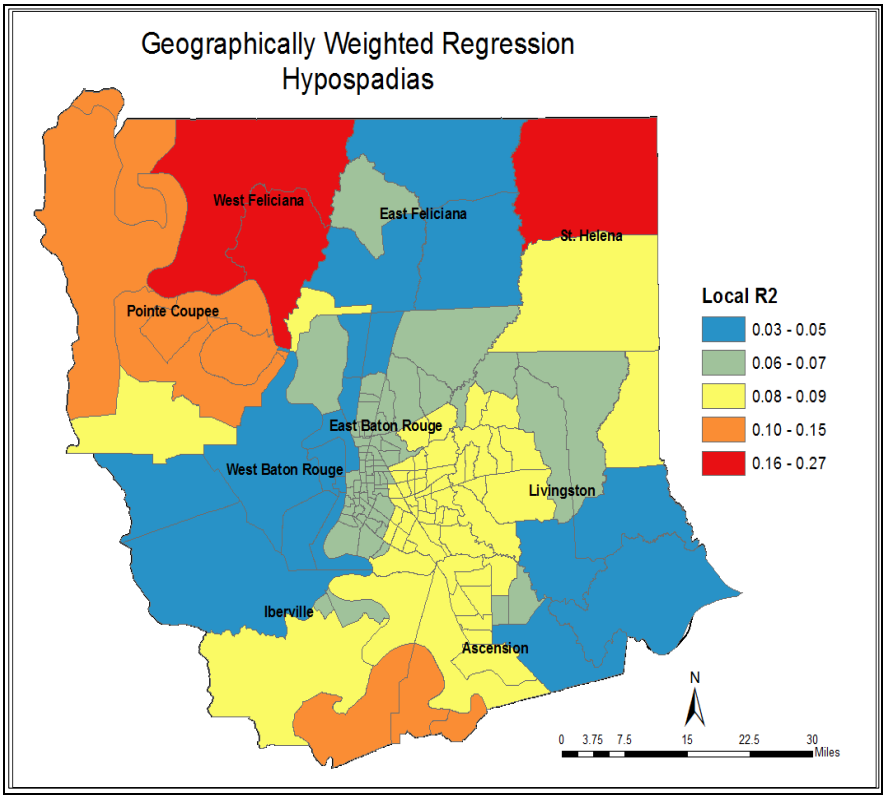

Figure 60: Geographically Weighted Regression Hypospadias

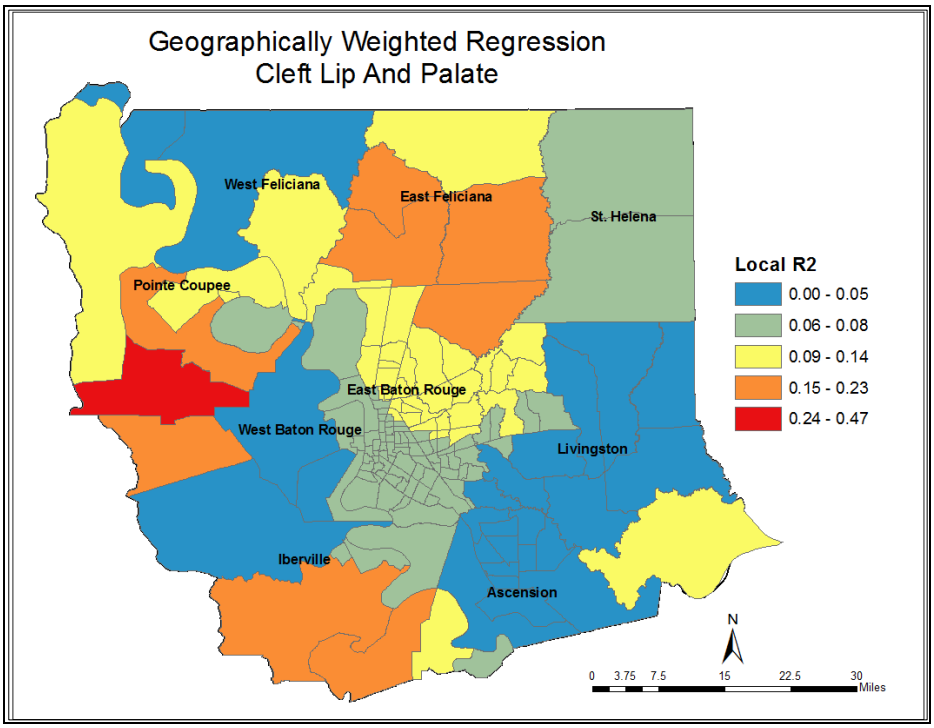

Figure 61: Geographically Weighted Regression Cleft Lip and Palate

CHAPTER 8 MULTILEVEL MODELING

Geographically weighted regression did a poor job of improving models which could explain the variation in birth defects. In an attempt to improve the results and also to avoid the risk of confusing group risk with individual risk, multilevel modeling was performed. SAS version 9.4 was used for this analysis. Census tract level variables and individual level variables were combined into one dataset. Additionally, the geographic mobility variables were combined into one variable by calculating a percentage of each census tract population that had reported moving either within or into the census tract in the last five years. The four mobility variables for each tract were averaged. Another addition was a categorical variable for urban/rural. Each census tract was given a binary code of 1=urban or 0=rural. The urban designation is defined by the U.S. Census Bureau as a densely settled area of at least 2,500 people. Rural encompasses any area not

considered urban (U.S. Census Bureau, 2013). While there are further gradations of this designation, for the purposes of this research, the definition was left as a dichotomy. This topic was covered briefly in chapter 3. A multilevel model was constructed to examine the effects of individual health risks and outcomes at both the individual and neighborhood levels. The analysis employed binary variables for birth defects. The individual mother either does not (0) or does (1) have an infant with a birth defect. Each birth defect type was modeled individually. Individual level categorical variables included Alcohol use, Tobacco, Black, Hispanic, Asian, or other, as binary variables with (1) representing presence of the risk factor, and (0) representing non-presence of the risk factor. Age remained a continuous variable. At the census tract (neighborhood) level, five covariates were included; Percent of population below poverty level, percent of population over age 21 with education below high school level, fertility rate of population, median age of population, geographic mobility as a whole for population, and urban/rural designation.

Age remained as an important variable in the models for trisomy 21, all birth defects, and heart defects. Coefficients remained steady between the two models. Of interest is the occurrence of a statistically significant negative relationship between black ethnicity and individual heart defects. While this relationship was negative with bivariate correlation, it was not significant. No other variables displayed a statistically significant relationship for either intercept only models or models with random variables added. Many of the bivariate correlations which were significant in prior analysis were no longer significant using a multilevel logistic modeling procedure. Table 31 and Table 32

illustrate the multilevel models in comparison with the logistic models with level one variables only.

Table 31: Multilevel Models for All Birth Defects, Heart Defects, And Cleft Lip And Palate

	All Birth Defects Model 1	All Birth Defects Model 2	Heart Defects Model 1	Heart Defects Model 2	Cleft Lip/Palate Model 1	Cleft Lip/Palate Model 2
Individual level variables						
Mother's Age	0.01**	0.01**	0.01**	0.02**	0.01	0.00
Alcohol	0.13	0.12	0.43	0.39	0	-0.51
Tobacco	0.02	0.03	0.06	0.06	-0.39	-0.43
Black	-0.17	-0.19	-0.27**	-0.31**	0.14	0.21
Hispanic	-0.08	-0.09	-0.09	-0.11	0.44	0.49
Asian	0.11	-0.08	0.24	0.19	-0.27	-0.12
Other	0.00	-0.255	0.00	-2.28	0.00	-0.59
Census Tract Level Variables						
Percent Poverty		0.00		0.00		-0.02
Percent Below High School		-0.02		0.00		-0.01
Geographic Mobility		0.00		0.01		-0.01
Median Age All		0.04		-0.02		0.01
Urban/Rural		0.41		-0.35		0.54

**p<.01 ***p<.001

Table 32: Multilevel Models For Trisomy 21, Hypospadias, And Neural Tube Defects

	Trisomy 21 Model 1	Trisomy 21 Model 2	Hypospadias Model 1	Hypospadias Model 2	Neural Tube Defects Model 1	Neural Tube Defects Model 2
Individual level variables						
Mother's Age	0.11***	0.11***	0.01	0.01	-0.01	0.00
Alcohol	0.00	-0.91	0.00	-0.9	0.00	-0.77
Tobacco	0.34	0.36	-0.16	-0.23	-0.44	-0.49
Black	-0.02	0.02	0.09	0.13	-0.24	-0.03
Hispanic	0.02	-0.08	-1.42	-1.49	0.00	-0.58
Asian	0.61	0.92	-0.72	-0.68	0.00	-3.75
Other	0.00	-0.61	0.00	-0.87	0.00	-0.48
Percent Poverty		0.04		0.00		0.01
Percent Below High School		-0.05		-0.02		0.04
Geographic Mobility		-0.01		0.00		-0.01
Median Age All		-0.65		0.03		0.06
Urban/Rural		0.45		-0.04		0.25

**p<.01 ***p<.001

CHAPTER 9 DISCUSSION

9.1 Overview And Contents Of The Chapter

This was a very broad project with multiple areas of inquiry. The goal was one of exploration, however there were some expectations based on what is already known about the factors which increase or decrease the incidence of birth defects. Overall prevalence was expected to fall within the nationally typical range. What follows is a discussion of the questions posed in the introduction, and how these answers fit into the existing knowledge. As always, there were limitations for the interpretation of results and these are also discussed. Typically, any topic involving humans, raises even more questions than it answers and this research was no exception. This final section discusses findings and some possible directions for future exploration.

9.2 Findings Regarding Prevalence Rates

The research area had very normal and possibly even lower than normal prevalence rates for birth defects. The typically quoted U.S. average is 3% of all births (Weinhold, 2009) though this sometimes includes those birth defects discovered after the newborn period. This study revealed a rate of 2.5% of all recorded births over the four year time span. There were however, census tracts with higher than expected prevalence and census tracts with lower than expected prevalence rates. Those types of birth defects singled out for closer inspection displayed no alarming numbers, though again, some areas exceeded expected rates. Total birth defects, cleft lip and palate defects, and trisomy 21 rates were within normal range overall. Heart defects were increased at 1.2 % of births, which was higher than the 0.9% anticipated. Hypospadias cases were also

slightly increased at 0.13 percent of male infants (anticipated was .001 percent) Reasons for both numerical and spatial variations were explored with global and local cluster analysis, chi-square tests, bivariate correlations, regression analysis, geographically weighted regression analysis and multilevel modeling.

9.3 Findings Regarding All Birth Defects As A Whole

Relationships between birth defects as a whole and independent variables were for the most part as expected. For the category of all birth defects, age was the only consistent predictor both as an individual risk factor and as a census tract level factor. The rise in birth defect rates becomes gradually more apparent with age and by age 42, the rate has risen from 2.5% overall to 3.8% of live births with a defect. As expected, the search for hot spots and cold spots did reveal some clustering and higher than expected rates. Both Global Moran's *I* and local Moran's *I* showed clustering of birth defects. The search for risk factors also revealed that geographic mobility variables (movement within the census tract and into the census tract from other areas) were related to overall birth defect rates. This finding was not anticipated. When these variables were combined into one mobility variable for multilevel logistic models however, the relationship disappeared. This variable begs for more investigation in future research.

9.4 Findings Regarding Heart Defects

Heart defects were the most numerous of the individually explored birth defects and exceeded the expected percentage. Not surprisingly, alcohol use, tobacco use and the age of the mother were related to heart defects in chi-square tests. Global clustering was significant for both Geary's *C* and Moran's *I.* There were also significant local clusters defined by the spatial scan statistic with SaTScan. Age was a predictor for heart defects

with rates rising along with the age of the mother. For bivariate regression analysis, Asian ancestry was positively correlated with heart defect incidence for individual mothers. Since Asian mothers were older as a group, this was not unexpected, however the relationship reversed at the census tract level. Those census tracts with higher rates of Asian population had *lower* rates of heart defects. Multilevel logistic models were invaluable for clarifying this issue. The relationship between Asian mothers and heart defects was not evident in the multilevel models. The most likely explanation is that while Asian mothers may have a higher rate of heart defects, this is unlikely to be a result of census tract level variables. When multilevel logistic modeling was employed, black mothers had a significantly *lower* risk of heart defects. This was also not unexpected as these mothers also had the youngest average age at time of delivery. Multiracial ancestry for individual mothers and geographic mobility at the census tract level (within the same parish) were additional predictors of heart defects. Multiracial ancestry is included for the first time in the 2010 census and as pointed out in earlier discussions, little is known about this group. As research emerges on this group it may be possible to tease out the risk factors for birth defects for these individuals.

9.5 Findings Regarding Hypospadias

Hypospadias rates exceeded expected numbers overall and there was a large apparent temporal jump in cases in 2007 and 2008 which is displayed visually in bar graphs (page 8, Figure 37). Because of the minimal number of years available this was not evaluated statistically. Age was significantly related to hypospadias with the largest jump occurring in mothers older than 38. Geographic mobility rates between parishes were a significant predictor but when multilevel logistic models were employed, the

mobility variable was not significantly related to hypospadias rates. Stepwise regression produced a model which included census tract level fertility rate, percent of Native Americans and percent of Hispanic individuals in the census tract. This was a somewhat unexpected result especially with regard to fertility rates. While fertility rates are sometimes related to poverty and so possibly poor infant health, the relationship between poverty and fertility rate was not significant in this dataset. There were no significant local clusters of hypospadias found. The cause of the large jump in rates temporally remains an unknown, and cannot be tested statistically with the available data. Multilevel logistic models did not produce any significant relationships. Overall, age was the only significant individual predictor.

9.6 Findings Regarding Trisomy 21

As expected, Trisomy 21 rates were highly related to increasing age of the individual mother using chi-square tests. Neither global nor local Moran's *I* revealed any clustering. There was a visually apparent temporal jump in 2006 which would be worth exploring with a larger number of time stamps. What was less easy to explain was a negative relationship between age and trisomy 21 at the census tract level. All median age variables, total, male, and female, showed this negative relationship. Additionally tracts with higher education levels were more at risk for higher rates of trisomy 21. One interpretation may be that because younger people are more likely to have children in the first place, there is more likelihood that a younger census tract will have a higher rate of trisomy 21 affected infants. To sort this out, multilevel logistic models were constructed. Only the individual mother's age was related to trisomy 21 with this analysis and the coefficient did not change when census tract level variables were added.

9.7 Findings Regarding Cleft Lip And Palate

Cleft lip and palate rates were slightly lower than expected and small numbers within each census tract made it difficult to draw conclusions at the census tract level. This was one of only two birth defects unrelated to age of the mother. Bivariate regression revealed a significant relationship to percentage of Native Americans in a census tract ($r^2 = .34$, $p < .01$). However there were no individuals claiming Native American ancestry with an infant born with cleft lip and/or palate. The reasons for this relationship are unknown. Multilevel logistic models found no significant relationships for cleft lip and palate rates among the available variables. While there was no evidence of global clustering, there were two local clusters found with Moran's *I*. Investigation with the available correlates and processes did not reveal any reasons for these clusters. Much remained unexplained for this birth defect.

9.8 Findings Regarding Neural Tube Defects

Neural tube defect rates were as expected, however, the very low numbers made it difficult to discover any relationships by census tract groupings. There were no significant bivariate or multivariate relationships observed. Geary's *C* did find global clustering and there were two hotspots in central Baton Rouge found with local Moran's *I.* Multilevel logistic models did not find any relationships to explain the clustering.

9.9 Conclusions, Limitations and Future Research

The Baton Rouge Metropolitan Statistical area did not have any extreme birth defect rates during the years of the study, at least not any revealed by this research project. Future investigations could focus on several areas including heart defects, geographic mobility rates and birth defects, and temporal rates of birth defects. Of

interest is the apparent increase in birth defects in several categories following Hurricane Katrina. Spatial temporal analysis was completed with SaTScan, however no statistically significant spatial-temporal clusters were found, likely due to having only four different time periods available. Secondary to the inability to test these findings statistically, the spatial temporal analyses were not discussed in any detail in this dissertation. Confidentiality issues at the time that the data was provided did not allow for births by month rather than year. Hopefully this data can be obtained for future research efforts so that this time period can be explored in more detail. Heart defects should be investigated by individual types. Even though they develop at the same time in fetal development, they are known to have different causal processes. The rates were higher than expected and also clustered geographically. Other than age of the mother, reasons for the clustering were not revealed. More relationships should be apparent when they are studied individually. The relationship between birth defects and geographic mobility rates are also worth investigating. Even though this variable was not significant in multilevel logistic models, this predictor continued to appear throughout other types of statistical analyses and begs for an explanation.

There was no information about the years 2005 and 2006 for St. Helena Parish, however the numbers of births reported for 2007 and 2008 in St. Helena Parish are small and thus is was assumed that 2005 and 2006 had low numbers of births also. One possibility would be to remove this parish and others with very small numbers of births from calculations in future investigations so that efforts can be concentrated on those with the highest fertility rates and also to prevent the extremely low fertility rates in those areas from diluting any processes which might be affecting birth defect rate calculations.

Another consideration is that while geocoding rates were reasonable for urban areas, there was less success in rural areas. This was not unexpected, but it limits the conclusions made about the spatial aspects of the research in rural areas. The multilevel logistic models did not reveal any effects of the rural/urban variable, however, since births that could not be geocoded and thus not included in multilevel analyses were more likely to be rural, the lower geocoding rates may have adversely affected the accuracy of those outcomes.

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VITA

Born the youngest child to two (mostly) Irish/Scotch parents in the U.S. Midwest, Aimee Beth Hall (Moles) was transplanted in infancy to what was then the rather unpopulated state of Florida. Running mostly barefoot on the Florida beaches and the cattle farms and in the welcoming comfort of book-loving people, she became an eclectic and voracious reader, often reading whole novels in the branches of the oak and magnolia trees.

Moles started college in 1978 and obtained a B.S. in psychology. Following that, she worked as a lab assistant and a restaurant manager while waiting for the love of her life, her husband Michael, to catch up. They married and moved to Baton Rouge, Louisiana where Michael's family lived. After working at various forms of employment, Moles found herself in graduate school at Louisiana State University in social work. She graduated with an MSW in 1990 while expecting her second child, Karl. Her first child, Sean, was three years old. Moles went to work immediately out of school at Woman's Hospital in Baton Rouge where she became a medical social worker. Eventually, seeking the love of education and books again, Moles made two tries at a doctoral program, first in social work when baby number three, Jack was 2 years old, and then finally in geography in 2010. Amazingly, this felt like home too. A fascination with people, maps, and medicine were combined into a tremendously challenging and satisfying project. Moles continues to work as a hospital social worker on the weekends and to teach at LSU during the week. She has several other hobbies including yoga (especially headstands). Her husband hopes she is finally through with school.