DRIVING FACTORS OF OBESITY IN SOUTH TEXAS: EXPLORING SPATIAL ACCESS IN THE NEIGHBORHOOD PHYSICAL ACTIVITY ENVIRONMENT IN NUECES COUNTY, TEXAS

By

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ABSTRACT

Nueces County, Texas contains over 200 parks, more than 100 fitness and recreation sites and year-round, free access to beaches along the Gulf coast. Yet, Nueces County is disproportionately affected by both obesity and diabetes. So much so that Corpus Christi, the county seat of Nueces County, was infamously titled “the fattest city in America” by Men’s Health Magazine in 2010 (Colletti and Masters, 2010). In addition, there are few local research studies available to help explain the relationship between obesity and the physical activity environment within the county.

In this study, spatial accessibility to physical activity (PA) sites was measured using network analysis. Results show that the majority of all physical activity groups including parks, sports and fun sites, fitness sites, youth and recreation centers and golf courses are located within urban areas. Close to 90% of all neighborhoods in Nueces County contain a physical activity site that has a travel distance of less than 1.5 miles from where the majority of people in the neighborhoods live. Parks accounted for 67% of the physical activity data. Therefore it was not surprising that spatial accessibility results were similar for parks compared to analyses where all physical activity sites were considered. Spatial regression and Pearson’s correlation analysis were used to identify relationships between spatial accessibility to PA sites and socioeconomic characteristics of Nueces County urban area neighborhoods. Regression revealed that spatially-explicit variables, that is, those that revealed geographically-based relationships rather than socioeconomic ones, were more important in explaining spatial accessibility both when various types of physical activity sites were considered and when only parks were considered. Finally, the association between spatial access to PA sites and obesity in Corpus Christi was examined. Pearson’s correlation was calculated for spatial accessibility and 9 socioeconomic and health variables selected from data for two combined health surveys. The first survey was targeted to persons with diabetes in Nueces County. The second survey was an amendment to the first and was not targeted. More than 80% of those surveyed were overweight or obese even though 67% lived less than half a mile from the nearest physical activity site. The results show that

spatial access alone does not mitigate obesity nor does it provide the full picture of resource scarcity with respect to physical activity opportunities in neighborhoods. Other dynamics must be considered in helping to understand the factors that impact anti-obesogenic behavior in Nueces County neighborhoods. This thesis examines some of these extenuating factors.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

In the United States less than fifty percent of the population is physically active for at least 30 minutes per day, three to four days / week, which is the amount of regular physical activity that is recommended by the U.S. Center for Disease Control in order to maintain a healthy lifestyle (Wilson et al., 2004). An important consequence of not getting enough exercise is becoming overweight. One indicator of overweight is body fat. Body fat can be measured in several ways including taking skinfold thickness measurements, underwater weighing and isotope dilution methods (CDC, 2013). In this study body fat is calculated by using Body Mass Index (BMI). BMI is calculated by dividing the weight in pounds by the square of the height in inches and multiplied by 703. Though not a direct measure, it is considered a reliable indicator of body fat and is a preferred method for assessing population overweight and obesity because it can be calculated quickly and easily (CDC, 2013). According to the CDC, a person is overweight when their BMI is greater than 25. When BMI reaches 30, a person is then classified as obese. Overweight and Obesity can be defined as "abnormal or excessive fat accumulation that may impair health" and is now recognized as a worldwide epidemic (WHO, 2014).

In the United States obesity has reached alarming proportions and its consequences on human health are pronounced. During their lives, obese individuals are much more likely to suffer a myriad of chronic diseases and complications such as cardiovascular disease, hypertension, insulin resistance, decreased fertility, hyperlipidemia, gout, heart disease, heart failure, stroke, venous thrombosis, dementia, GERD, cancer (endometrial, breast, colon), osteoarthritis, sleep apnea, asthma, kidney disease, and psychosocial conditions (Swaney, 2012; Maria and Evagelia 2009; CDC, 2012). Further, up to 80% of persons with Type 2 diabetes are also obese (Swaney, 2012; Maria and Evagelia, 2009). Some statistics show that obesity may account for between

112, 000 – 400, 000 deaths in the United States annually (Vojnovic, 2003). Another study finds that "across all taxpayers, per capita medical spending for the obese is $1,429 higher per year, or roughly 42 percent higher, than for someone of normal weight resulting in an aggregate annual medical burden of up to $147 billion per year (in 2008 dollars)" (Finkelstein et al., 2009; p. 822). By 2018 46%, nearly half of the adult population of the United States, is projected to be obese (Swaney, 2012).

Such statistics and other research findings have led some researches to conclude that individual risk factors for obesity are insufficient to explain the disease's alarming rate of increase. This change is reflected in the apparent shift in the literature from focusing on causes such as genetics to environmental or community-level factors such as accessibility to resources (e.g. parks, gyms, sports venues, pools and other recreational activity sites) in an attempt to understand the factors that are driving obesity (Maroko et. al., 2009). While the national statistics on obesity are cause for concern; obesity seems to affect states and various regions within them disproportionately. Texas, for example, where 65.9% of the state population was overweight in 2010, has one of the highest incidences of obesity in the United States (CDC, 2012).

There may be a number of factors involved in the maintenance of health and vitality; however, the two main factors are diet and exercise. While the role of diet in the maintenance of good health is critical, the main focus area of this thesis concerns the function of the physical activity environment in influencing individual and community-level physical activity behavior. This research uses currently available data from the U.S. Census Bureau; spatial data on parks and other physical activity sites in Nueces County, Texas; new research data from two socio-demographic health surveys were examined to determine if spatial access to recreational activity sites is influenced by socioeconomic factors and whether obesity is influenced by access to physical activity sites at the neighborhood-level.

1.2 STATEMENT OF THE PROBLEM

Numerous studies have shown that proximity to recreational facilities is positively correlated with measures of physical activity and obesity. Objectively measured characteristics of the physical activity environment – such as distance to and density of resources – have been shown to correlate with fitness activity (Popkin et al., 2005). These measures exert influence on human behavior because they may make it more challenging for individuals to participate in a physical activity, thereby decreasing the likelihood of engagement in anti-obesogenic behaviors such as walking or utilizing a gym. Therefore, it is important that physical activity sites are easily accessible (e.g. shortest distance possible) and well-distributed in the neighborhood because there is "substantial evidence that people who live closer to a variety of recreation facilities are more physically active overall" (Sallis and Glanz, 2009; p. 127). In one study, researchers hypothesized that ease of access alone figures prominently in explaining why spatial accessibility to physical activity sites from residences encourages engagement in physical activity (Loon, 2010).

In addition, it is clear that socioeconomic and demographic factors are strongly associated with physical activity behavior. Typical socioeconomic factors considered throughout the literature include household income, neighborhood crime, education, race/ ethnicity, means of transportation, sex, occupation and age. Studies routinely indicate that neighborhoods that are characterized by low-income, low-education and high minority populations (e.g. Low SES) do not participate in physical activity to the same degree as high-income, high-education and predominately White neighborhoods (High SES) (Wilson et al., 2004). Neighborhoods that are characterized by low SES also tend to be comprised of physical activity environment characteristics that do not favor participation in physical activity. Such characteristics include, for example, lack of physical/recreational activities and sites; poor condition of physical activity amenities; traffic; lack of transportation infrastructure that facilitates bi-pedal movement (such as sidewalks), nature trails and bicycle lanes; susceptibility to weather effects, especially heat; safety, crime and lack of walking or exercise partner(s) (Wilson et al. 2004). In addition, characteristics related to perceptions of neighborhood environment such as perception of access, safety and aesthetics have also been found to impact physical activity behavior (Wilson et al. 2004; Klingerman et al. 2006). One study found that perceived spatial access to neighborhood trails and other physical activity opportunities was positively correlated to actual participation in physical activity (Popkin et al., 2005). This is significant in terms of low SES neighborhoods because studies show that these neighborhoods tend to report that their neighborhoods are not pedestrian friendly and/or otherwise do not favor participation in physical activity. Low-income neighborhoods have been associated with both reduced spatial access to healthy foods and fewer recreational amenities (Loon, 2010). Each of the aforementioned neighborhood environment characteristics serve as barriers to participation in physical activity and have been shown to increase the risk of obesity in some cases.

1.3 NEED FOR THE STUDY

Once it became clear that individual health determinants could not adequately account for the staggering increases in obesity over the last several decades, examining the contribution of environmental effects on physical activity behavior became a public health imperative:

> Understanding the population impact of environmental factors is critical to pushing forth population-wide interventions to promote physical activity – now a major focal point in public health (Popkin, 2005; p. 605).

Leading public health institutes such as the World Health Organization, the International Obesity Task Force and the Center for Disease Control (CDC, 2013) determined that environment-wide and policy level changes would be critical in a framework geared toward the reduction of obesity (Sallis and Glanz, 2009). One of the reasons that environment changes are so appealing is because adjustments made to the built environment are more visible, quantifiable and have the potential to impact more people. Popkin et al. (2005; p. 606) put it best when they reported:

> Research on physical activity determinants has ignored the most modifiable factors for public policy – the physical environment. Clearly a major source of potential change is the community and its social/physical environment. These factors change tremendously for young adults as they transition into middle adulthood. It is critical to understand the biological impact of these social/physical environment factors on physical activity, a major determinant of health.

In addition, some researchers believe that studying the physical activity environment will enhance our ability to understand and predict health behaviors including participation in physical activity (Wilson et al. 2004). The implication is that once more is known about the characteristics of the environment that promote utilization of physical sites or increases in physical activity we may be able to begin to improve public health by encouraging behaviors that reduce obesity (e.g. exercise) on a community-level. However, though research on the impact of the physical activity environment on health outcomes is increasing there are still information gaps:

> It is difficult to generalize built environment findings across populations or across behaviors. Most studies have been conducted with adults, and analyses stratified by race, ethnicity or socioeconomic status are rare. It is thus high priority to improve our understanding of environmental correlates of physical activity and sedentary behaviors in diverse samples, especially those at high risk for obesity (Sallis and Glanz, 2009; p. 133)

Thus, current information on environmental effects is piecemeal. Results from one study may not explain phenomena happening in other locations. Further, because there is an established need to target populations that are at high risk for obesity, a neighborhood physical activity environment study is well suited for residents of Nueces County, Texas. Incidences of obesity and diabetes seem to disproportionately impact the County and the City of Corpus Christi in particular. It is a curious phenomenon that despite the fact that Nueces County contains well over 200 parks and more than 100 non - park recreational sites it was determined to be “the fattest city in America” by Men’s Health Magazine in 2010 (Colletti and Masters, 2010). Yet there are few, if any, community-level endeavors investigating the potential links between the high rates of obesity and characteristics associated with the built environment.

1.4 PURPOSE OF THE STUDY, RESEARCH QUESTIONS AND OBJECTIVES

The purpose of this research is to assess and visualize the physical activity environment of Nueces County, Texas by examining spatial access to physical activity sites within neighborhoods (e.g. census tracts). The second purpose of the research is to determine if there is a relationship between spatial access to physical activity sites and socioeconomic factors. Finally, the third purpose of the research is to determine if there is an association between spatial access to physical activity sites and obesity from individual perceptions. The research questions and objectives are more formally stated below.

1. **Research Question 1: What is the physical activity environment in Nueces County, Texas?**

   Object 1: Measure spatial accessibility of physical activity sites in neighborhoods within Nueces County.

2. **Research Question 2: Is spatial access influenced by neighborhood-level socioeconomic factors in Nueces County, Texas?**

   Objective 2: Determine if there is a relationship between neighborhood socioeconomic factors and spatial accessibility to physical activity sites.

3. **Research Question 3: Is there an association between spatial access to physical activity sites and obesity in Nueces County, Texas neighborhoods from the individual perceptions?**

Objective 3: Determine if there is a relationship between Body Mass Index (BMI) and spatial accessibility to physical activity sites at an individual - level using data from a human subject survey questionnaire.

Network analysis was used to measure spatial accessibility and map the neighborhood physical activity environment in Nueces County in Research Question One. The outcome is a neighborhood visualization of the location, distribution, spatial access and scarcity of physical activity resources in the county. Using census tracts as the unit of analysis, the relationship between spatial accessibility to physical activity sites and socioeconomic factors created from census data was examined using Ordinary Least Square (OLS) regression in Research Question Two. The outcome was a set of variables that helped to explain important factors that influences spatial accessibility in Nueces County urban areas. Finally, in Research Question Three, Pearson's correlation was calculated among individual spatial accessibility to PA sites, BMI and socioeconomic variables obtained from the human subject questionnaire previously mentioned. The outcome was range of descriptive statistics and correlations that show the strength and direction (positive or negative) of relationships between BMI and socioeconomic / health variables.

1.5 LIMITATIONS

Data on physical activity (PA) sites in Nueces County was purchased through InfoUSA and supplemented with available data from Corpus Christi Parks and Recreation and other online sources. Still, site data may not be complete and other physical activity sites such as in-home gyms were not accounted for. Similarly, analysis does not account for physical activity that is not directly associated with a site structure such as kayaking, for example. Second, census tracts were used to represent neighborhoods in Research Questions One and Two. However, census tracts are not the smallest census units. Census tracts were selected because they were the most appropriate unit to manage the third limitation of the research, namely, the small PA data sample. Lastly, while the use of census tracts has advantages, scaling and zoning effects may occur due to the variability in unit sizes across the study area. This issue is discussed in more detail in sub-section 2.3.4 in Chapter Two.

1.6 ETHICAL CONSIDERATIONS

Data from two related health surveys were used to conduct Research Question Three. The *Neighborhood Food Environments and Disparities in Persons with Diabetes in Nueces County* survey was targeted to English-speaking, adult persons living in Nueces County who have diabetes. The purpose of the survey was to collect data in support of a research study to understand how neighborhood conditions affect the health of residents. It was funded by the Coastal Bend Diabetes Initiative (CBDI). An amendment was made to the survey in order to assess how neighborhood recreation sites such as parks and gyms impact the health of Nueces County residents. Additional questions concerning health and exercise were added in the amended survey which was titled the "*Diet, Exercise and Physical Activity Environment Survey for Adult Residents of Nueces County"* (see Appendix A). The latter was distributed online via Survey Monkey as well as in person. The surveys were approved through the Texas A&M University – Corpus Christi Institutional Review Board (IRB# 98-12). All responses were kept confidential.

CHAPTER TWO
LITERATURE REVIEW

2.1 DEFINING ENVIRONMENT

"The consensus among public health experts is that changes in genes, biology, and psychology at the individual level cannot explain the rapid rise in obesity, so the explanation must lie in broader environmental policy and societal changes" (Sallis and Glanz, 2009; p. 124).

The subject of physical activity and obesity has many dimensions and has been examined in several fields including sociology, economics, demography as well as the health and spatial sciences (Loon, 2010). Therefore, when discussing the external environment there are many conceptualizations of what the environment is and what it entails. Generally, the environment can be defined as "the external context in which individuals and households are making decisions" (Popkin et al., 2005; p. 603). Three types of external contexts are apparent in the literature: 1) socioeconomic environments (SES), 2) physical environments and 3) geo-political environments. The socioeconomic environment is also a behavior influencing milieu. Common characteristics of the socioeconomic environment include average household income, neighborhood crime, race/ ethnicity, gender, means of transportation, education and occupation. The physical environment is perhaps the most commonly studied environment with regard to studies about recreational environments. Physical environment is tangible and involves interaction with individuals. It can be further categorized into 1) the natural environment and 2) the built environment (Loon, 2010). The natural environment includes characteristics like weather and topography while the built environment refers to places where physical activity can take place. This includes parks, recreation facilities, sidewalks, gardens, the sea and urban design features. Finally, environments may be defined in terms of their geopolitics. Like the socioeconomic context, the geo-political environment is a behavior-influencing milieu. It encompasses trends, policies, economic systems, production systems and societal norms that influence human behavior in everyday life: "Policies pertaining to parks, recreation, education, transportation and planning departments in governments at multiple levels have direct responsibility for physical activity environments” (Sallis and Glanz, 2009; p. 125). Each of the three environmental contexts mentioned affect everything from how individuals arrive at work to the food and products purchased to decisions on if, when and how physical activity is undertaken. In addition, it is apparent that these environments operate at different scales in terms of sphere of influence on behavior (Loon, 2010). At the micro scale, environmental influences tend to impact particular groups such as those in workplaces, school cafeterias and churches (Sallis and Glanz, 2009). Thus, for example, “proximity to schools might influence the physical activity behavior of school-age children and their parents, but is less likely to influence other populations” (Loon, 2010; p. 692). Likewise, “at a very local level, family policies control food and physical activity environments at home” (Loon, 2010; p. 692). At the meso scale, anywhere from a few hundred to a few thousand people may be impacted depending on the size of the neighborhood or community. Policies, the primary mechanisms for making changes to the environment, are controlled by local and national government and by industry (Sallis and Glanz, 2009). Characteristics that affect obesity, such as urban design, operate at the meso scale. Finally, the macro scale environment has regional or global impacts. Such environments may be influenced by international government and popular culture through media and the internet.

2.2 MECHANISMS BY WHICH NEIGHBORHOOD CHARACTERISTICS INFLUENCE OBESITY

The premise that the physical activity environment is linked to human health at the population level is widely supported in the literature. This section examines some of the mechanisms by which the physical activity environment exerts influence on obesity.

The physical activity environment primarily influences obesity by influencing human behavior through its effect on two main factors: 1) impact on aggregate physical activity and 2) impact on eating opportunities (Loon, 2010). The key mechanism through which the environment impacts aggregate physical activity is by its mediation of 1) proximity to facilities and 2) its mediation of opportunities to engage in physical activity; both of which are factors related to spatial accessibility to physical activity resources. Though impact on eating opportunities is briefly addressed, this thesis primarily concerns environmental effects on physical activity. Aggregate physical activity effects refer to cumulative (the total amount of physical activity that an individual is likely to engage in within a given time frame) and collective (population level effects) physical activity undertaken by individuals. According to Popkin et al. (2005; p. 605) "environments may restrict a range of physical activity behaviors by promoting or discouraging physical activity through factors such as, access to safe recreation, accessibility of recreation facilities and transit options."

Finally, perceived physical activity environment characteristics such as traffic, aesthetics (e.g. waterfront view, beautiful architecture, green spaces), convenience, perceptions of access to facilities and perceptions of neighborhood safety can all serve as barriers to aggregate physical activity. In one study, "perceived presence of neighborhood trails and general access to places for physical activity were positively associated with actual physical activity" (Popkin et al., 2005). In their review of literature on *Environments that Support Active Recreation* (Sallis and Glanz, 2009; p. 127) found that the "aesthetics of physical activity settings in consistently related to adult activity, with five of six reviews that covered aesthetics supporting this conclusion. In addition, features like trees, attractive buildings and water views may make recreational physical activity more pleasant (Vojnovic, 2006).

2.3 SPATIAL ACCESSIBILITY

Measures of spatial accessibility to physical activity sites are used globally to help uncover the nexus between human health as it relates to obesity, overweight and the built environment. According to Cutumisu and Spence (2012; p. 296) "accessibility quantifies the spatial distribution of relevant opportunities available within a selected area and the spatial separation between an origin of interest and these opportunities." More specifically, the authors define spatial accessibility to recreational facilities as “the ease of reaching desired activities; indicating both the distribution of activities offered by facilities and the travel to these activities” (Cutumisu and Spence, 2012; p. 295). More researchers now favor the use of geographic information systems (GIS) as a tool to study the relationship between spatial accessibility to physical activity resources and obesity due to the system’s unique ability to, quantitatively and objectively, help uncover the factors that control people’s behaviors and attitudes toward physical activity (Comber et al., 2008; Oreskovic, et al., 2009; Wilson, et al. 2004). The latter are essentially subjective factors that determine whether an individual chooses to participate in health-promoting physical activity and avoid obesity, overweight and numerous associated risk factors. Thus, spatial accessibility allows for the evaluation of subjective factors (behaviors and attitudes) using objective methods.

Part of the objective in many spatial accessibility studies is to paint a picture of resource distribution within an area of analysis. The results of such studies are often spatial accessibility maps. Brabyn and Sutton (2013; p. 127) produced a series of maps depicting spatial access to ‘walking tracks’ by travel time in their investigation of regional variation of spatial accessibility to outdoor recreational facilities in New Zealand. Spatial accessibility maps can be instructive and persuasive instruments for influencing public policy due to their visual nature. For example, Brabyn and Sutton found their work to “evoke questions regarding the fair allocation of resource for providing outdoor recreation opportunities throughout NZ” (p. 130). For Billaudeau et al. (2011; p .14) the equitable distribution of physical activity resources is a question of environmental justice because of the health implications for people living in ‘obesogenic’ (lacking in or devoid of easily accessible healthy diet and/or physical activity opportunities) environments. In this thesis spatial accessibility was measured using network analysis and thematic maps were created using GIS to display the geographic distribution of physical activity sites in Nueces County as well as to provide a basic analysis of the distance cost associated with traveling to the nearest physical activity site within each neighborhood in the county. These maps provide an overall sense of the physical activity environment in Nueces County. However, while GIS can simplify the process of calculating spatial accessibility, interpreting spatial accessibility and its relationship to environmental factors and obesity is complicated. First, both inter-personal and extra-personal socio-economic status (SES) can interact or act independently to alter the effect of spatial accessibility on overweight/obesity promoting behaviors; second, spatial accessibility is often interpreted geographically. However, spatial accessibility may be altered by the ancillary characteristics of the physical activity facilities under consideration; third, spatial accessibility may be influenced by the type of physical activity facilities or sites analyzed and whether such sites are grouped and; fourth, the interpretation of spatial accessibility to physical activity sites can be influenced by the scale at which spatial accessibility is calculated. Each of these considerations is explained in more detail in the following subsections.

2.3.1 Effects of inter-personal and extra-personal socioeconomic status on spatial accessibility

Aside from showing resource distribution, spatial accessibility studies are often concerned with capturing the effects of the socio-economic status (SES) of study participants at the individual, neighborhood, municipal or regional level. As such, researchers commonly test for associations among gender, race/ethnicity, indicators of wealth (e.g. income, occupation, home ownership, blue collar etc.), education or means of transportation and spatial accessibility to physical activity resources. Socioeconomic characteristics are often reported in relation to other socioeconomic characteristics or analyzed as an index of deprivation.

Although there are some inconsistencies in the literature about the relationship between income, race/ethnicity, education and spatial access to physical activity opportunities, there is a great deal of evidence associating high income neighborhoods with characteristics that encourage physical activity while low income neighborhoods are often associated with obesogenic characteristics that hinder participation in physical activity and put residents at greater risk of becoming obese and developing diabetes. For example, in their research on the disparity in spatial access to public parks and private recreation facilities Ambercrombie et al. (2008) found no significant effect of income or percent minority on spatial access to public parks, open space and private recreation facilities. However, using provincial income and unemployment as indicators of wealth and deprivation respectively, Pascual et al. (2009) found that provinces with higher per capita income and low unemployment rates tended to have higher percentages of people who swam and went to the gym. In addition, these provinces tended to have greater numbers of sports facilities than lower income / high deprivation Provinces. Further, the authors found that jogging, swimming and gym attendance was lower among residents with low education and income at an individual socioeconomic level. The authors, did not however, find a relationship between the availability of sports facilities the uptake of swimming or gym use.

Spatial accessibility to “greenspaces” is believed to be so important in Leicester, England, that proximity to greenspaces is legislated by the government with guidelines such as “there should be 2 ha of accessible natural greenspace per 1000 population” (Comber et al., 2008; p. 108). Comber et al. (2008) found that when applying this rule to Leicester in its strictest sense (e.g. for a population of approximately 280,000 with 980 ha of greenspace producing a ratio of 3.5 ha per 1000 people) access to green spaces is comfortably within guidelines. However, when the distribution of greenspaces is more carefully analyzed only 40% of the total population actually has adequate spatial access to greenspaces and the disparity is split along ethnic and religious lines. Comber et al. (2008; p. 113) emphasized the need to “embrace a much wider concept of ‘access’ that relates to individual people and therefore includes transport (car ownership and public transport to/from individual greenspace sites.” For this reason, a transportation variable was included in the analysis of Research Question Three.

Sallis et al. (2011) found that with two of their environmental attributes – count of convenient recreation facility and spatial access to a gym or fitness facility within a 20-min walk – neighborhood income was a main effect and that high income neighborhoods experienced a greater frequency of both attributes. Neighborhood income was also found to be a significant main effect with regard to measures of pedestrian friendly infrastructure (e.g. sidewalks and pedestrian/bike trails), aesthetic qualities (e.g. shade trees and attractive sights), pedestrian traffic safety (e.g. amount and speed of nearby traffic and presence of crosswalks) and safety from crime. Casey et al. (2012) tested the hypothesis that socioeconomic factors can interact and change the effect of spatial accessibility on youth overweight and obesity-regulating behaviors. In this case, obesity-regulating behavior was measured by participation in physical activity at least once a week. The researchers found that the likelihood of being overweight is inversely related to spatial accessibility in what they classified as "urban physical facilities" (including athletic tracks, open-space playgrounds, large collective playgrounds, indoor PA facilities, tennis courts and swimming pools) for children of blue-collar-workers in France (Casey et al., 2012; p. 915).

Finally, Wilson et al (2004) compared the association of socioeconomic characteristics, perceptions of safety and spatial access to physical activity sites between low socioeconomic status (SES) and high SES neighborhoods. In this study, high SES neighborhoods were consistent with having higher household income, higher education and being predominately White. They found that residents of low SES neighborhoods were more likely to perceive that their neighborhoods were unpleasant, plagued by unattended dogs, entertained higher neighborhood crime, included more residents who felt that neighbors were untrustworthy and reported lower spatial access to PA facilities. In Low SES neighborhoods, higher perceptions of having and using walking/biking trails were significantly associated with walking 150 min/week – a PA standard that obese residents were not demonstrated to maintain.

2.3.2 Effects of ancillary characteristics of physical activity sites on spatial accessibility

A second factor adding to the complexity of interpreting the effect of spatial accessibility to physical activity sites is the fact that individuals may make decisions about whether to use physical activity resources based on the characteristics of those facilities despite what is geographically accessible to them. Joseph and Phillips (1984) distinguish spatial accessibility from accessibility based on site characteristics by terming them as “locational” and “effective” accessibility. According to the authors, locational accessibility refers to the proximity of discrete infrastructures or services while effective accessibility is more complicated as it takes into consideration features of discrete infrastructures such as the cost or business hours of a facility. Cutumisu and Spence (2012; p. 294) discuss similar concepts in their work when they distinguish “objectively-assessed” accessibility, which they measured “using catchments around facilities and individuals homes” and “subjectively-assessed” accessibility which is “based on individual’s perceptions in terms of facilities (e.g. whether a person considers that they have access to recreational facilities in their neighborhood).” Locational and objectively-assessed accessibility are synonymous with spatial accessibility and are typically assessed using GIS databases (Braybn and Sutton, 2013; Cutumisu and Spence, 2012).

Though both “effective” and “subjectively-assessed” accessibility are less easily assessed with a GIS and both concern the ancillary characteristics of physical activity sites, the latter focuses specifically on an individual’s perception of the physical activity environment, which in turn may influence activity patterns. In the case of effective accessibility, individuals may self-exempt from utilizing geographically available physical activity resources based on features that are associated with a physical activity facility. One study showed that neighborhoods containing higher proportions of African American and Latino residents tended to have a significantly higher frequency of parks and that a higher frequency of parks was also positively correlated with percentage of residents living below the poverty line (Weiss, 2011; p.303). From the standpoint of spatial accessibility, this result shows that African American and Latino and residents struggling with poverty have greater spatial accessibility to parks. However, the researchers also found that when park characteristics such as noxious land use, traffic hazards and crime (homicide) – features which they call “disamenities” - were used as explanatory variables for spatial accessibility, the opposite result was produced. Now the percentage of neighborhoods containing mostly African

Americans was negatively correlated to number of parks. (Weiss, 2011; p. 304). In a similar test, when all parks containing disamenities were removed from the model, results showed that lower income neighborhoods and those living below the poverty line, a demographic that had previously been shown to enjoy higher spatial accessibility to parks, now had less access to park facilities. The researchers conclude that "attention to neighborhood disamenities can appreciably alter the relationship between neighborhood composition and spatial access to parks" (Weiss, 2011; p. 297). Billadeau et al. (2001) incorporated several "comfort" characteristics - including presence of heated changing rooms and showers at the nearest tennis court, indoor/ outdoor status of nearest tennis court and presence of lighting at the nearest athletic facility - to assess spatial accessibility to different types of sports facilities in the Paris metropolitan area. Their analysis showed that the probability that the nearest tennis court would have a heated changing room or shower increased with local area income (Billaudeau et al., 2001; p.118).

This thesis primarily concerns spatial access to physical activity sites; however it is important to understand that ancillary characteristics associated with physical activity sites, whether they include amenities such as heated changing rooms, "disamenities" like crime, or other factors such as cost, aesthetic appearance and even how a site is marketed to the public may all have an impact on spatial accessibility and whether individuals will choose to utilize these facilities. This is why according to Brabyn and Sutton (2011; p. 125) "it is important that GIS-generated information on geographical accessibility is supplemented with information on other factors that influence people's reaction patterns such as surveys on motivations, expectations and satisfaction." Individual-level data from a human subjects survey (see Appendix A) was used in Research Question 3 (see section 4.3) to accompany spatial accessibility results from Research Question 1 and 2 (see sections 4.1 and 4.2) and to capture locally relevant information about other important factors that influence Nueces County resident's decisions to participate in physical activity.

2.3.3 Effects of type of sports and recreation facilities on spatial accessibility

Another important complicating factor in the interpretation of spatial accessibility concerns the heterogeneity in type, grouping and classification of the physical activity sites analyzed. Countries such as France and New Zealand have well-defined national databases of sports and recreation facilities (Brabyn and Sutton, 2011; Karusisi et al., 2013; Billaudeau et al., 2011). Others do not and measures of accessibility are impacted by the availability of data (Cutumisu and Spence, 2012). However, even for countries with well-developed databases accessibility outcomes are influenced by the researcher's choice of how to classify the data. Table 1 shows the heterogeneity with which sports, recreation and physical activity opportunities have been evaluated in the accessibility literature.

Table 1.1: Inventory of Sports, Recreation & Physical Activity Literature

Source	Study Area	PA Database	PA Sites Analyzed	Grouping	Total # PA Sites
Casey et al. (2012)	Bas-Rhin, France	1998 French National Institute of Statistics Economic Studies Inventory Database	**6 Urban facilities** (athletic tracks, open space playgrounds, large collective playgrounds, indoor PA facilities, tennis courts, swimming pools. **5 Nature facilities** (hiking trails, outdoor recreational parks, boating centers, ski resorts, beaches)	2 PA types (Urban & Nature), 11 groups	N/A
Brabyn and Sutton (2013)	New Zealand	Dept. of Conservaton (DOC), Territorial Local Authorities, Regional Councels, Private Land Owners	**Level 1** (serviced campgrounds, standard campsites, serviced alpine huts, serviced huts, basic huts, back country track shelters, short walks, short, walks for disabled, walking tracks, easy tramp/Great Walks, hard tramping tracks, Routes); **Level 2** (road end camp sites, serviced huts, basic huts, short walks, walks and easy tramps, long hard tramps); **Level 3** (road end camp sites, all huts, all walks)	3 levels of successive, nested PA types: Level 1 = 14 groups, Level 2 = 6 groups, Level 3 = 3 groups.	4,900
Billaudeau et al. (2011)	Paris, France	2008 Census of Sport Facilities (Ile-de-France Regional & Departmental Direction of Youth, Sports, and social cohesion)	Tennis courts, large collective playgrounds (soccer & rugby fields), sporting rooms (muscle building exercises, cardio-training, collective courses), athletic facilties, swimming pools, proximity facilties (free 24hrs). (individual pools, tennis courts etc. counted separately, though potentially in the same physical address. This is the difference b/w an "installations" & "facility"). All analyses conducted at the "facility" level.	6 groups & total # of facilties	27,267
Cutumisu and Spence (2012)	Edmonton, Canada	2005 GeoEdmonton	Sport field complexes (outdoor sports fields that include diamonds, rectangular fields, tracks and some containing indoor facilities such as gyms, hockey rinks and swimming pool)	1 group (i.e. sports fields) analyzed individually	362
Karusisi et al. (2013)	Paris, France	2008 Census of Sport Facilities (Ile-de-France Regional & Departmental Direction of Youth, Sports, and social cohesion)	Team Sports (basketball, football (soccer), handball, rugby, volleyball); Racket sports (tennis, squash, badminton, ping pong); water (swimming, aquaerobics); fitness (aerobics, cardio training, weight training, gymnastics)	outcome variables created based on 4 PA groups	2 binary variables created for ea. group
Weiss et al. (2011)	New York, U.S.	New York City Dept. of Parks & Recreation	Parks (analyzed by # of parks accessible from a tract, total # of facilities in parks accessible from a tract, # of acres of parkland accessible from a tract and # unique facility types accessible from tract).	1 PA group (i.e. parks) analyze by 4 criteria	1,795

Table 1.1 shows differences in the total number and diversity of physical activity resources across research studies. Physical activity opportunities range from athletic tracks, basketball, swimming and tennis courts to campgrounds, huts, nature trails and ping pong. These differences largely reflect differences in database sources and the geography associated with each study area.

Before discussing differences in physical activity opportunities further, however, it is also necessary to discuss the differences in sports activity and recreation terminology both in terms of classification and array of activities. The terms facility, site, recreational opportunity, amenity and "build and service structure" have all been used to describe resources that may not be synonymous in the literature. Indeed there does not appear to be a standard vocabulary for describing what I refer to as *physical activity opportunities*. Similarly, there does not appear to be uniformity for the categorization or arrangement of homogeneous physical activity opportunities with the terms physical activity type, category and group recurring most often. For the purpose of clarity in organizing and describing the various terms that are part of the physical activity literature, I have created a catalogue of terms and definitions below.

- Physical activity (PA) opportunity – describes a physical place, object or action that presents an occasion to conduct physical activity or implies/indicates that physical activity has or can be done. The physical activity opportunity can be looked at as the basic building block of physical activity analysis. Examples include – athletic track, tennis court, gym, swimming pool, swimming, nature trail, beach, campsite, cardio training or aerobics.
- Physical activity (PA) type – This is essentially a level of aggregation containing physical activity groups. Examples include Urban vs. Nature. Brabyn and Sutton (2013) refer to types as "Levels." Their levels represent successive, nested groups such that Level 3 contains all the elements of Level 2 and Level 1. Each level of activity is equivalent to what I refer to as an activity type because it encompasses lower levels of aggregation, in this case, physical activity groups. Thus, for example, Level 2 contains the groups *serviced campgrounds* and *standard campgrounds*. One result of mapping accessibility based on their three tier classification system has been to show the impact of how you choose to group physical activity opportunities on accessibility outcome visualizations: "There is also an issue regarding the conceptual granularity of the classification: i.e. the level of generalization that should be used for describing opportunities. This granularity can have a significant effect on the statistics that result from the analysis. Individual analysis of very specific opportunities may show poor accessibility, but when many

specific opportunities are grouped together there may be good accessibility" (Brabyn and Sutton, 2013; p. 126).

- Physical activity (PA) groups – This is a level of aggregation containing physical activity opportunities. Cutumisu and Spence (2012; p. 304) refer to these as "domains of physical activity." Going back to the Brabyn and Sutton (2013) example, the group *serviced campgrounds* would contain several individual campgrounds (e.g. physical activity opportunities).

For this thesis, I will use the terminology described above. In addition, the terms *physical activity opportunity, site, physical activity (PA) site*, *recreation site* or *activities* are considered synonymous for the purposes of this thesis.

Returning to the main discussion of differences in physical activity opportunities, Table 1 demonstrates the fact that most researchers, for example Billaudeau et al. (2010), choose to analyze several groups of activities while those, usually with the benefit of having large national sports and recreation activity databases at their disposal, use higher levels of aggregation (e.g. PA types) to form the basis of their analyses. Some researchers, on the other hand, choose to examine a single group of physical activities. Cutumisu and Spence (2012), for example, use a homogenous database of sports complexes as part of their assessment of the association between objective and perceived accessibility to sports fields and levels of self-reported physical activity among Canadian adults. However, even if only one group of activities is the basis of analysis it can be analyzed by multiple criteria. For example, from a database of 1,795 parks Weiss et al. (2011; p. 300) used the number of parks and park acres accessible from a tract as well as the total number of facilities and unique facility types accessible from a tract. In some cases, the PA opportunities are not material objects like a building or swimming pool but rather the opportunity is analyzed as an activity that is/has been performed by study participants. In one study activities like swimming, cardio training, weight training, badminton and squash were categorized into four groups (team sports, racket sports, water sports and fitness). Each group was then used to create binary variables to examine the association between accessibility to each sports group and the practice of the corresponding sport in Parisian adults (Karusisi et al., 2013).

Finally, it is clear that even when the same database of physical activities is used research groups may analyze them very differently. Billaudeau et al. (2010) and Karusisi et al. (2013) both use data from the well-developed Census of Sport Facilities established by the Ille-de-France Regional & Departmental Direction of Youth, Sports and Social Cohesion. This large database affords two kinds of classification - one based on building and structure location (“installations”) and the other based on individual PA opportunities (“facilities”): “An instillation is identified by a unique street address and may include different types of facilities, e.g. a tennis court and a volley ball ground, as well as different facilities of the same type (e.g. three tennis courts)… thus, 2 swimming pools in the same building, e.g. one for children and one for adults, would count for 2 in our variables on the number of facilities” (Billaudeau et al., 2011; p. 115). The latter use 27,267 “facilities” aggregated into 6 groups to conduct their analyses while karusisi et al. (2013) use the same data to create 4 groups. It is not clear whether their data is based on installations or facilities.

To conclude, there is clear heterogeneity with regard to the grouping, classification and array of physical activity opportunities in the literature. To further complicate matters, there are also differences in terminology, availability and characterization of the data. I developed a standard nomenclature for this thesis to organize and clarify terms; however, each of the complicating factors mentioned will impact the results for analysis on accessibility from study to study.

2.3.4 Effects of scale at which spatial accessibility is calculated

There seems little doubt that measuring spatial accessibility to physical activity sites at the neighborhood level can provide useful insight into factors that affect the behavior-environment dynamic and its health impacts. However, another major complicating factor that occurs when investigating ‘area effects research’ is the degree of difference in the conceptualization and measurement of neighborhoods. In fact there is no consensus on what constitutes a neighborhood among researchers and therefore there is a high degree of variation in the measurement of neighborhoods in the literature. Neighborhoods are typically constructed with GIS by creating buffers about a household or population center, creating or utilizing existing geographic zones or by using administrative area units such as the census block groups. Determining an appropriate neighborhood boundary for the study area and research questions under investigation is an issue of scale that is important in geography based research including spatial accessibility (Billaudeau et al., 2011; Duncan; Openshaw, 1983). If the scale of analysis is too small, it may not be possible to detect meaningful relationships in the data. This occurs because when built environment variables are aggregated using small spatial units a greater amount of variability is produced in the data and creates what can be described as statistical 'noise' (Mitra and Buliung, 2012). On the other hand, if the scale is too large, as sample variance decreases causes "data smoothing" underlying patters may be obscured (Mitra and Buliung, 2012). Duncan et al. (2010) tested for scale and zoning effects by varying the spatial scale and configuration of a neighborhood in their study which investigated the relationship between land use mix (LUM) and the physical activity behavior of 2,506 adults in Adelaide, Australia. The work was based on previous research findings that correlate the heterogeneity of the built environment landscape (e.g. assessing the degree of mixture of various land use types such as residential, commercial, institutional, industrial, recreational and agricultural) to increases in walking, biking and other physical activity. Areas of higher LUM, then, may be thought of as anti-suburban areas that provide greater bipedal destination opportunities. They found that the models that were adjusted for accurate geographic scale showed greater significant associations to frequency of walking as well as duration of walks (Duncan et al., 2010; p.782). A scaling effect is evident when disparity in research results can be attributed solely to changes in the size of the study area. Similarly, a zoning effect occurs when disparity in research results can be attributed to the way in which the study area is partitioned (Duncan et al., 2010). Scaling and zoning effects are referred to as modifiable areal unit problem (MAUP) in geography. The problem presented by MAUP to geographically based research including spatial accessibility is explained by Openshaw (1983; p. 4):

> The crux of the modifiable areal unit problem (MAUP) [is that] there are a large number of different spatial objects than can be defined and few, if any, sets of non-modifiable units. Whereas census data are collected for essentially non-

> modifiable entities (people, households) they are reported for arbitrary and modifiable areal units (enumeration districts, wards, local authorities). The principle criteria used in the definition of these units are the operational requirements of the census, local political considerations, and government administration. As a result none of these census areas have any intrinsic geographical meaning. Yet it is possible, indeed very likely, that the results of any subsequent analyses depend on these definitions. If the areal units or zones are arbitrary and modifiable, then the value of any work based upon them must be in some doubt and may not possess any validity independent of the units which are being studied.

There appear to be trends in the literature that could potentially offer prescriptive scaling guidelines to aid in constructing neighborhood boundaries to help manage MAUP. For example, correlations for public spaces and playgrounds seem to be stronger when measured at a radius of between 400 – 800m (local scale) whereas fitness, sport, recreation and nature-centered (beaches, rivers, open spaces) tend to show more significant relationships when the radius is greater than 800m (regional scale) (Cutumisu and Spence, 2012). However, independent scale or zone sensitivity assessments are likely required to address the unique data, study area and objectives associated with individual spatial accessibility research. Mitra et al. (2012) tested the potential of MAUP to affect the correlation between characteristics of the built environment and the likelihood of children to walk or bike to school in Toronto, Canada. They found evidence of both scaling and zoning effects.

In this thesis census tracts are used to represent neighborhoods. Although census tracts are not the smallest level of enumeration available from the Census Bureau, they were the most appropriate to accommodate the distribution of physical activity data for this study. However, census units are primarily created to facilitate the collection of census data and therefore have only a conceptual relationship to the geographic areas that they represent and often do not exhibit homogeneity among these geographic areas (i.e. neighborhood size can vary widely over the study are) (Openshaw, 1983). Therefore, due to the potential scaling or zoning effects that may result when a single geographic unit is used to represent a neighborhood, there is a possibility that underlying patterns and trends in the data may not be detected (Duncan et al., 2010). This is true even when the smallest administrative unit available is used (Duncan et al., 2010). However, there are advantages to using enumeration units because complementary population data is usually available and data is collected and aggregated according to national standards, is widely accessible and in many cases it is free (Duncan et al., 2010). In addition, census tracts have been used to analyze spatial access to PA sites effectively in a GIS (Wilson et al., 2004; Messer et al., 2006)

CHAPTER THREE
METHODS

3.1 STUDY AREA

The study area, Nueces County, is located in the Gulf Coast region of South Texas. Nueces County has a land area of approximately 1,166 mi^2 (3, 020 km^2) with a population density of 376 mi^2 (145 people/km^2). In Nueces County, approximately 55% of the population is of Hispanic ethnicity. The total population according to the 2010 Census is 340, 223. The City of Corpus Christi is the County seat of Nueces County.

3.2 DATA

Census tracts were obtained online from the Census Bureau at census.gov. Data for parks were obtained from Corpus Christi Parks and Recreation online at ccparkandrec.com. This includes a total of 226 parks. The parks range in size from about 0.06 km^2 (.15 acres) to .55 km^2 (136 acres). There are also differences with regard to park amenities. These include presence of grills, sports equipment (e.g. for baseball, basketball or tennis), bike paths, fishing, fitness trails, restrooms, shelter, pools and beach access. However, neither park size nor amenities were considered in this study. Data for physical activity sites that were not parks were obtained from the business and consumer data distributor InfoGroup. Non-park physical activity sites include gyms, golf courses, youth centers and organizations, senior centers, public beaches, Yoga and other instructional courses, the physical activity resources of universities (Texas A&M University-Corpus Christi and Del Mar College), natatoriums, health clubs, sports fields, YMCAs as well as youth centers and organizations. A total of 112 Non-park physical activity sites were obtained. A portion of these sites were obtained via online sources to better represent peri-urban areas then all physical activity sites were geocoded. Nearly all of the newly added physical activity sites were parks or other greenspaces. There were 338 physical activity sites captured for Nueces County in total. The street network came from StreetMap Premium for ArcGIS for Windows Mobile NAVTEQ North America and Europe, 2012 Edition.

Socioeconomic data were obtained from the U.S. Census American Community Survey (ACS) using DataFerrett, an online data extraction and analysis tool provided by the U.S. Census Bureau. Four broad categories of socioeconomic data were used - household income, transportation, race/ethnicity and education as shown in Table 4.2. Individual variables chosen from these broad categories are discussed further in section 4.2 of Chapter Four.

3.3 MEASUREMENT OF SPATIAL ACCESSIBILITY TO PHYSICAL ACTIVITY SITES IN URBAN AND PERI-URBAN NEIGHBORHOODS, NUECES COUNTY, TEXAS

Network Analysis produced spatial accessibility data for both the County and City levels in distance (mi) to the nearest physical activity site. Census tracts were used as the unit of analysis for measuring spatial accessibility to physical activity sites and to represent individual neighborhoods within Nueces County, Texas. Nueces County is comprised of 82 census tracts. Tract 9900 was excluded from all analyses due to the fact that it is submerged under the Gulf of Mexico and does not contain either a population or physical activity (PA) sites. This is in contrast to Tracts 63 and 62 that are both inundated by Nueces Bay and Corpus Christi Bay, respectively, but are retained for analysis because both contain population and physical activity site data. Spatial accessibility was measured by calculating the travel distance from the Population Weighted Mean Center (PWMC) of each census tract in Nueces County, Texas to the nearest Physical Activity (PA) site using the Closest Facility analysis method in Network Analyst, ArcGIS 10.1 (ESRI). The PWMC was calculated for the population at the block group level within each census tract used using the following equation. Equation 3.1: PWMC is the average X and Y coordinate of the geometric center in block groups multiplied by the population at the block group level within each census tract (e.g. neighborhood).

The Closest Facility tool estimates the cost of traversing a street network from a start point to an end point where start points are known as "Incidents" and end points as "Facilities." Closest facilities were measured from Incident to Facility with the population center (e.g. PWMC) as the Incident and the Physical Activity Site as the Facility. No barriers or sources of impedance were added to the calculation before solving in Network Analyst. The search tolerance setting for finding network locations was 5,000 meters and the only restriction was "One-way." In addition, visualization of the frequency distribution of physical activity sites were displayed for each of seven Physical Activity Site groups used in this research (e.g. All physical activity sites, Parks, Non-park Sites, Sports and fun sites, Fitness Sites, Youth and Recreation Centers and Golf Courses) by dividing the total number of physical activity sites within each census tract by the total population within the tract and then multiplying by 1000 in ArcGIS. The output data was then joined to Tiger/Line census tract shapefiles (US Census Bureau) for Nueces County then symbolized by quantity to create thematic maps. Location maps were generated for each of the seven activity groups from parks data and Physical Activity Site data geocode in ArcGIS.

Finally, spatial accessibility and availability maps were generated from spatial accessibility (e.g. miles to nearest site) and distribution (e.g. site / population ratio) results. The most accessible and available neighborhoods were defined as neighborhoods where spatial accessibility was less than or equal to the first 2 of 6 classes in miles associated with each Accessibility map *and* that had a distribution that was greater than or equal to the first 3 of 5 classes associated with each Distribution map for each Physical Activity Site group. Spatial accessibility and distribution map data were classified using Jenks Natural Breaks, a standard GIS classification method.

3.4 INFLUENCE OF NEIGHBORHOOD-LEVEL SOCIOECONOMIC FACTORS ON SPATIAL ACCESSIBILITY TO PHYSICAL ACTIVITY SITES IN NUECES COUNTY, TEXAS URBAN AREAS

In the same manner as previously indicated, census tracts were used as the unit of analysis for measuring spatial accessibility to physical activity sites and to represent individual neighborhoods. In addition to the removal of Tract 9900, 5 additional census tracts representing the Corpus Christi airport and the four peri-urban neighborhoods were also excluded. Therefore a total of 76 census tracts were used to represent urban areas in Nueces County. A Pearson's Correlation Coefficient analysis was conducted for spatial accessibility to All Physical Activity Sites and several socioeconomic variables chosen from four broad categories – Household income, Transportation, Education and Race/ Ethnicity - indicated in Table 4.2. These four variable categories were selected because they are consistently presented as key variables that are potentially significant in explaining the relationship between spatial access to physical activity sites and obesity in the literature (see section 2.3.1) of their consistent appearance in the spatial accessibility literature as important socioeconomic variables were obtained from the U.S. census and the percentage of each variable was subsequently calculated for each census tract. The variables showing the highest correlation to spatial accessibility were then used to create the three socioeconomic variables that were used in a global Ordinary Least Square (OLS) regression analysis and Spatial Autocorrelation in ArcGIS 10.1 (ESRI).

OLS regression is a type of inferential statistical analysis method used to model, or to predict in some cases, the relationship between a dependent variable and a group of independent or explanatory variables. It shows the magnitude and direction (positive or negative) of a straight line relationship (that is a change in Y for changes in X) between the independent and dependent variables. Six criteria must be satisfied before a global OLS model is considered unbiased or trustworthy: 1) variable coefficients should have the expected sign; 2) There should be no multi-collinearity among explanatory variables (Variance Inflation Factor (VIF) should be < 7.5); 3) coefficients are statistically significant; 4) residuals are normally distributed (Jarque-Bera test is not statistically significant); 5) strong adjusted R^2 and R^2 values; and 6) check for non-stationarity of relationships across the study area. If non-stationarity exists, the Wald statistic is used to asses overall model significance (ESRI, 2009). Geographically Weighted Regression can also be used to detect local relationships between the independent and explanatory variables if no spatial regime variables are important in the regression (ESRI, 2009).

In order to assure that the regression model was not biased (e.g. model residuals were spatially random) a Global Moran's I Spatial Autocorrelation statistic was calculated. Global Moran's I gives a general idea about the overall spatial pattern of the data. When spatial pattern or important explanatory information is left in regression residuals, Spatial Autocorrelation will detect it as clustered. Since, it is desirable to capture as much explanatory power in the model as possible, a random spatial autocorrelation pattern is required. The test statistic works by comparing feature locations, in this case the physical activity sites, to a theoretical random pattern. From Tobler's First Law of Geography, we would expect that nearer features would be more similar to each other than features that are further away (ESRI, 2006). This pattern is inherent to spatial data but a violation of the laws of classical statistics. Therefore it is critical to examine spatial pattern at the global level to determine if nearby values as similar by chance or if they are exhibiting spatial clustering (ESRI, 2006).

3.5 CORRELATION AMONG BODY MASS INDEX (BMI), SPATIAL ACCESSIBILITY AND SELF-REPORTED NEIGHBORHOOD CHARACTERISTICS IN THE CORPUS CHRISTI, TEXAS URBAN AREA.

Spatial accessibility was measured by calculating the travel distance from geocoded residence location information obtained from human subject records obtained from two surveys - The *Diet, Exercise and Physical Activity Environment Survey for Adult Residents of Nueces County* and the *Neighborhood Food Environments* and *Disparities in Persons with Diabetes in Nueces County* survey mentioned in section 1.6. A combined total of 635 surveys were captured from both survey instruments. Of those, 357 were from the *Neighborhood Food Environments* survey and 278 from the *Diet, Exercise and Physical Activity Survey.* However, after processing and geocoding only about 73% (n = 465) of the original 635 were available for analysis. This was due to a number of factors. For example, of the original 635 surveys 53 respondents did not include a street number on their address or added a P.O. Box instead, 27 people included no location information, 4 respondents were from outside of the Nueces County area, 10 records were removed because no income information was provided and finally, differences in questions asked between surveys made it difficult to combine them in some cases. Body Mass Index and 8 other categorical variables were created from data in both surveys in addition and 1 other variable from individual spatial accessibility. Body Mass Index was calculated from weight and height data using the following equation: Equation 3.2 BMI is weight in pounds divided by the square of the height in inches all multiplied by 703.

CHAPTER FOUR
RESULTS

Chapter Four is divided into three subsections each presenting the research results for the three research questions presented in Chapter One. Briefly, Research Question One examines the physical activity environment in Nueces County, Texas with the objective of determining the spatial accessibility of physical activity sites in Nueces County. Research Question Two considers the widely hypothesized idea that neighborhood-level socioeconomic characteristics affect spatial access to physical activity sites like parks and recreation facilities. Finally, in Research Question Three, survey data is used to determine if there is an association between spatial access to physical activity resources and obesity in Nueces County neighborhoods.

A total of 81 census tracts were analyzed to measure spatial accessibility. Each census tract represents an individual neighborhood. Neighborhoods were separated into urban (n = 77) and peri-urban areas (n = 4). Urban areas include Bishop, Robstown, Nueces Bay, Corpus Christi Bay, Port Aransas and the Corpus Christi Urban Area. Peri-urban areas refer to those areas outside the urban area boundary and include Agua Dulce, Banquete, Driscoll and Chapman Ranch. Some neighborhoods are individually named others are identified by a regional title (e.g. Corpus Christi Urban Area). Neighborhood or area names and titles are based on regional, topographic or city names located in or near the neighborhood as opposed to the precise geographic location of cities or features. The output of spatial accessibility was a numerical value that represents distance in miles. Distance measures were joined to Tiger/Line census tracts using GIS then symbolized by quantity to create choropleth maps of spatial accessibility for seven groups of physical activity sites: All Physical Activity (PA) Sites (n = 338), Parks (n = 226), Non-park PA Sites (n = 112), Sports and Fun Sites (n = 46), Fitness Sites (n = 34), Youth and Recreation Centers (n = 22) and Golf Courses (n = 10). The latter four groups (Sports and Fun Sites, Fitness Sites, Youth and Recreation Centers and Golf Courses) are subsets of the group Non-park physical activity sites. Spatial accessibility is represented in miles to the nearest PA

Site on each spatial accessibility map and is symbolized into six classes represented by six colors that are referenced throughout the thesis as yellow, light orange, medium orange, light brown, dark brown and brick for descriptive purposes. Yellow hues represent neighborhoods with the shortest distances to the nearest Physical Activity Site from the population center while brick hues represents neighborhoods that are furthest from PA Sites.

4.1 MEASURING SPATIAL ACCESSIBILITY TO PHYSICAL ACTIVITY SITES IN NUECES COUNTY, TEXAS NEIGHBORHOODS

A ratio of PA Sites to population was calculated and symbolized into 5 classes represented by the colors yellow, light orange, medium orange, dark orange and red to create a series of Distribution maps for each PA Site group. Values in the Distribution maps do not have intrinsic meaning; rather they can be used to assess the adequacy of the number of physical activity resources for the size of the population within each neighborhood. Higher values, symbolized with lighter colors, imply that the number of physical activity sites is adequate for the size of the population. Darker colors imply that there are too few PA Sites to accommodate the size of the neighborhood population. A set of Location maps display the geographic location of physical activity sites for each of the seven activity groups. In the analysis of Research Question One that follows, all 3 types of maps are cross referenced, especially Distribution and Spatial Accessibility maps, to provide a wider scope for understanding resource availability among neighborhoods. Finally, a series of choropleth maps were generated combining results from the Spatial Accessibility and Distribution maps to visualize neighborhoods where physical activity resources are greatest in terms of both spatial accessibility and availability.

4.1.1 Spatial accessibility and distribution of All Physical Activity Sites, Parks, and Non-park physical activity sites

4.1.1.1 All Physical Activity Sites

A total of 338 physical activity sites, comprised of 226 parks and 112 Non-park physical activity sites, were analyzed to measure spatial accessibility (Figures 4.1 and 4.5). The Location and Distribution maps, Figures 4.1 and 4.2 respectively, show that neighborhoods located outside urban areas contain considerably fewer physical activity sites in general and that the majority of the sites in peri-urban areas are parks or green spaces. A dark purple hue was used to symbolize the neighborhood containing the Corpus Christi (CC) International airport because it contains a negligible population size of just 11 people and contains no physical activity sites. The CC airport neighborhood is therefore an outlier in the dataset and was excluded from statistical analyses in Research Question Two. However, the CC airport neighborhood is retained for the analysis of accessibility in Research Question One due to the fact that the value (and therefore symbology) of the neighborhood varies with variation in spatial accessibility (e.g. distance measurements) among the seven activity groups.

In terms of spatial accessibility, Figures 4.3 and 4.4 show that distances to the nearest physical activity sites in peri-urban areas are, in some cases, more than double the distance to the nearest PA Sites in urban areas. For example, the nearest physical activity sites in Banquete and Driscoll are 5 - 10 miles from areas where the majority of the population live compared to Agua Dulce and Chapman Ranch were travel distances to the nearest PA Site is between 3 - 5 miles (Figure 4.3). Thirty-eight percent (31/81) of all Nueces County neighborhoods have high accessibility whereby the nearest Physical Activity Site is less than half a mile (0.357 miles) from population centers; 73% (59/81) travel less than one mile (0.769 miles) to the nearest PA Site; and 89% (72/81) travel less than 1.5 miles (1.448 miles) to access the nearest Physical Activity Site. All of these neighborhoods are located in urban area. By contrast, in 2.5% (2/81) of county neighborhoods - or in half (2/4) of peri-urban neighborhoods - travel distances are greater than 5.3 miles (Figure 4.3). In the peri-urban neighborhoods of Agua Dulce and Chapman Ranch the nearest physical activity site is 5 miles from the population center. In fact, with the exception of certain physical activity groups, peri-urban neighborhoods always have larger travel distances to physical activity sites than urban area neighborhoods. Figure 4.4 shows the disparity in frequency distribution of spatial accessibility to All physical activity sites in urban and peri-urban areas. There are only 4 peri-urban neighborhoods compared to 77 urban neighborhoods in the county and the average travel distance for peri-urban neighborhoods is 7.5 miles compared to 0.6 miles in urban areas. Due to this disparity in neighborhood number and spatial accessibility peri-urban neighborhoods were excluded from statistical analysis in Research Question 2. Figures 4.3 – 4.5 make it clear that for residents living in peri-urban areas, especially Banquete, Driscoll and Chapman Ranch, it is necessary to travel outside the neighborhood in order to access varied kinds of activity sites including gyms, swimming pools, Golf Courses, recreation centers or places that offer instructional courses such as yoga, Pilates or parasailing.

In urban areas, Nueces Bay and the adjacent mushroom-shaped neighborhood located between Nueces Bay and Corpus Christi Bay are characterized by a high site to population ratio on the Distribution map in Figure 4.2. The high ratio values suggest that there are an adequate number of PA Sites to accommodate the size of the population in these neighborhoods and this is supported when compared to the high concentration of park and non-park physical activity sites in these neighborhoods shown in Figure 4.1. However, at 1 - 3 miles to the nearest physical Activity Site, spatial accessibility to PA Sites in Nueces Bay and the adjacent mushroom-shaped neighborhood (located between Nueces Bay and Corpus Christi Bay) is lower than would be expected (Figure 4.3). It does not intuitively make sense for travel distances to be this lengthy in two neighborhoods where there are higher than usual numbers of physical activity sites.

In Nueces Bay, the discrepancy is due to the geographic distribution of sites and the location of the population center (e.g. PWMC) of the neighborhood. This neighborhood is mostly inundated by the Nueces Bay creating a situation where the majority of the population resides on the western side of the neighborhood while the vast majority of physical activity sites are located under or adjacent to the Nueces Bay Causeway/U.S. Highway 181 on the eastern side of the neighborhood. Thus, although there are adequate numbers of physical activity sites (n = 11) for the size of the population (approximately 2,600 inhabitants) residents can travel up to 3 miles to access those sites. Therefore, it is not surprising that the nearest PA Site is located in an adjacent neighborhood rather than within the neighborhood. However, the travel distance between the population center and the nearest PA Site in an adjacent neighborhood is still relatively large (2.16 miles). The mushroom-shaped neighborhood contains 19 physical activity sites, 13 of which are Parks and 6 Non-park Sites. This is by far the largest number of physical activity sites in any one neighborhood (Figures 4.1 and 4.6). Yet, again, the high number PA Sites within this relatively compact neighborhood boundary do not match the larger travel distances shown on the accessibility map in Figure 4.3. In this case, the discrepancy is due to the location of the population center near the Nueces Bay Causeway/U.S. Highway 181, which was determined to be the most optimal route to the nearest Physical Activity Site using network analysis. Using the highway route, however, means that residents would need to travel at least one mile outside of the neighborhood when there are a number PA Sites less than half a mile from where most people live within the neighborhood. In reality, it is highly doubtful that residents would bypass local resources and travel outside the neighborhood to access physical activity sites in this particular case. For these reasons, therefore, the mushroom-shaped neighborhood is an anomaly in the accessibility research results in that travel distances are likely to be much shorter than indicated on Accessibility maps.

4.1.1.2 Parks

Two hundred twenty-six parks and green spaces were geocoded and visualized accounting for 67% (226/338) of the total number of physical activity sites in the dataset (Figures 4.6 and 4.9). Therefore, it is not surprising that there is a great deal of similarity between maps that display data for All physical activity sites and the maps that display the Parks data. In fact the accessibility results for All physical activity sites and Parks are nearly identical. For example, Figures 4.3 and 4.8 show that spatial accessibility to All physical activity sites and Parks is similarly high in Bishop, Robstown and several neighborhoods in the Corpus Christi Urban Area (0.009 – 0.357 miles to nearest site). However, although spatial access is generally high in urban areas, a stark contrast is apparent when the ratio of parks to neighborhood population is considered in the same area. Figure 4.7 shows that several of the neighborhoods where parks a highly accessible (yellow and light orange hues in Figure 4.8) appear dark orange or red (ratio value 0.00 – 0.62) in Figure 4.7. The indication is that while many parks in urban area neighborhoods may be highly accessible (e.g. located less than 1.5 miles from population centers), there may not be enough parks to accommodate the size of neighborhood populations.

In 38% (31/81) of Nueces County neighborhoods the nearest park is less half a mile (0.356 miles) from population centers (e.g. PWMC); in 74% (60/81) of neighborhoods the nearest park is less than one mile (.768 miles) from population centers; and in 91% (74/81) of Nueces County neighborhoods the nearest park is about a mile and half away (1.444 miles) from population centers (Figure 4.8). As in the case of the All physical activity sites results, all of these neighborhoods are located in urban areas. Conversely, 3% (2/81) of neighborhoods require residents to travel 5 or more miles to the nearest park. These two neighborhoods, Banquete and Driscoll, are located in peri-urban areas (Figure 4.8).

Figure 4.8 shows that the mushroom-shaped neighborhood located between Nueces Bay and Corpus Christi Bay exhibits a case where accessibility to parks is relatively moderate (1.445 - 2.707 miles to the nearest park) but where the ratio value of parks to population is high (1.47 - 3.85) in Figure 4.7. Again, the spatial accessibility results for this neighborhood is anomalous because actual travel distances to the nearest park are likely to be much shorter than indicated in Figure 4.8 for reasons previously stated in the All physical activity sites results. In peri-urban areas the Location map (Figure 4.6) shows that there are no parks in Banquete, Driscoll or Chapman Ranch. It may be expected that accessibility to parks would be correspondingly low (e.g. that there would be greater travel distances in areas where there are no parks). This is indeed the case in Banquete and Driscoll where the nearest park is 5 - 10 miles from where the majority of the respective population lives. On the other hand, in Chapman Ranch at 3 - 5 miles to the nearest park, travel distances are nearly half that of Banquete and Driscoll, even though none of these three neighborhoods contain parks. The difference in spatial access in Chapman Ranch is due to the fact that its population center (e.g. PWMC) is closer to south side neighborhoods located in the Corpus Christi Urban Area that contain several parks. Similarly, it may be expected that neighborhoods containing greater numbers of physical activity sites would display corresponding greater accessibility (e.g. there should be shorter travel distances to physical activity resources). This is not always the case. For example, in Agua Dulce and Chapman Ranch the nearest parks are 3 - 5 miles from the respective population centers (Figure 4.8). However, while spatial access is within the same range, these accessibility results mask the fact that there is significant variation in number of parks between these two neighborhoods which is observable in Figure 4.7 and visually apparent in the distribution map in Figure 4.6.

4.1.1.3 Non-park physical activity sites

Thirty-three percent (112/338) of the physical activity sites in the dataset used to conduct this research are classified as Non-park physical activity sites. These sites were grouped into four categories – Sports and Fun sites, Fitness sites, Youth and Recreation Centers and Golf Courses - based on the relative similarity of the activity type (Figure 4.10). These activity sites correspond to actual geographic locations that were geocode and used to create the Location maps. Continuing the general trend exhibited in maps in Chapter Four, there is notable disparity between spatial accessibility in peri-urban vs. urban neighborhoods with regard to Non-park PA Sites (Figures 4.13 and 4.14).

In contrast to peri-urban areas, approximately 44% (34/77) of urban area neighborhoods are located just under a mile (0.72 miles) from the nearest Non-park Physical Activity Site; 82% (63/77) of urban neighborhoods are within 1.5 miles of the nearest Non-PA Site while 96% (74/77) of urban neighborhoods are less than 3 miles from where the majority the population lives to a Non-park PA Site (Figure 4.13). However, though Non-park PA Sites are generally less accessible in the peri-urban areas, Figure 4.13 shows heterogeneity with respect to spatial access across the four peri-urban neighborhoods. At roughly 3 - 6 miles to the nearest Non-park

PA Site, Chapman Ranch shows the greatest accessibility, followed by Agua Dulce and Driscoll where the nearest Non-park PA Site is 6 - 11 miles from where the majority of the population lives (Figure 4.13). Finally, Banquete exhibits the worst spatial access in peri-urban areas where it is 11 - 17 miles to the nearest Non-park PA Site from the population center. On the other hand, while Chapman Ranch appears to have slightly better accessibility to Non-park PA Sites compared to other peri-urban neighborhoods, Figure 4.11 shows that there is only one site in the neighborhood. This is not adequate to accommodate the size of a population of nearly 3,000 people, as is made apparent by the low ratio value of 0.17 – 0.46 (dark orange hue) on the Distribution map in Figure 4.12.

4.1.2 Spatial access and distribution of grouped physical activity sites: Sports and Fun Sites, Fitness Sites, Youth and Recreation Centers and Golf Courses

4.1.2.1 Sports and Fun Sites

Fourteen percent (46/338) of the physical activity dataset is classified as Sports and Fun Sites. This group, like the three physical activity groups that follow, are a subset of the group Non-park physical activity sites. Included in this group are public and private swimming pools, sports fields, athletic organizations, university athletic facilities, public and private tennis courts, one beach (McGee) and sites where instructional courses are taught such as parasailing, baton twirling and gymnastics. Fun sites include miniature Golf Courses, skating/skateboard rinks and parks, bowling allies and family entertainment centers. Generally, the contrast between urban and peri-urban accessibility is pronounced when considering distance to Sports and Fun Sites.

In approximately 23% (19/81) of Nueces County neighborhoods, a sports or fun site is located less than 1 mile (0.74 miles) from the areas of highest population concentration; in 54% (44/81) of neighborhoods the population live less than 1.5 miles (1.44 miles) from the nearest sports or fun site; and 77% (62/81) of neighborhoods contain population concentrations that live just over 2 miles (2.39 miles) from the nearest sports or fun site (Figure 4.16). All of these neighborhoods are located in urban areas. However, approximately 10% (8/81) of neighborhoods within Nueces County travel close to 4.5 miles (4.43 miles) to access the nearest sports or fun site (Figure 4.17). Regarding peri-urban areas, in Chapman Ranch the nearest sports or fun site is 4 - 7 miles from where the majority of the population resides while in Agua Dulce, Banquete and Driscoll travel distances could range between 7 - 23 miles to the nearest sports or fun site. This low accessibility to Sports and Fun Sites in peri-urban areas is mirrored in the corresponding low site to population ratio values on the Distribution map in Figure 4.16. Notice that there are so few neighborhoods that contain sports or fun sites that the bottom ratio value (symbolized in a red hue) represents 0 sites. The effect is that the Distribution map reflects the presence or absence of physical activity sites in a similar way to the Location maps; portraying a clearer illustration of resource scarcity. The same is true the other maps of Grouped data as well (Figures 4.16, 4.20, 4.24, 4.28). The presence and absence of resources is not as clear when physical activity sites are aggregated (e.g. All PA Sites and Non-park PA Sites). This is also especially true in the case of Spatial Accessibility maps where every neighborhood contains a distance measurement to the nearest physical activity site, even if the neighborhood does not contain physical activity sites and the nearest site is therefore outside of the neighborhood. Thus, from referencing the Distribution map in Figure 4.16 alone, it is clear that Agua Dulce, Banquete and Driscoll contain no sports or fun sites in addition to lacking spatial access to any Sports and Fun sites in adjacent neighborhoods.

4.1.2.2 Fitness Sites

Ten percent (34/338) of the Physical Activity Site dataset used in this study is comprised of Fitness Sites that include health club studios/ gyms as well as sites that offer fitness related instruction such as Pilates and yoga. Figure 4.21 shows that the pattern whereby peri-urban areas are characterized by greater distances to physical activity sites compared to urban area neighborhoods holds when considering spatial accessibility to fitness resources. The Distribution map in Figure 4.20 displays how few neighborhoods contain Fitness Sites and how these sites are distributed throughout the county. Areas symbolized in a red hue indicate areas where there are no Fitness Sites located in the neighborhood and in urban areas include Bishop, Robstown, Nueces Bay and several neighborhoods within the Corpus Christi Urban Area. With the exception of Agua Dulce, which contains a single site, Fitness Sites are exclusively located in urban areas. Within urban areas, Fitness Sites appear to be concentrated on the south side of the Corpus Christi Urban Area, Corpus Christi Bay and Port Aransas (Figures 4.19 – 4.21). The spatial accessibility to fitness map corroborates these results (Figure 4.21). Notice that the region of greatest accessibility in urban areas in Figure 4.21 (symbolized in yellow hue) - neighborhoods where the nearest Fitness site is generally less than 1.5 miles (0.31 – 1.37 miles) from population centers - exceeds the area containing a result in the same region on the Distribution map in Figure 4.20 (e.g. areas symbolized in various non-red hues). Again, this indicates that proximity to neighborhoods containing physical activity sites benefits adjacent neighborhoods by reducing travel distances to resources and thereby increasing accessibility in neighborhoods that do not themselves contain physical activity sites.

Approximately 49% (40/81) of neighborhoods in Nueces County have spatial access to a Fitness Site that is less than 1.5 miles (1.37 miles) from population centers; in 72% (58/81) of neighborhoods, population centers have access to a Fitness Site that is less than 3 miles (2.92 miles) away; and in 83% (67/81) of neighborhoods, the majority of the population has access to a Fitness Site that is 3 - 5 miles (2.93 – 5.12 miles) from where they live (Figure 4.21). In peri-urban areas residents in Chapman Ranch travel 5 - 8 miles to reach the nearest Fitness Site, a considerably shorter distance compared to Agua Dulce, Banquete and Driscoll. In Agua Dulce and Driscoll the nearest Fitness Site requires a travel distance of 8 - 16 miles while in Banquete the nearest Fitness Site is up to 22 miles away from where the majority of the population lives. Notice that even though Agua Dulce contains a Fitness Site and Chapman Ranch does not, Figure 4.21 shows that at 5 - 8 miles to the nearest Fitness Site, Chapman Ranch has better access to Fitness Sites compared to Agua Dulce where the nearest Physical Activity Site is between 8 - 16 miles from where most people in the neighborhood live. Chapman Ranch's adjacency to physical activity sites in the Corpus Christi Urban Area benefits the population in Chapman Ranch by reducing the travel distance required to attain access to Fitness Sites. Here again, the fact that the nearest Physical Activity Site may be in an adjacent neighborhood is readily apparent. This result is similar to others previously mentioned and shows how adjacency to neighborhoods with a greater number of physical activity sites helps to mediate lack of accessibility in neighborhoods that do not have adequate physical activity resources.

4.1.2.3 Youth and Recreation Centers

Six percent (22/338) of the physical activity dataset used to conduct this research are comprised of Youth and Recreation Centers. These sites include youth organizations such as the Boys and Girls Club of America and the YMCA as well as senior centers and recreation centers like the Joe Garza Recreation Center. A youth or recreation center is located less than a mile (0.79 miles) from population centers in approximately 14% (11/81) of the neighborhoods in Nueces County; in 48% (39/81) of county neighborhoods a youth or recreation center is less than 2 miles (1.93 miles) away from population centers; and in 80% (65/81) of county neighborhoods, the nearest youth or recreation center is less than 4 miles (3.97 miles) from where the majority to the population lives. All of these neighborhoods are located in urban areas (Figure 4.25). The Youth and Recreation Centers Distribution and Location maps (Figures 4.23 and 24) show that no youth or recreation centers are located in peri-urban neighborhoods. However, the Youth and Recreation Accessibility map (Figure 4.25) shows that in about 6% (5/ 81) of county neighborhoods the nearest youth or recreation center is more than 8 miles (8.19 – 14.58 miles) from the where the majority of the population lives. These five neighborhoods include all peri-urban neighborhoods (Agua Dulce, Banquete, Driscoll and Chapman Ranch) and Port Aransas.

4.1.2.4 Golf Courses

Public and private eighteen - hole Golf Courses account for approximately 3% (10/338) of the physical activity dataset used for this research study. There are no Golf Courses in or adjacent to peri-urban areas while all 10 Golf Courses are sparsely distributed in the Corpus Christi Urban Area and Port Aransas (Figures 4.27 – 4.30). In roughly 10% (8/81) of Nueces County neighborhoods the nearest Golf Course is approximately 1 mile (1.11 miles) from where the majority of the population lives; in 37% (30/81) of neighborhoods the majority of the population lives approximately 2 miles or less (1.12 - 2.20 miles) from the nearest Golf Course; and in 63% (51/81) of county neighborhoods the majority of the population lives less than 3.5 miles (2.21 - 3.38 miles) from the nearest Golf Course. Conversely, approximately 19% (15/81) of county neighborhoods are 5.5 miles or further from the nearest Golf Course.

With two Golf Courses, Corpus Christi Bay contains the largest number of Golf Courses and has a corresponding high degree of spatial access to Golf Courses that are located less than 1 mile to the nearest course (Figure 4.29). The neighborhood adjacent and directly south of the Corpus Christi International airport is one of the few neighborhoods that has a Golf Course and where the population in low enough to reflect a high course to population ratio (0.31 – 0.46, yellow hue) on the Distribution map (Figure 4.28). Port Aransas contains one Golf Course; however, it is not as accessible to residents as they must travel 1 - 2 miles to access the nearest Golf Course (Figure 4.29). Both Corpus Christi Bay and Port Aransas have the same comparatively high course to population ratio value (0.23 to 0.46 / light orange hue). This indicates that the number of Golf Courses is relatively proportional to the number of people living in the neighborhoods. Note that although there are no Golf Courses in peri-urban areas and no Golf Courses in most urban areas, resulting in a red hue covering most of the Distribution map in Figure 4.28, only three neighborhoods - Banquete, Bishop and Driscoll – reflect corresponding degrees of exceedingly low spatial access (e.g. 12 – 22 miles from population centers to the nearest Golf Course, Figure 4.29). Again, this result is due the fact that proximity to neighborhoods containing Golf Courses increases variability in spatial accessibility measures on the Spatial Accessibility map. Thus, even when several neighborhoods do not contain Golf Courses, spatial accessibility is increased (e.g. distances to nearest course decrease) when these neighborhoods are located near a neighborhood(s) that contain one or more Golf Courses.

4.1.3 Greatest spatial access and availability to physical activity sites

Comparing Distribution and spatial access results from previous analyses makes it clear that spatial accessibility alone can only provide a limited view of resource distribution within neighborhoods. While spatial accessibility results offer insight into whether a physical activity site is nearby, they do not provide an indication of whether there are enough PA Site resources within the neighborhood to accommodate the size of the population. Thus, to obtain a wider scope of resource availability, information from both the (Spatial) Accessibility and Distribution maps is required. The map series in Figures 4.31 – 4.37 combine the Accessibility and Distribution results for all seven Physical Activity Site groups to visualize neighborhoods with the greatest accessibility *and* availability within the seven groups of PA activities. The classes used to determine the greatest accessibility and availability map results (Figures 4.31 – 4.32) were defined by the terms in Table 4.1.

Table 4.1 Spatial Accessibility and Distribution classes used to determine Greatest Accessibility and Availability of physical activity sites in Nueces Co., TX

Data	Accessibility (miles)	Distribution (Site / population ratio)	Interpretation
All physical activity sites	≤ 0.769	≥ 0.82	Best access and availability to any PA site
Parks	≤ 0.768	≥ 0.63	Best access and availability to a park
Physical activity sites (Non-park)	≤ 1.48	≥ 0.43	Best access and availability to any PA site that is not a park
Sports and Fun Sites	≤ 1.44	≥ 0.24	Best access and availability to public and private swimming pools, sports fields, athletic organizations, university athletic facilities, public and private tennis courts, one beach (McGee) and sites where instructional courses (e.g. parasailing, baton twirling and gymnastics) and Fun sites including miniature Golf Courses, skating/skateboard rinks and parks, bowling allies and family entertainment centers
Fitness Sites	≤ 2.92	≥ 0.26	Best access and availability to health club studios/ gyms as well as sites that offer fitness related instruction such as Pilates and yoga
Youth and Recreation Sites	≤ 1.93	≥ 0.22	Best access and availability to youth organizations such as the Boys and Girls Club of America and the YMCA as well as senior centers and recreation centers like the Joe Garza Recreation Center
Golf Courses	≤ 2.20	≥ 0.19	Best access and availability to public and private eighteen - hole Golf Courses

The results indicate that the greatest spatial access and availability of physical activity sites is exclusive to urban areas. As physical activity sites become more disaggregated into groups, fewer neighborhoods met the defined accessibility and availability criteria as expected. Approximately 42% (34/81) of neighborhoods in Nueces County met the criteria for spatial accessibility and availability when all physical activity sites were considered; 33% (27/81) met the criteria for parks; 27% (23/81) met the criteria for Non-park PA Sites; 17% (14/81) met the criteria for Sport and Fun Sites; 15% (12/81) met the criteria for Fitness Sites; 11% (9/81) met the criteria for Youth and Recreation Centers; and approximately 4% (3/81) of county neighborhoods met the criteria for both spatial accessibility and availability of Golf Courses (Figures 4.31 – 4.37).

The selection of Spatial Accessibility and Distribution classes referenced above are somewhat arbitrary. Because every neighborhood has a spatial accessibility value (e.g. travel distance in miles) and adjacent neighborhoods benefit from proximity to neighborhoods containing physical activity sites, there tend to be many more neighborhoods with high spatial accessibility values than neighborhoods with high site / population ratios. Therefore, the first two accessibility classes (map hues yellow and light orange) represent a conservative estimate in defining neighborhoods of greatest accessibility and availability. Regarding the Distribution class selection, since the site to population values do not have intrinsic meaning, the three selected classes are also subjective. However, since the lowest ratio values (red hue) typically indicate the absence of PA Sites and the class above it (dark orange hue) can be interpreted as areas containing too few activity sites to accommodate the neighborhood population, excluding these two classes and accepting the remaining three classes was a reasonable, conservative approach to identifying neighborhoods with acceptable PA Site resources to accommodate neighborhood population sizes.

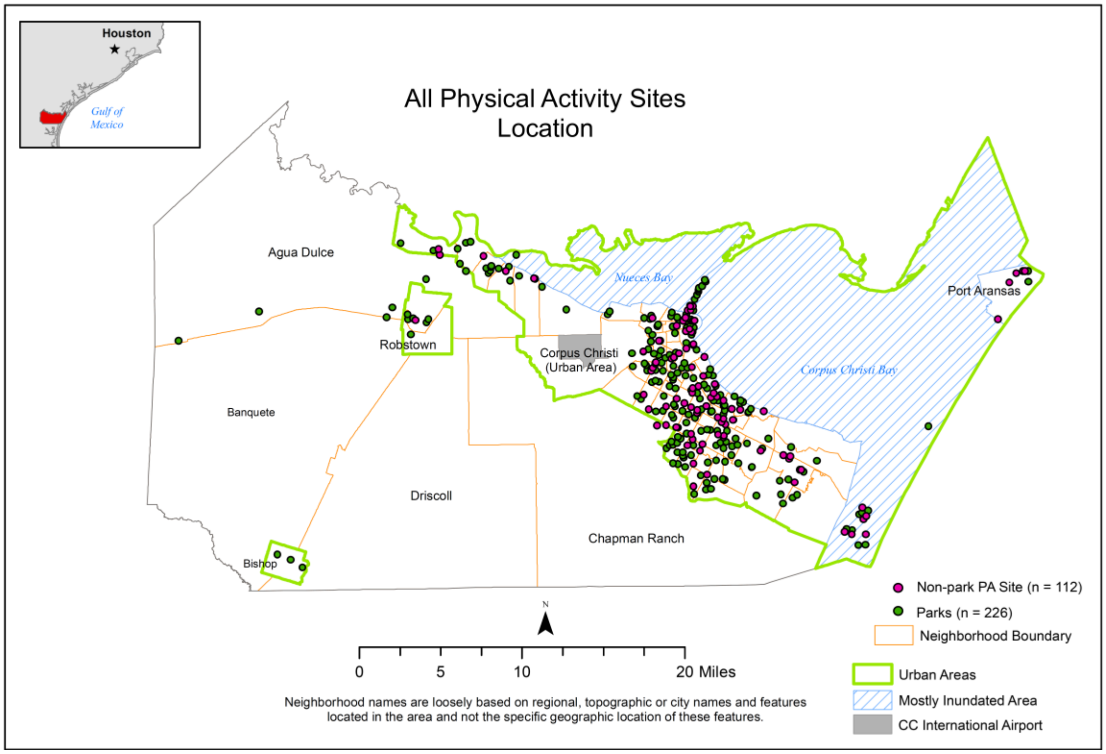


Figure 4.1 Geographic location of all physical activity (PA) sites, Nueces Co., TX

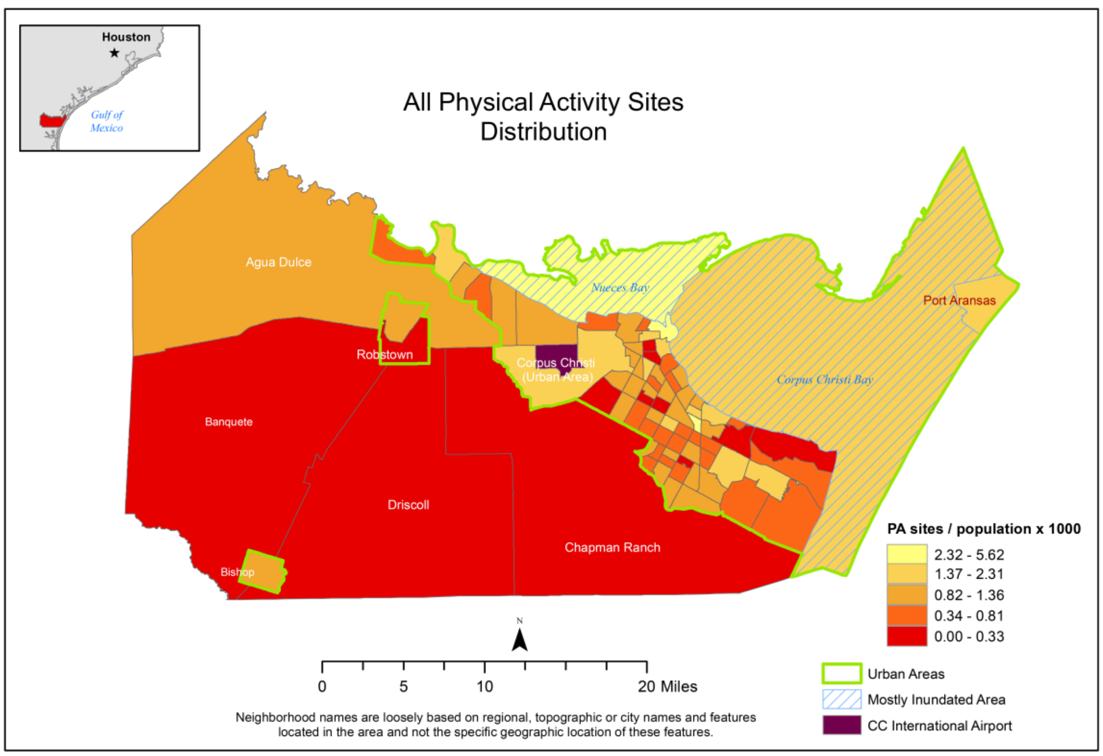


Figure 4.2 Distribution of all physical activity (PA) sites by count per neighborhood population, Nueces Co., TX

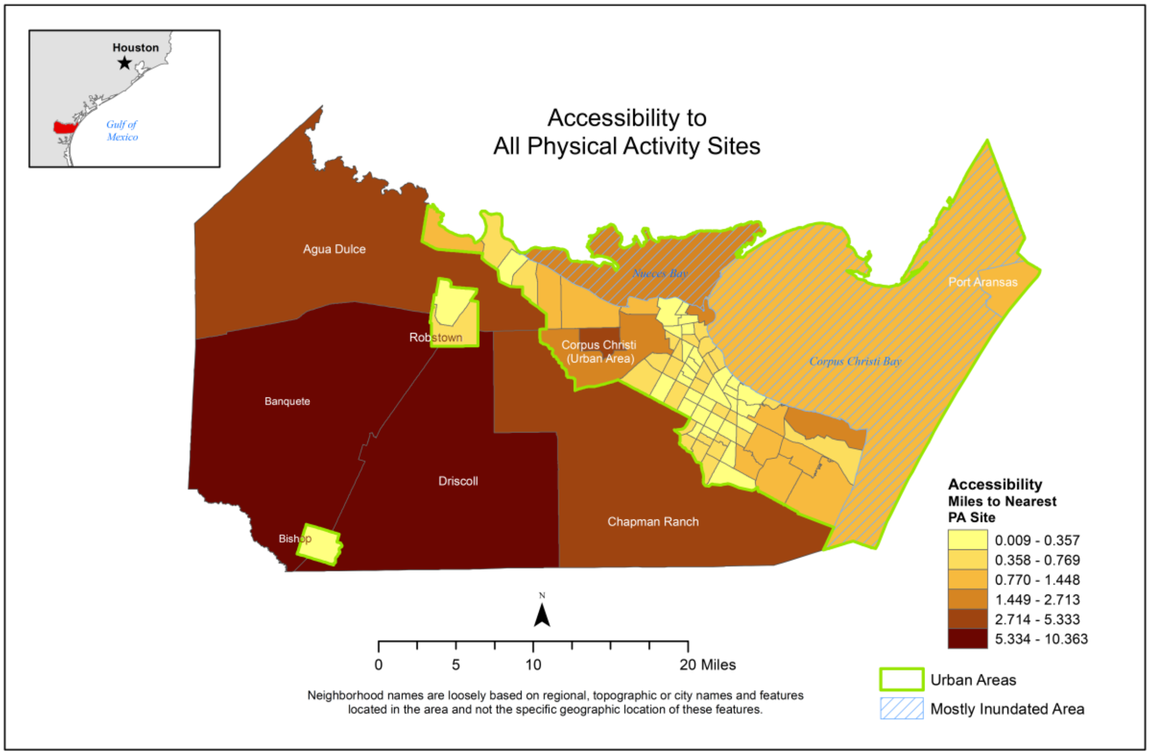
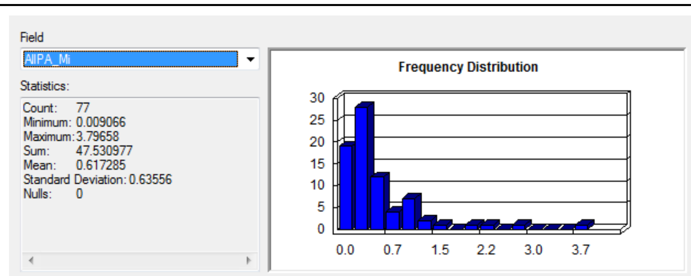
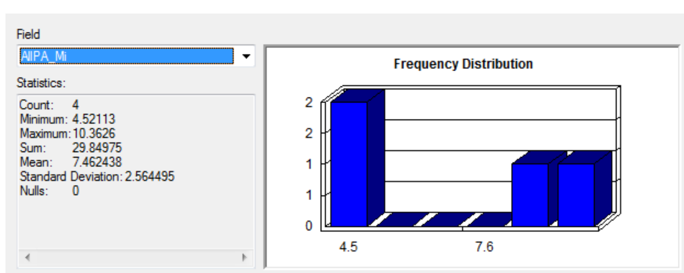


Figure 4.3 Spatial accessibility to all physical activity (PA) sites, Nueces Co., TX

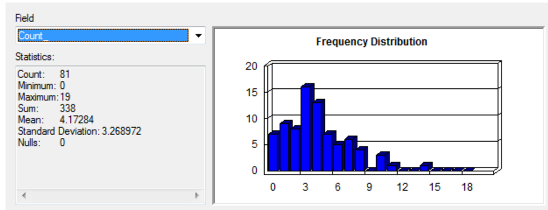


Urban area neighborhoods (n = 77)

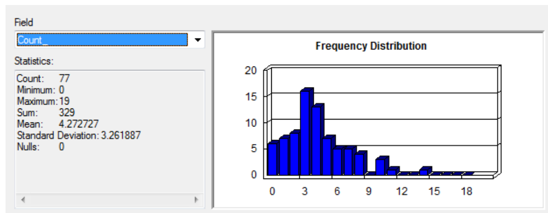


Peri-urban area neighborhoods (n = 4)

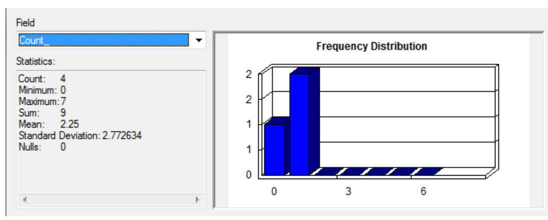
Figure 4.4 Disparity in frequency distribution of accessibility to all physical activity (PA) sites in urban and peri-urban areas, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.5 Frequency distribution of all physical activity (PA) sites in county, urban and peri-urban neighborhoods, Nueces Co., TX

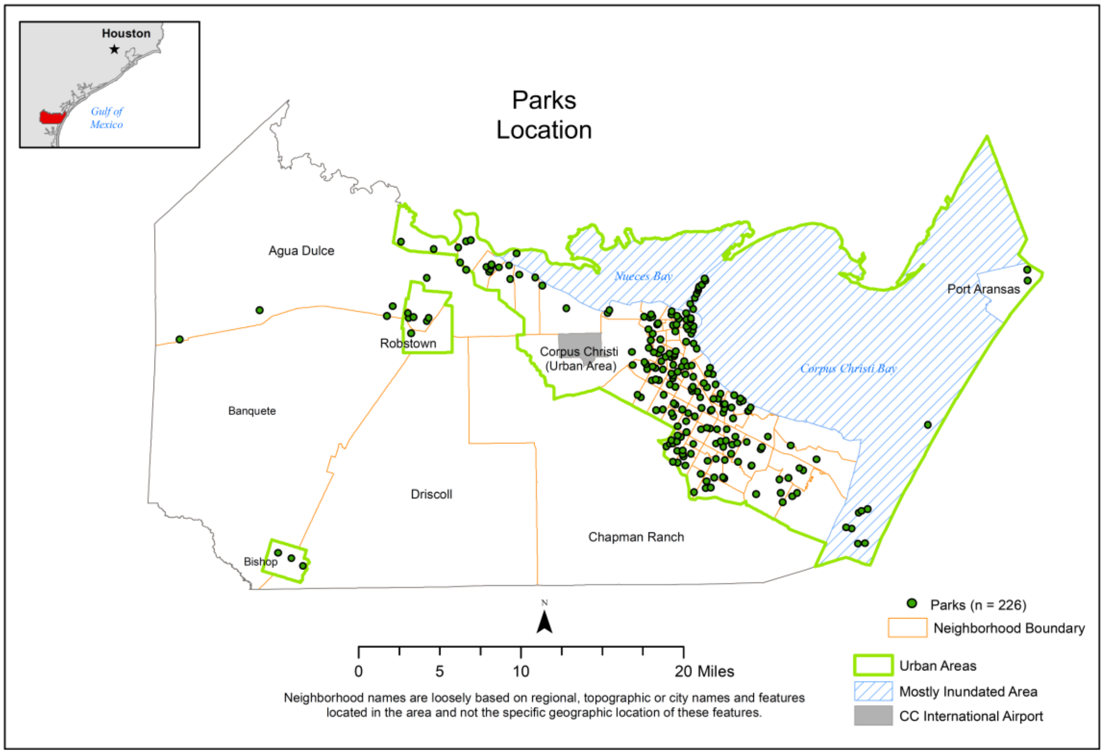


Figure 4.6 Geographic location of parks, Nueces Co., TX

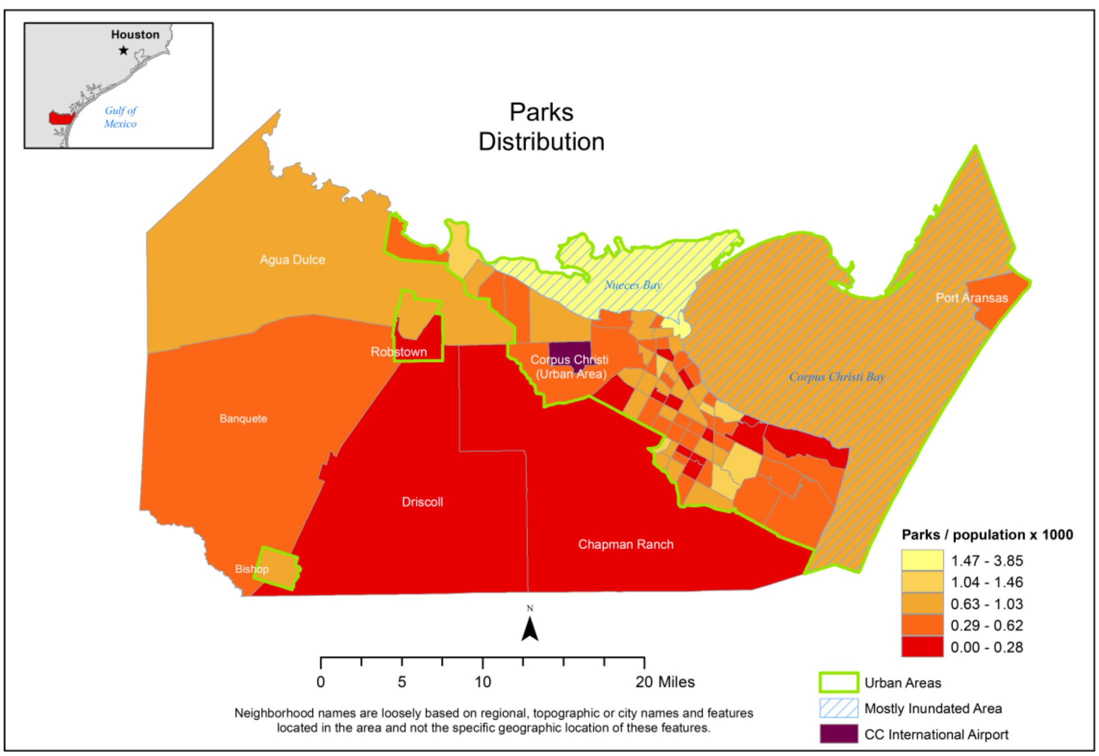


Figure 4.7 Distribution of parks by count per neighborhood population, Nueces Co., TX

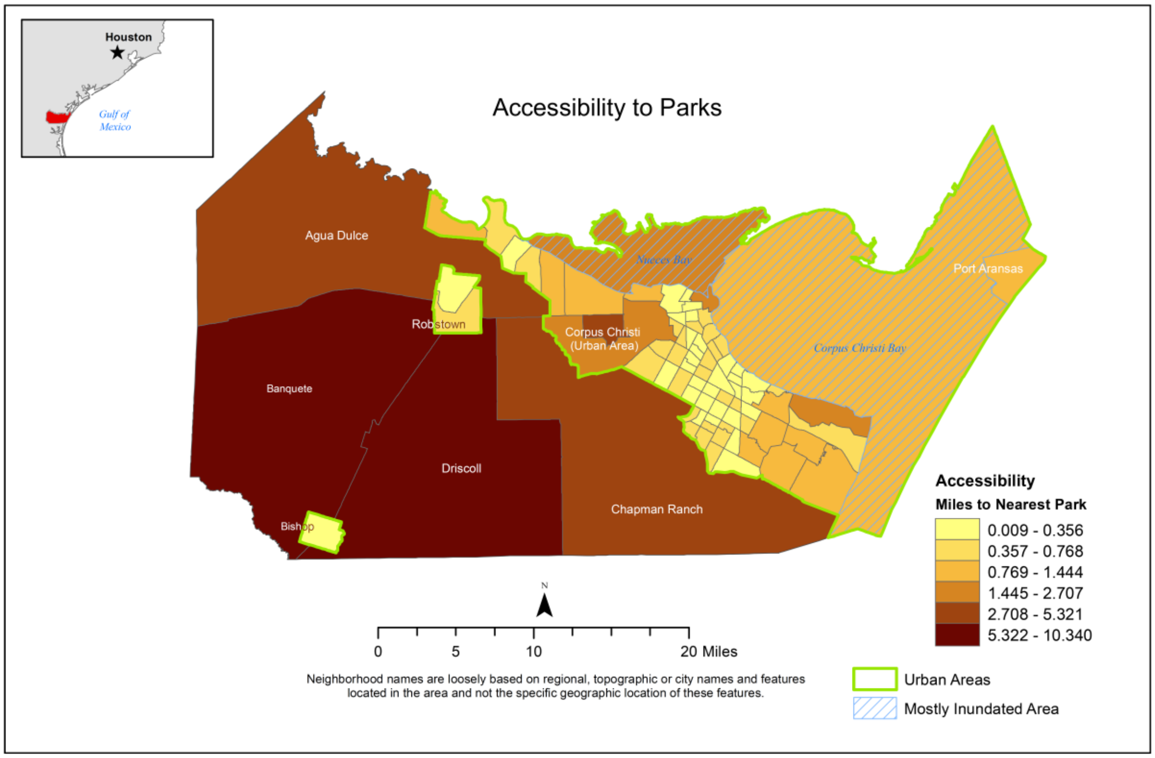
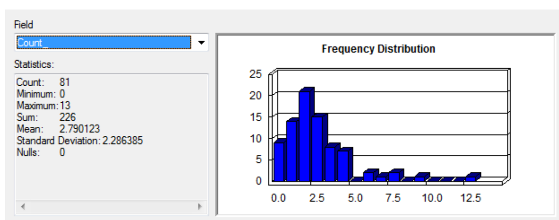
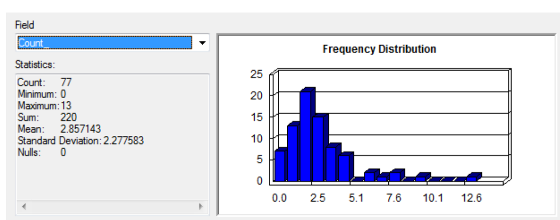


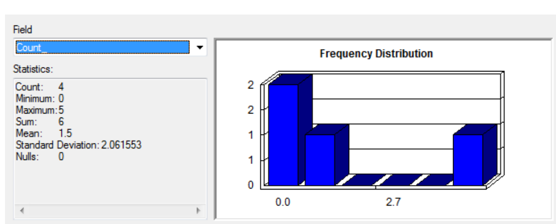
Figure 4.8 Spatial accessibility to parks, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.9 Frequency distribution of parks in county, urban and peri-urban neighborhoods, Nueces Co., TX

As indicated previously, the total number of physical activity sites used to conduct this research (n = 338) were partitioned into Park and Non-park sites. Non-park physical activity sites were further divided into four groups (Sports & Fun Sites, Fitness Sites, Youth & Recreation Centers and Golf Courses). Each of the five resulting physical activity groups is shown in Figure 4.10 below.

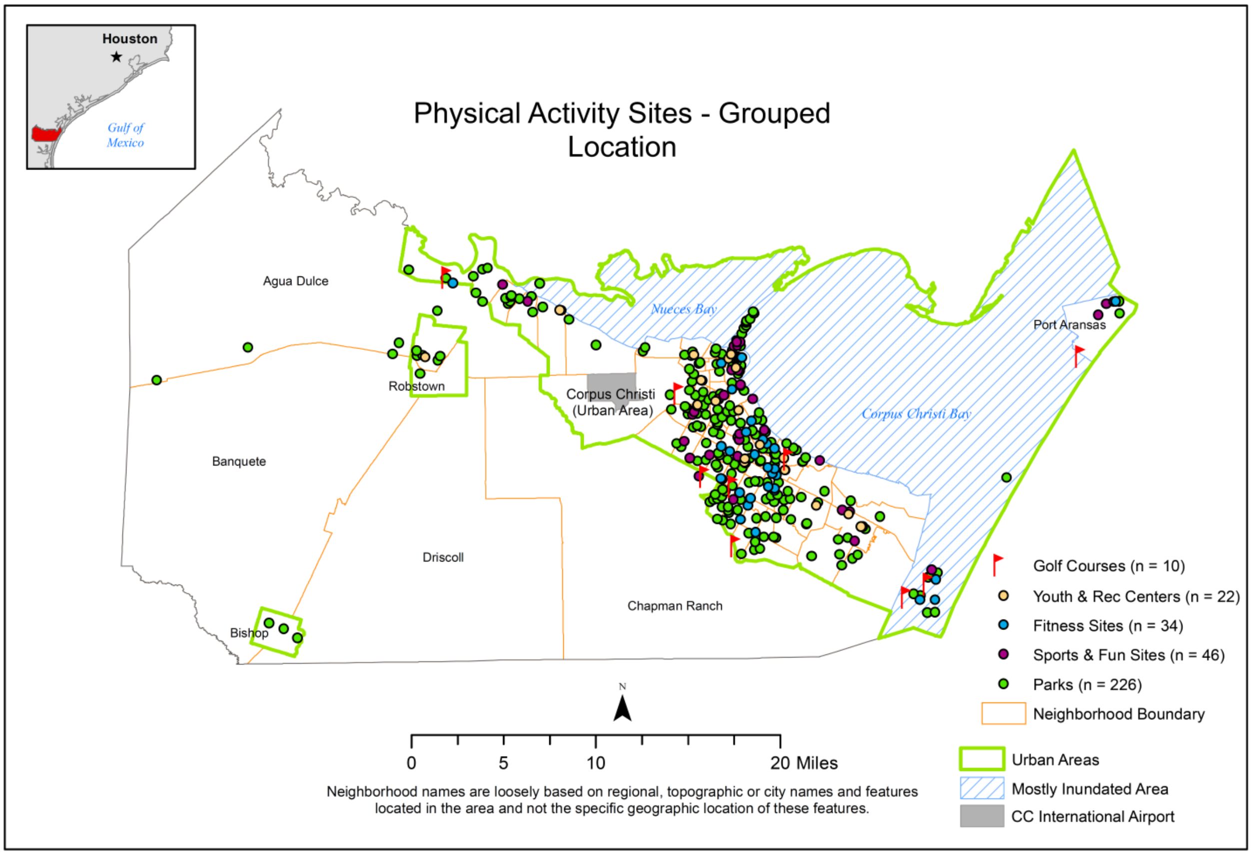


Figure 4.10 Geographic location of physical activity sites grouped into like categories, Nueces Co., TX

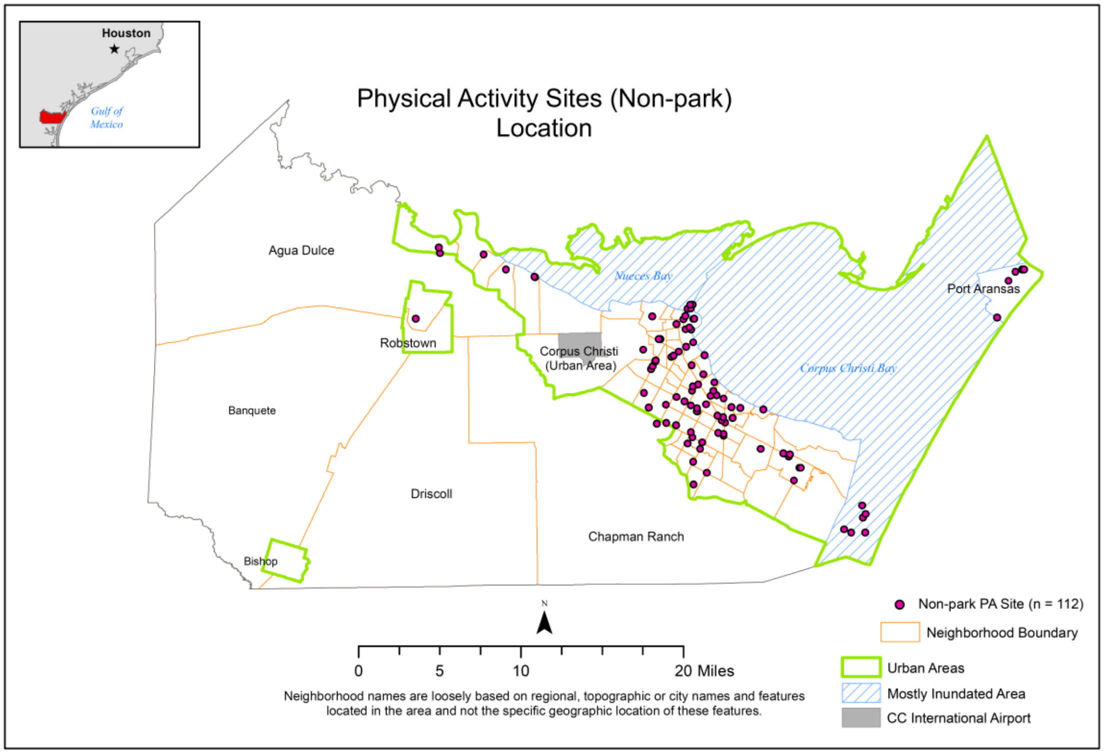


Figure 4.11 Geographic location of non-park physical activity sites, Nueces Co., TX

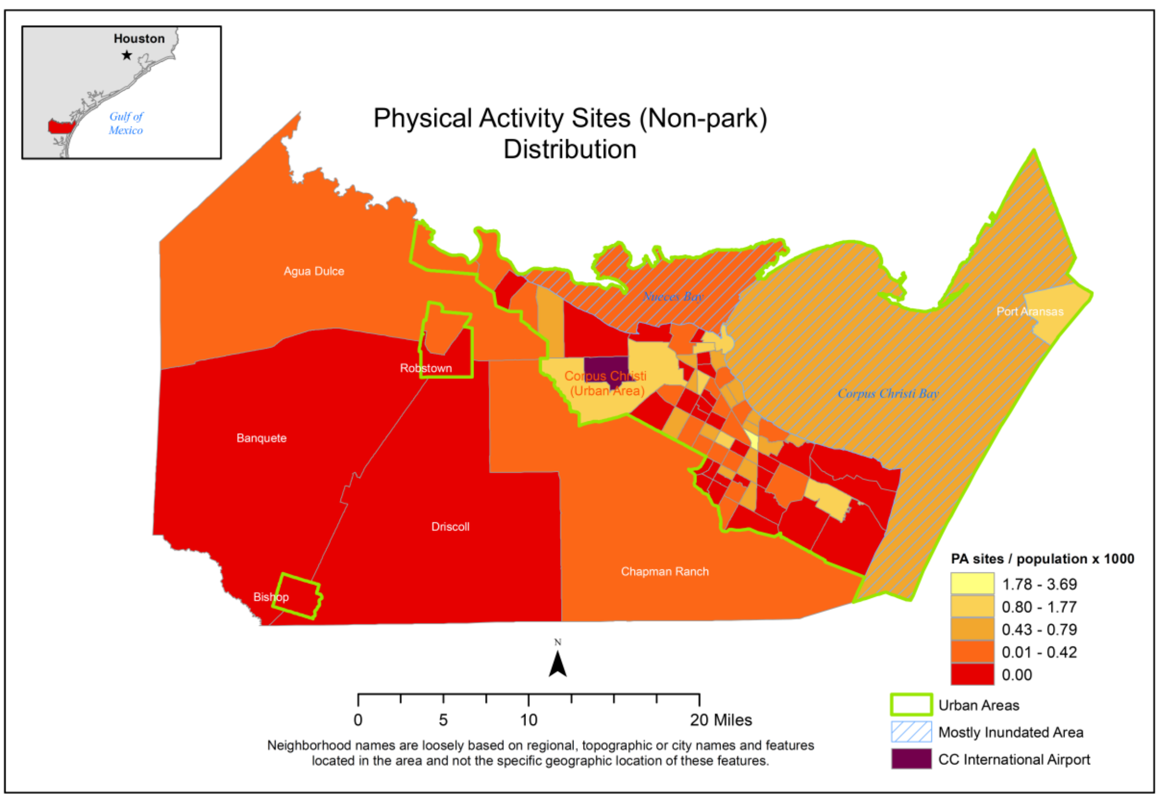


Figure 4.12 Distribution of non-park physical activity (PA) sites by count per neighborhood population, Nueces Co., TX

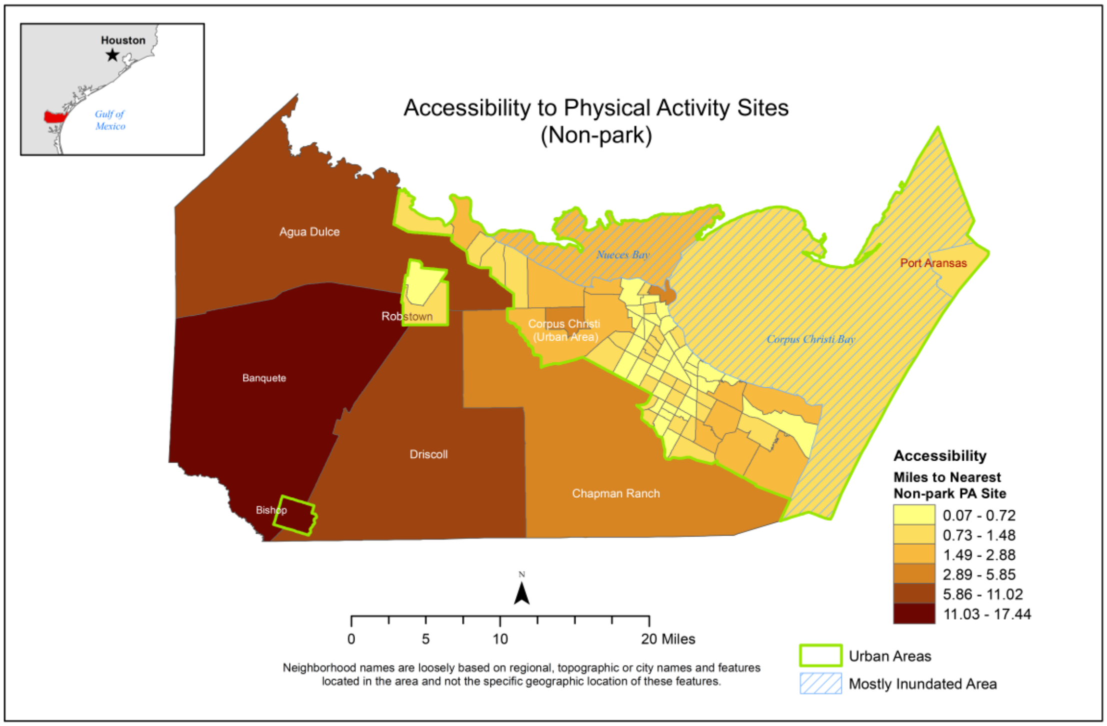


Figure 4.13 Spatial accessibility to non-park physical activity (PA) sites, Nueces Co., TX

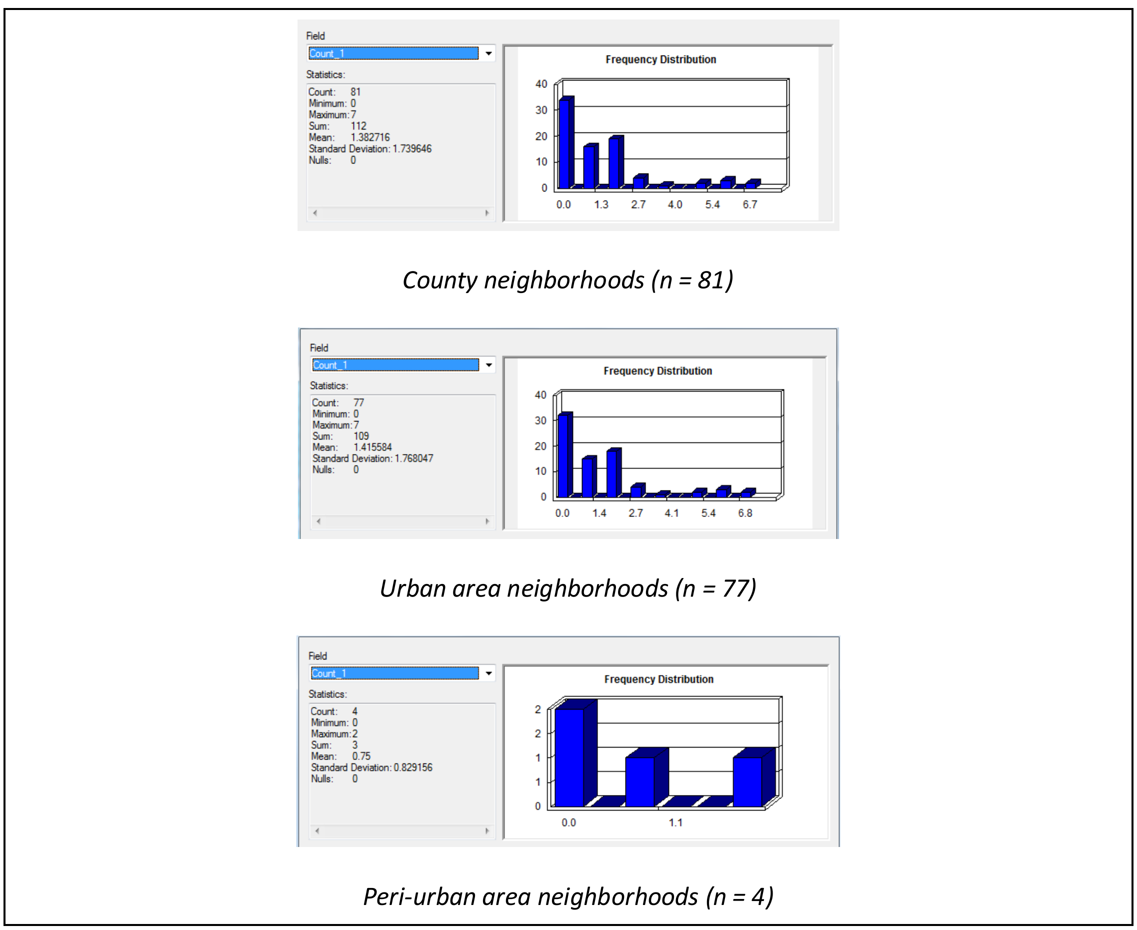


Figure 4.14 Frequency distribution of non-park physical activity sites in county, urban and peri-urban neighborhoods, Nueces Co., TX

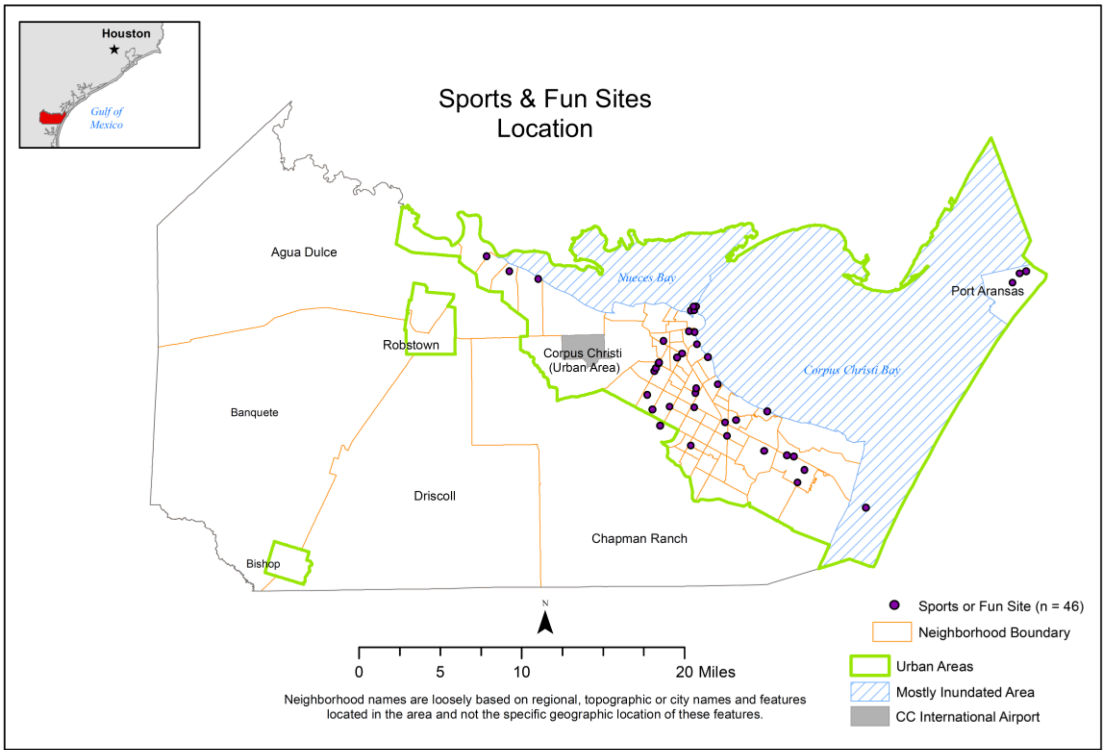


Figure 4.15 Geographic location of sports and fun sites, Nueces Co., TX

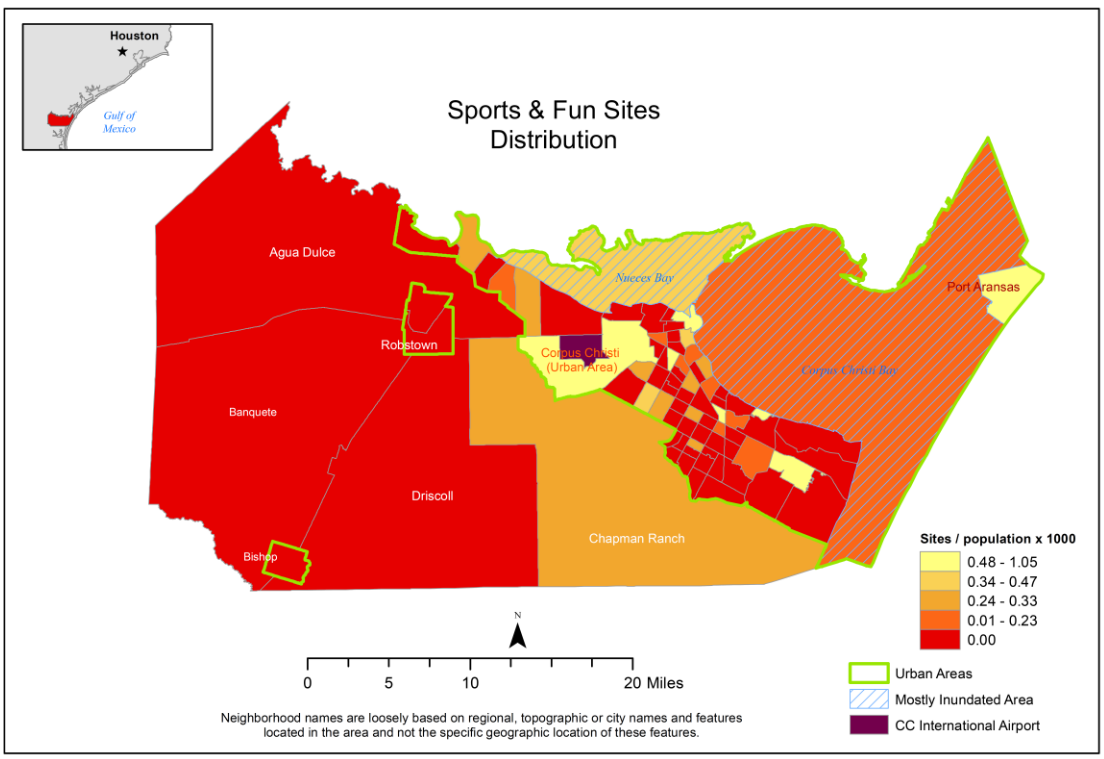


Figure 4.16 Distribution of sports and fun sites by count per neighborhood population, Nueces Co., TX

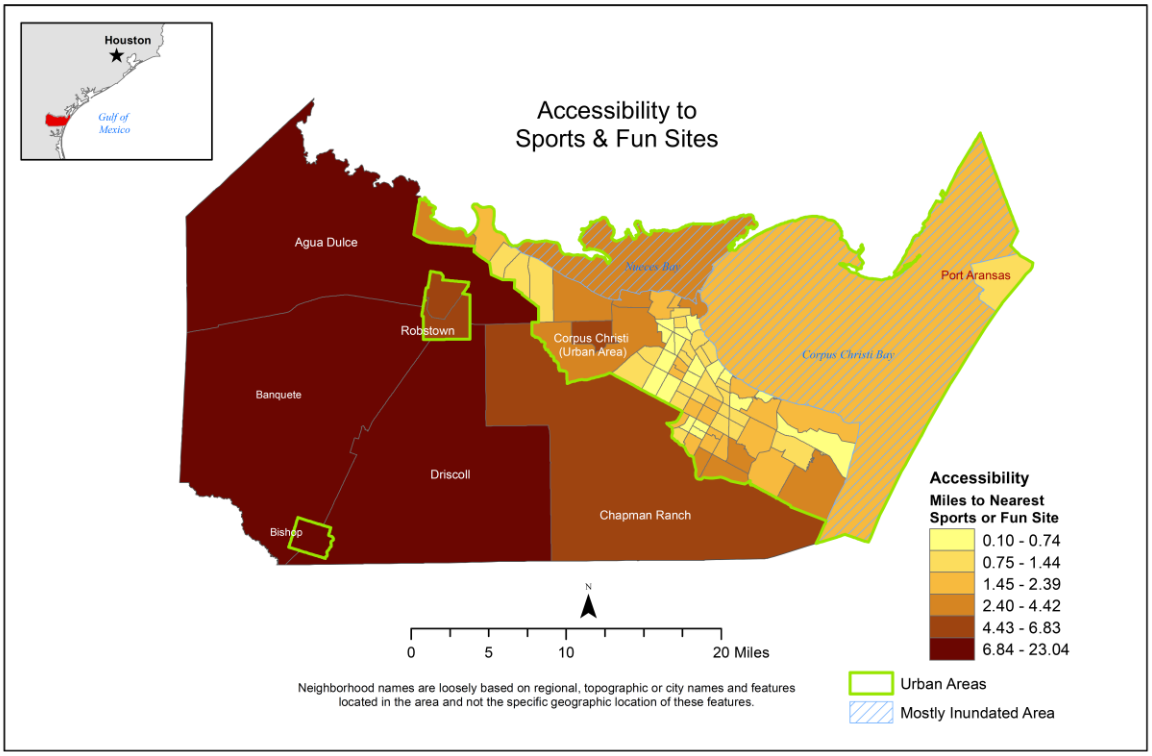
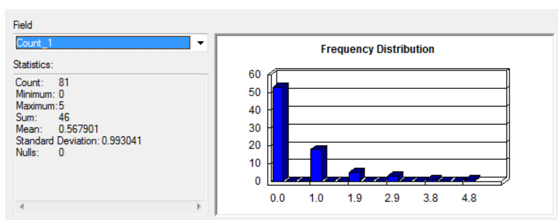
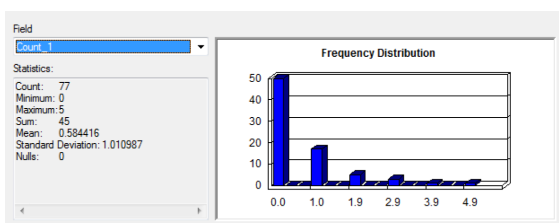


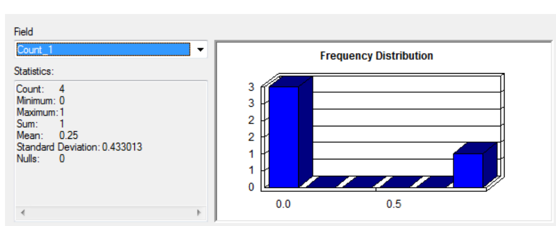
Figure 4.17 Spatial accessibility to sports and fun sites, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.18 Frequency distribution of sports and fun sites in county, urban and peri-urban neighborhoods in Nueces Co., TX

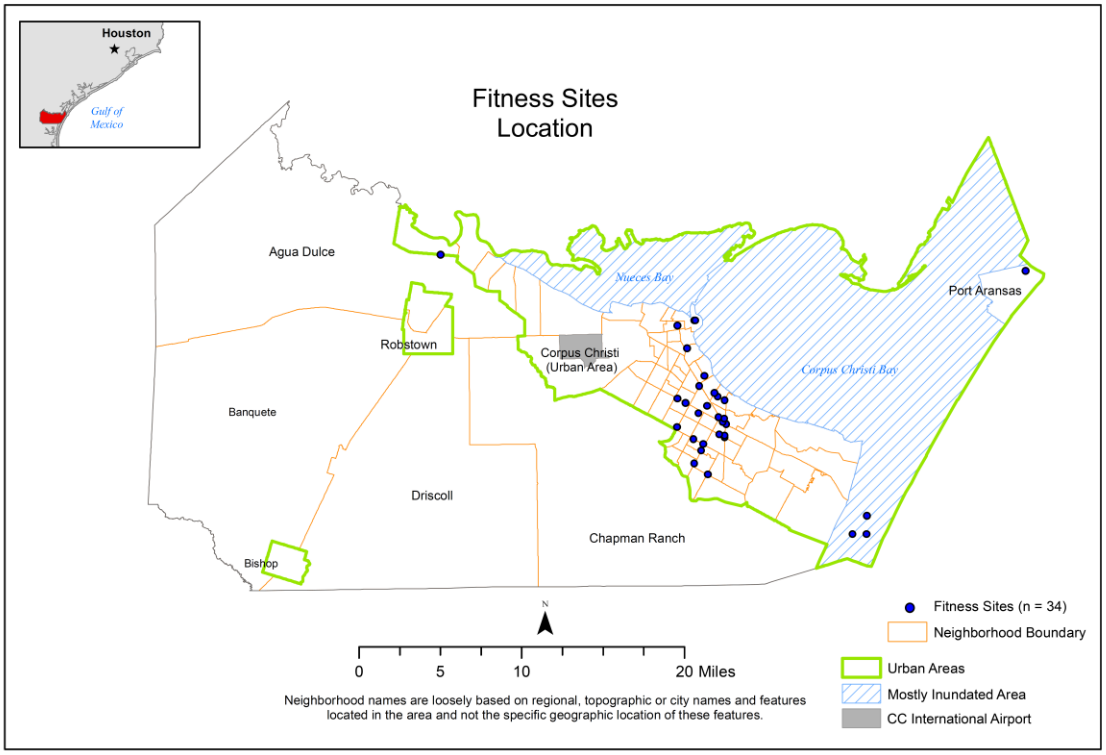


Figure 4.19 Geographic location of fitness sites, Nueces Co., TX

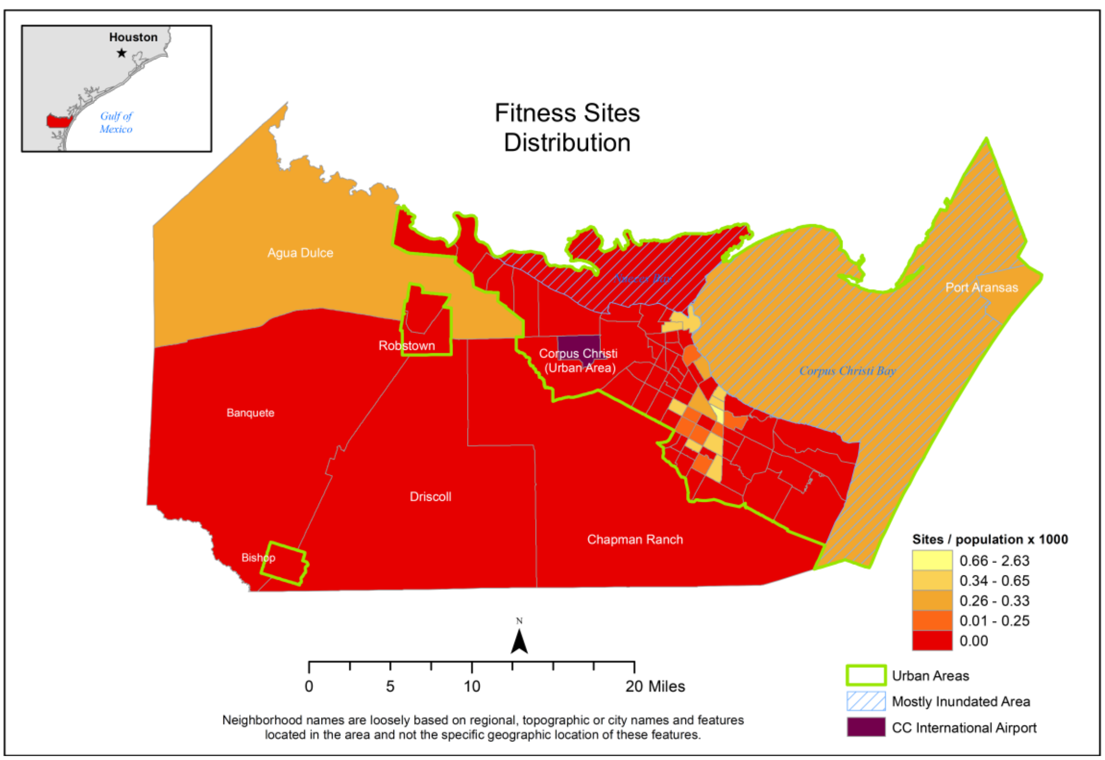


Figure 4.20 Distribution of fitness sites by count per neighborhood population, Nueces Co., TX

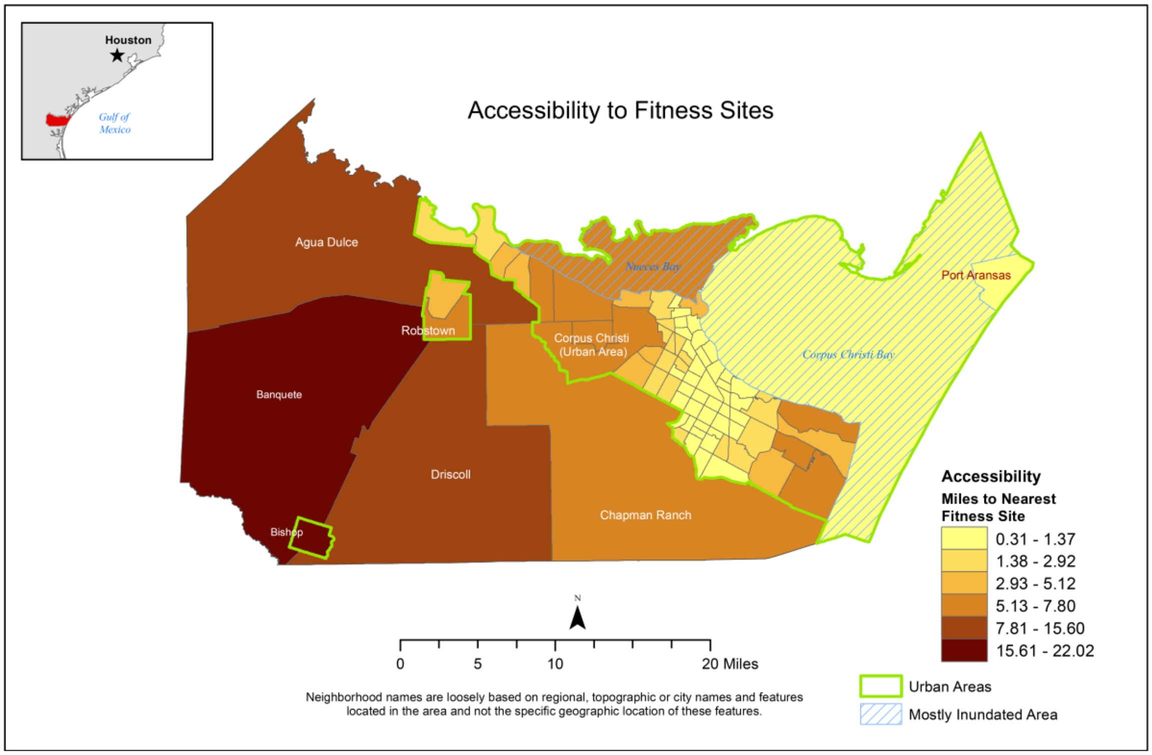
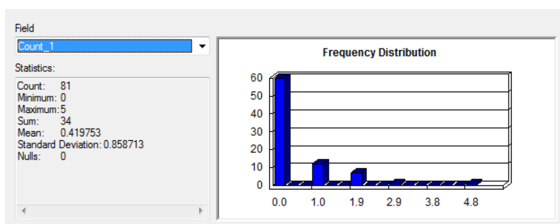
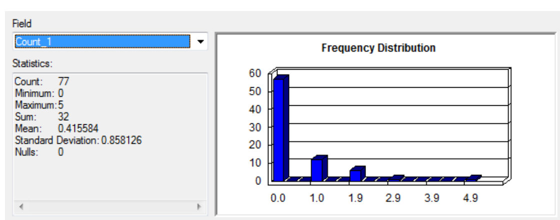


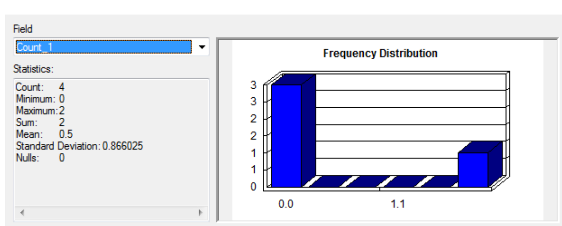
Figure 4.21 Spatial accessibility to fitness sites, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.22 Frequency distribution of fitness sites in county, urban and peri-urban neighborhoods in Nueces Co., TX

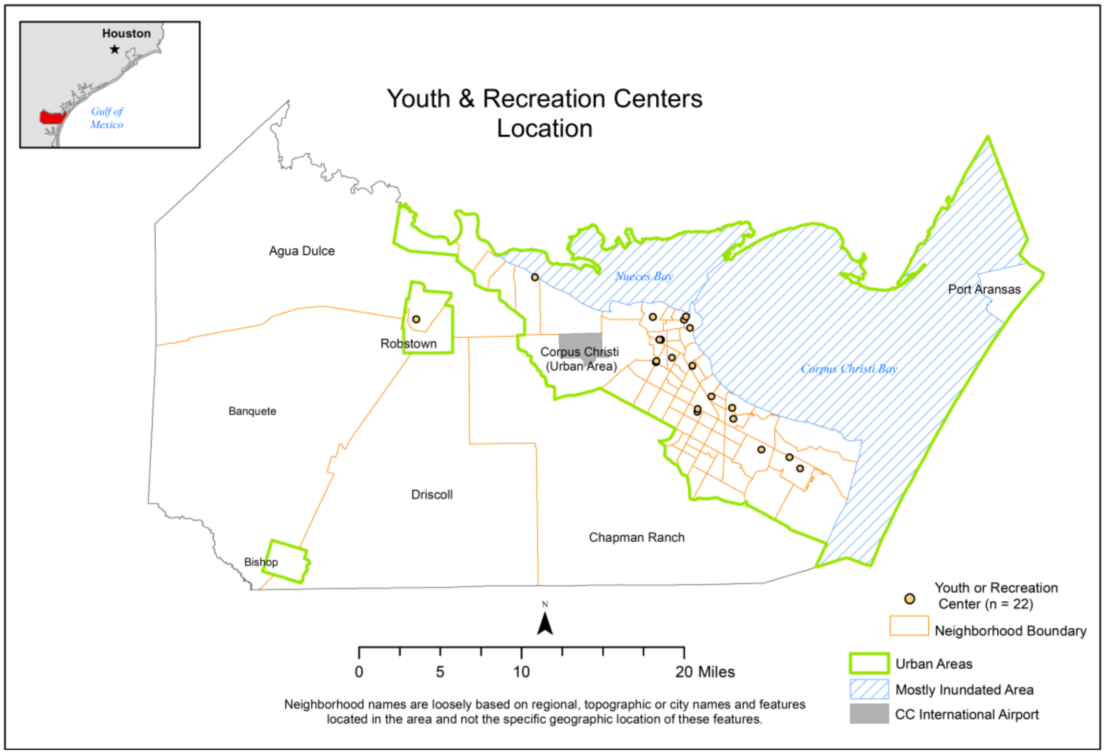


Figure 4.23 Geographic location of youth and recreation centers, Nueces Co., TX

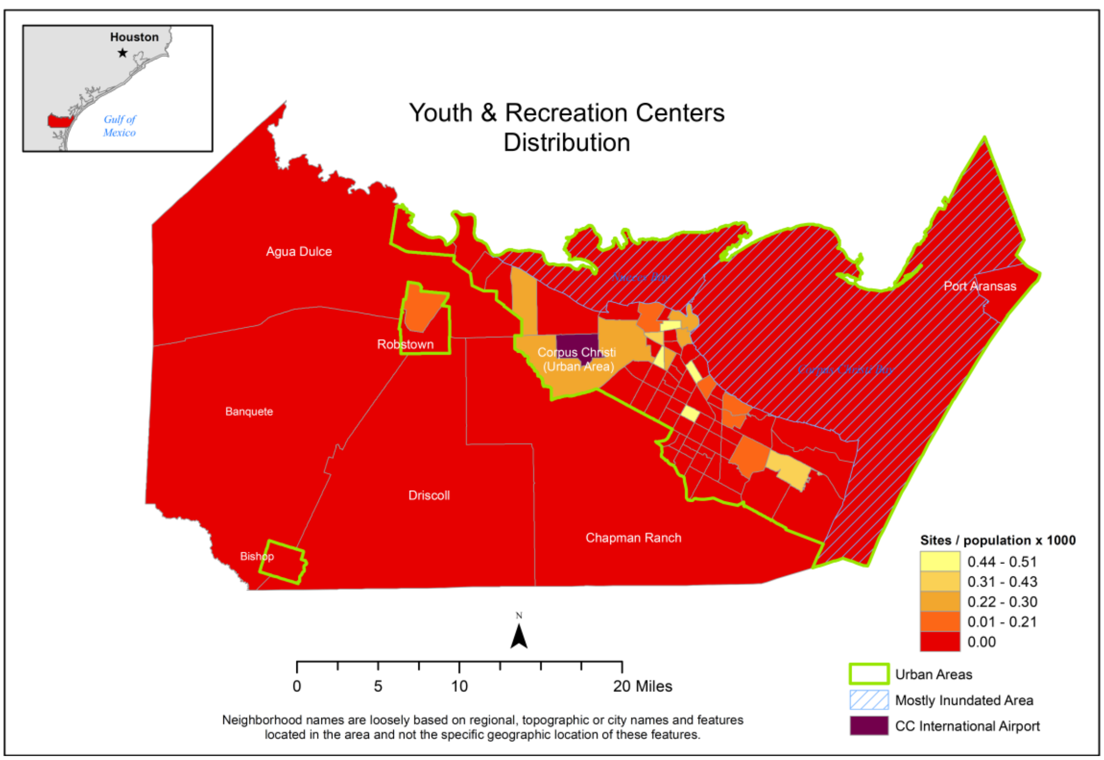


Figure 4.24 Distribution of youth and recreation centers by count per neighborhood population, Nueces Co., TX

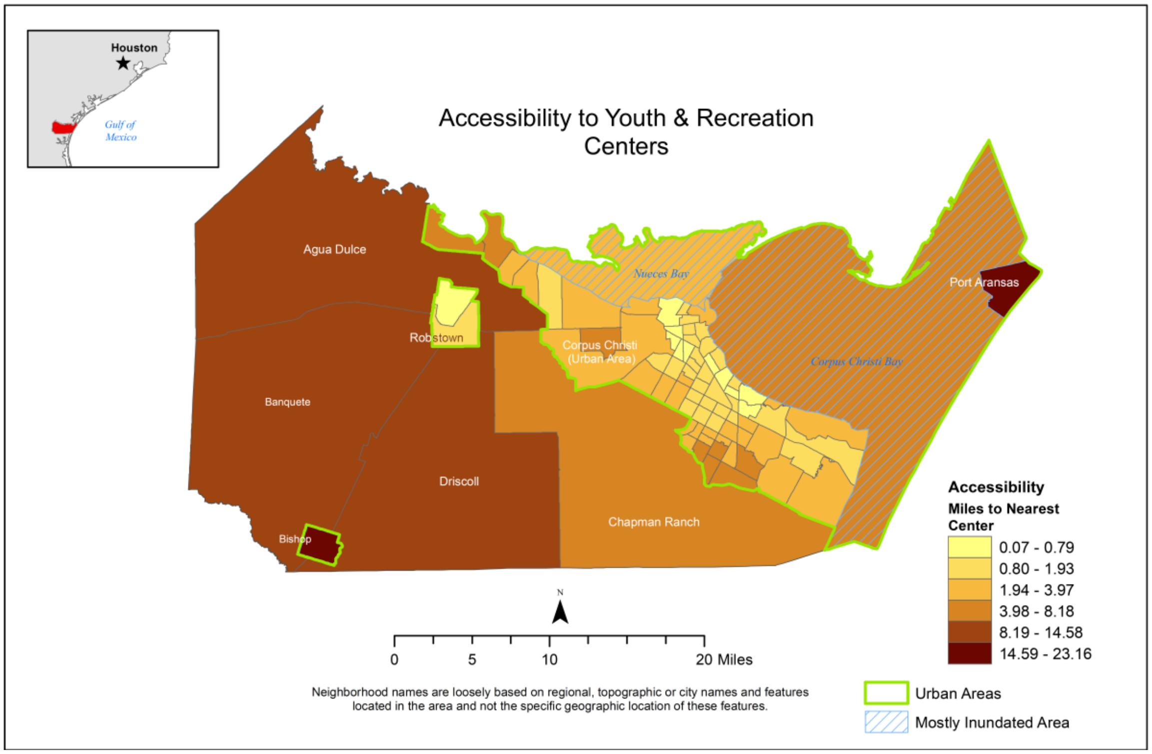
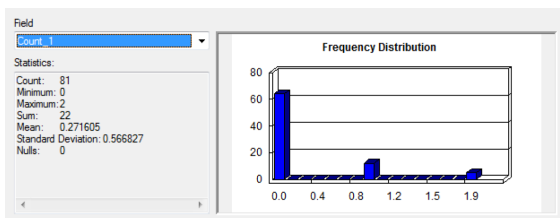
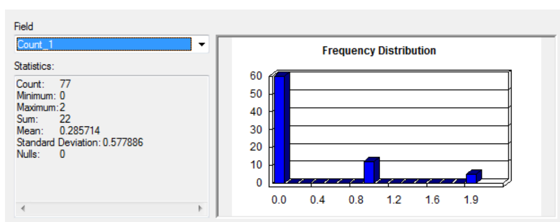


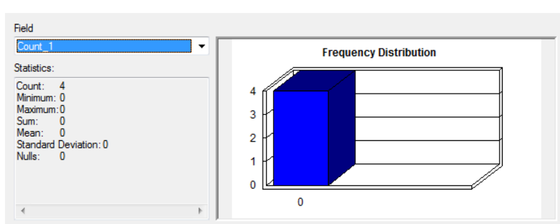
Figure 4.25 Spatial accessibility to youth and recreation centers, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.26 Frequency distribution of youth and recreation centers in county, urban and peri-urban neighborhoods in Nueces Co., TX

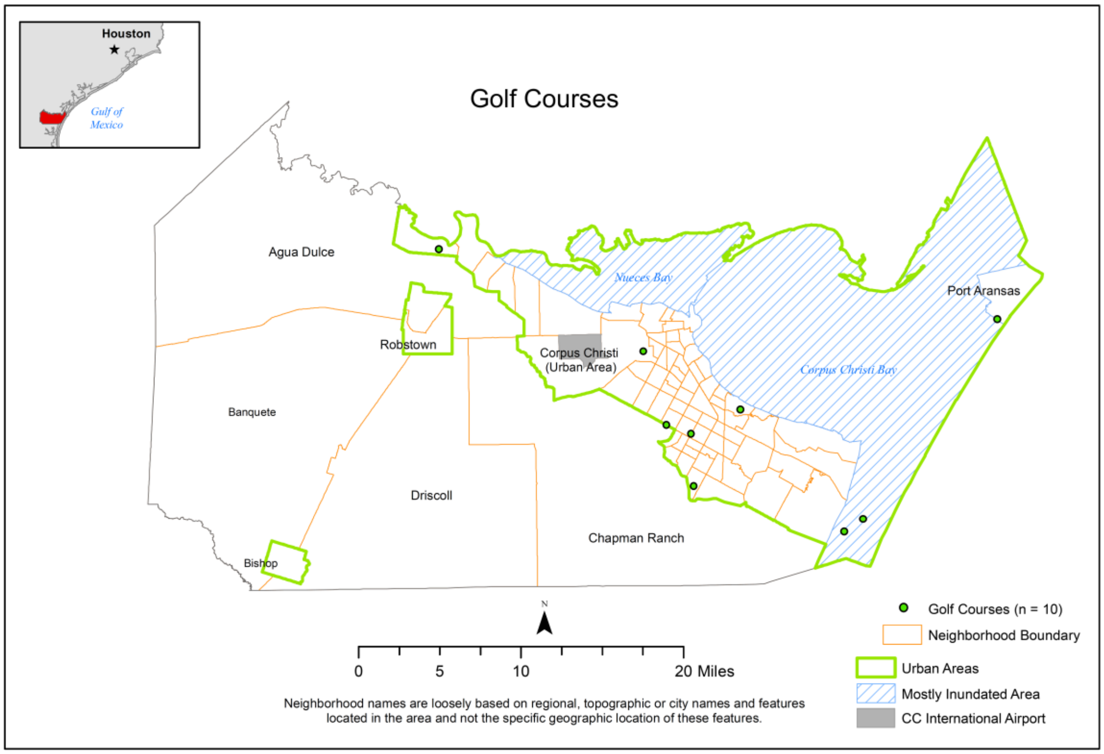


Figure 4.27 Geographic location of golf courses, Nueces Co., TX

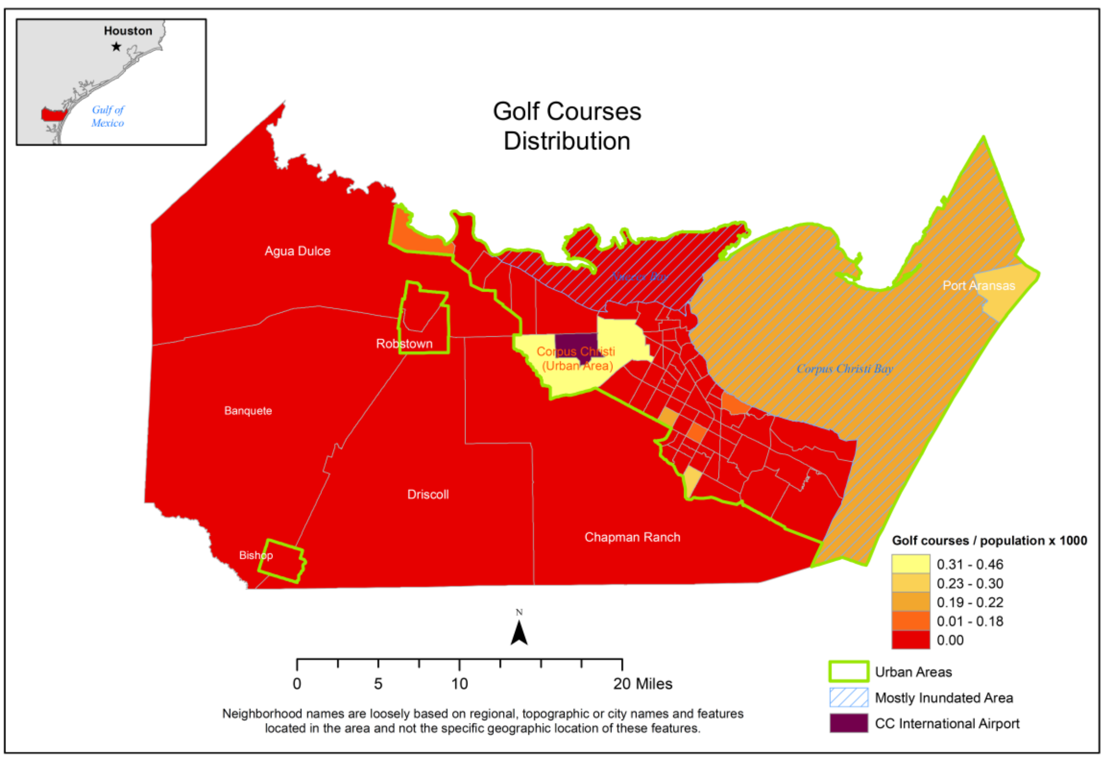


Figure 4.28 Distribution of golf courses by count per neighborhood population, Nueces Co., TX

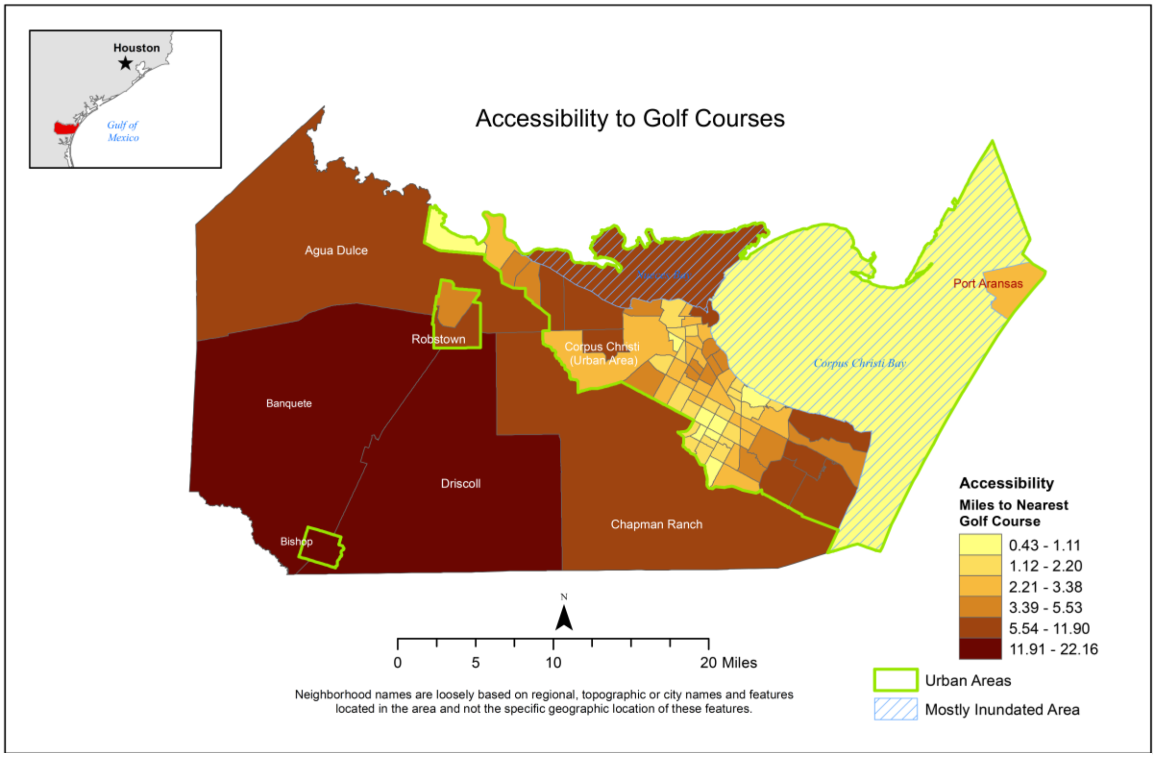
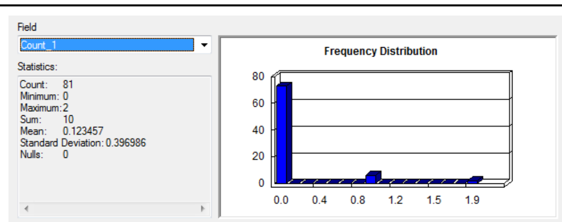
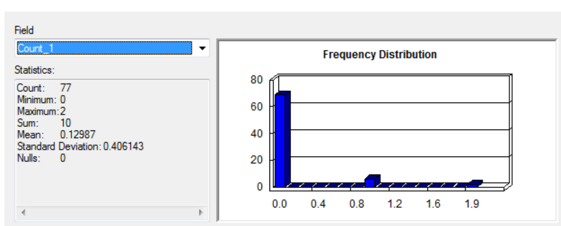


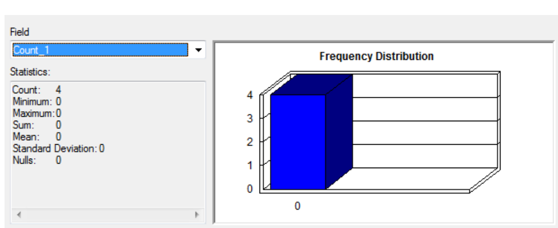
Figure 4.29 Spatial accessibility to golf courses, Nueces Co., TX



County neighborhoods (n = 81)



Urban area neighborhoods (n = 77)



Peri-urban area neighborhoods (n = 4)

Figure 4.30 Frequency distribution of golf courses in county, urban and peri-urban neighborhoods in Nueces Co., TX

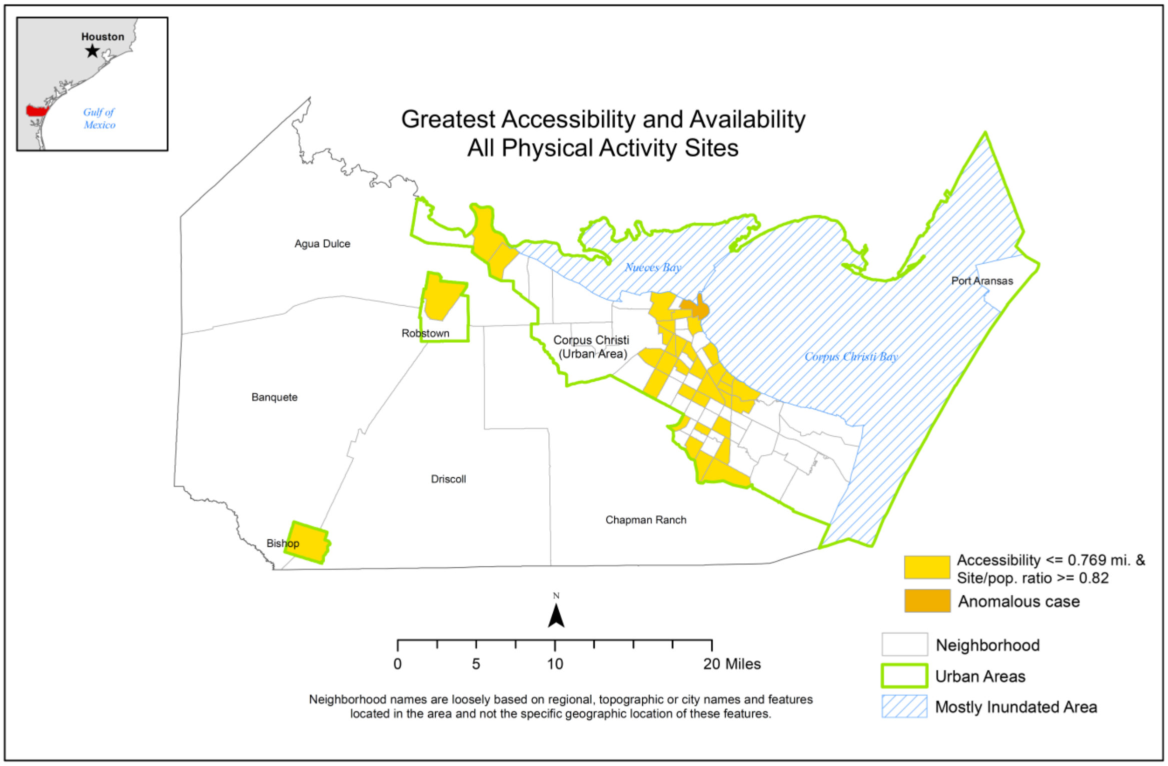


Figure 4.31 Greatest spatial accessibility and availability of all physical activity (PA) sites, Nueces Co., TX

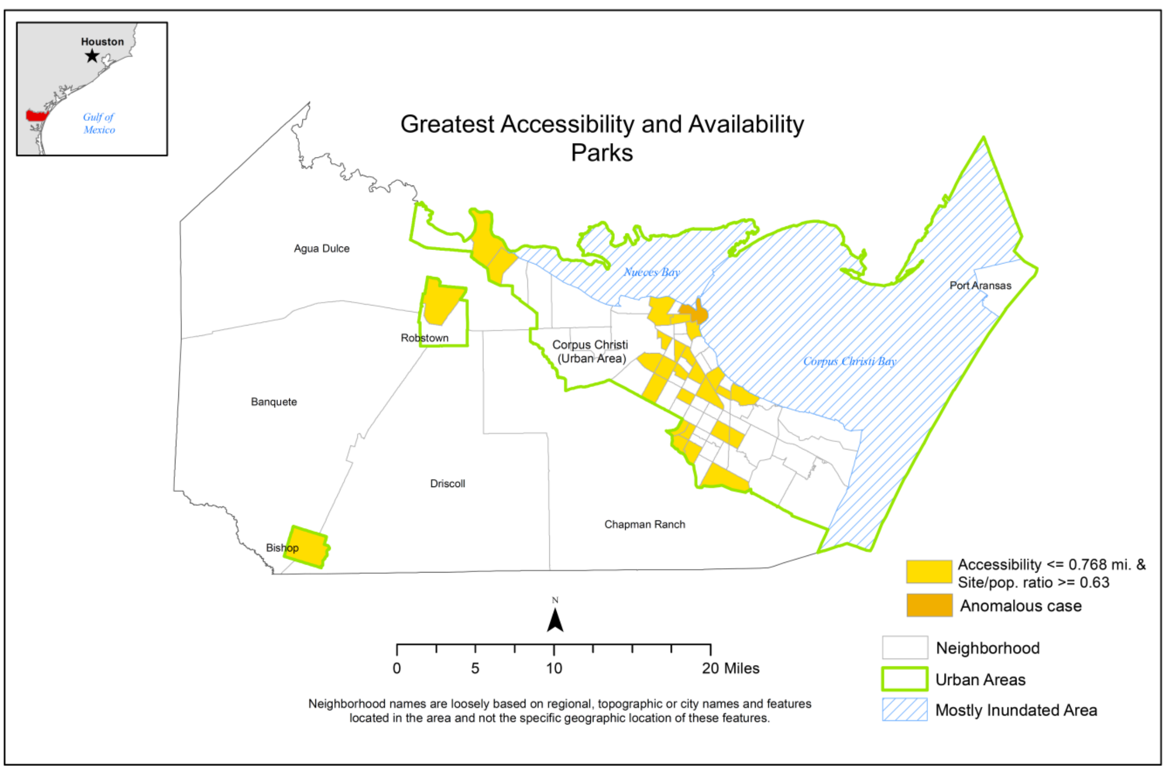


Figure 4.32 Greatest spatial accessibility and availability of parks, Nueces Co., TX

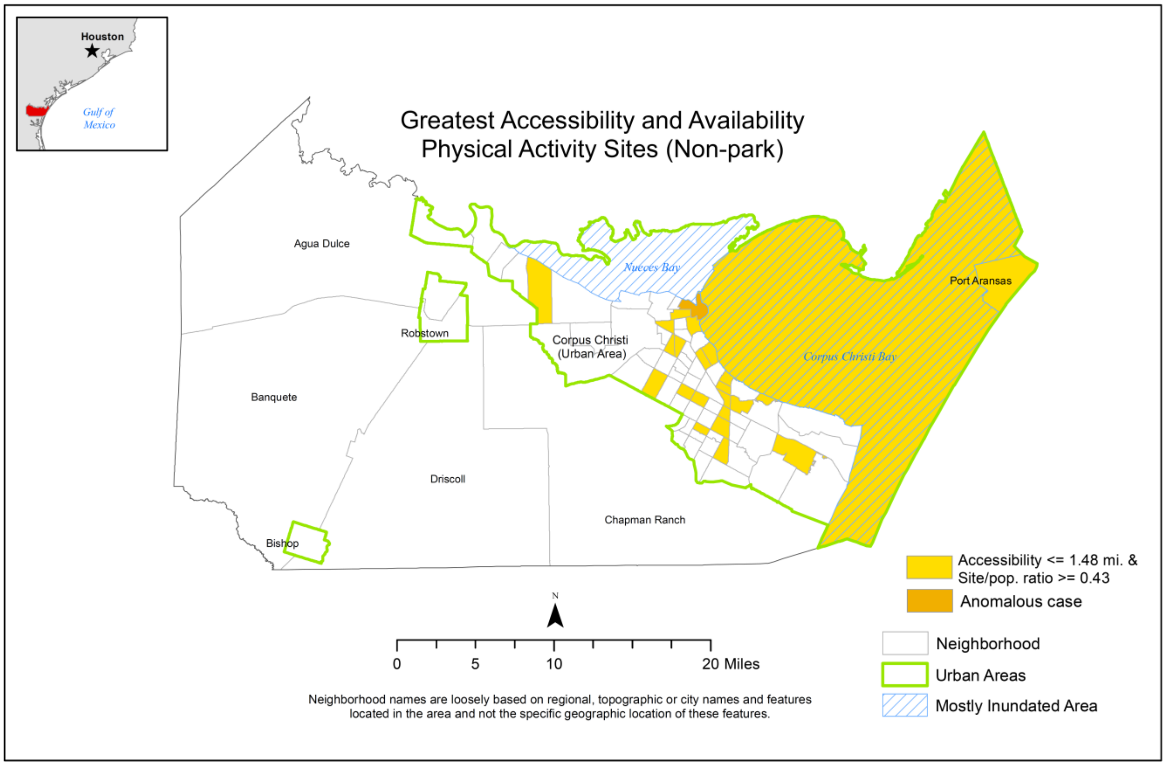


Figure 4.33 Greatest spatial accessibility and availability of physical activity sites (Non-park), Nueces Co., TX

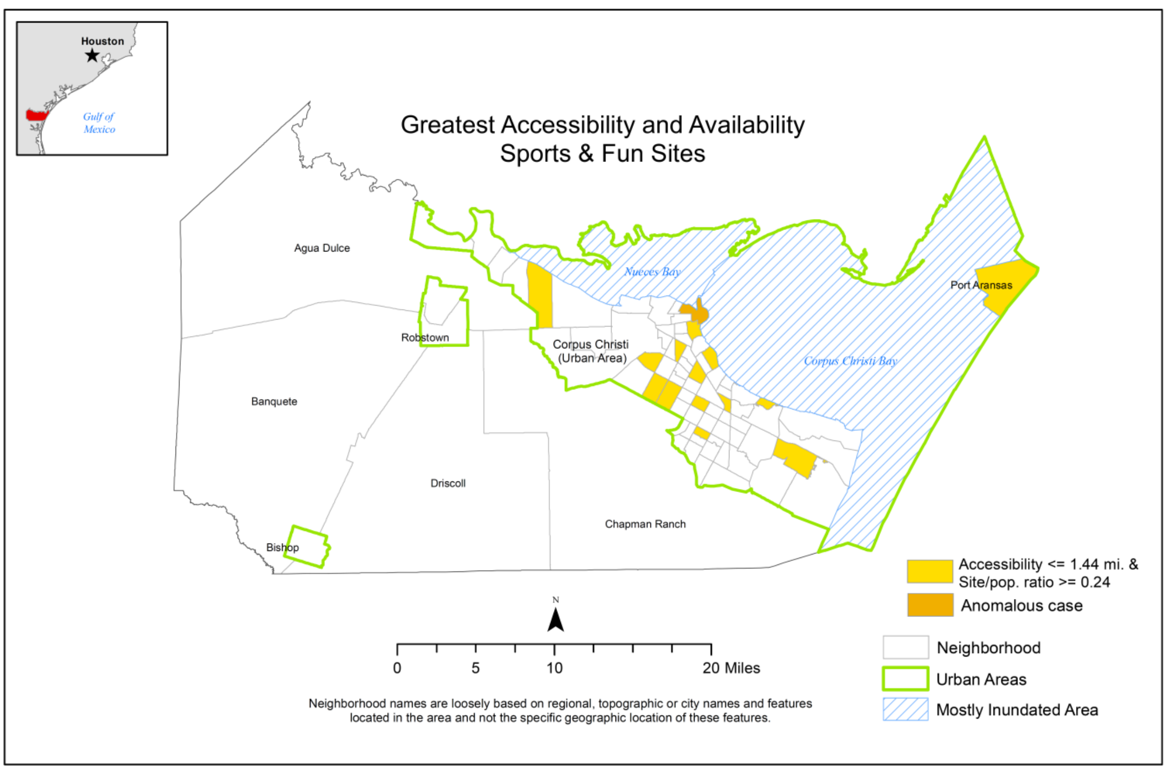


Figure 4.34 Greatest spatial accessibility and availability of sports and fun sites, Nueces Co., TX

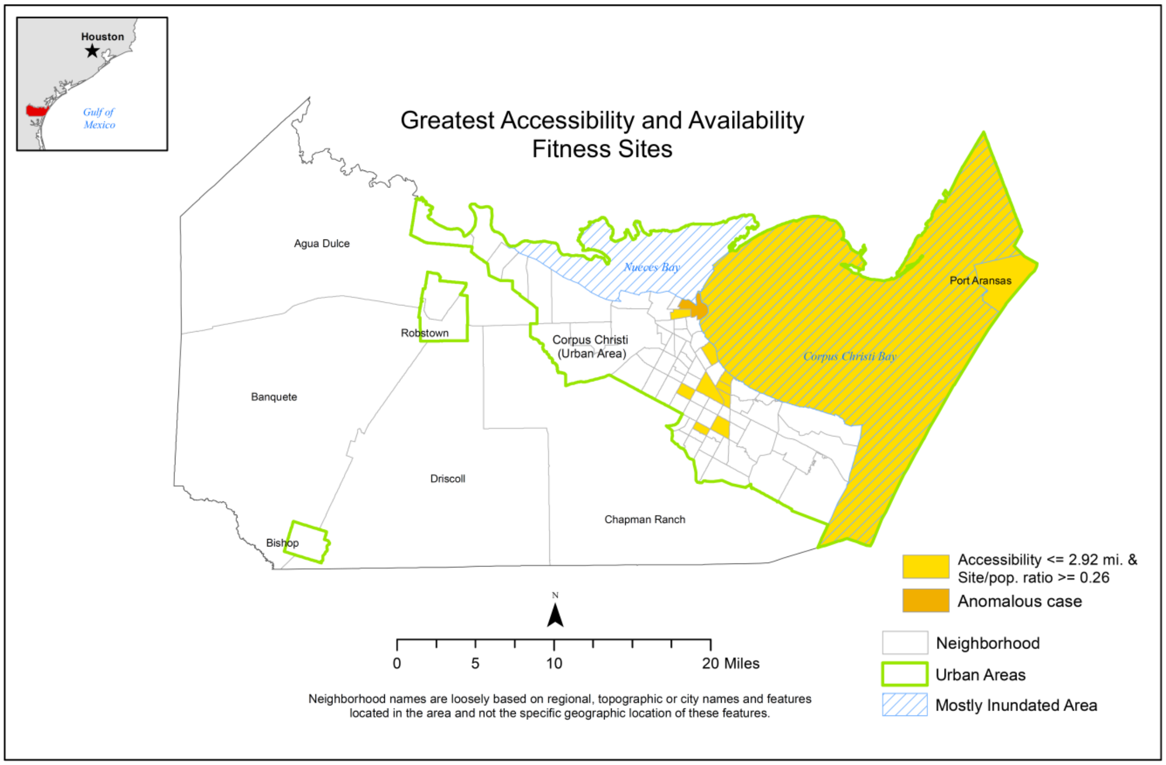


Figure 4.35 Greatest spatial accessibility and availability of fitness sites, Nueces Co., TX

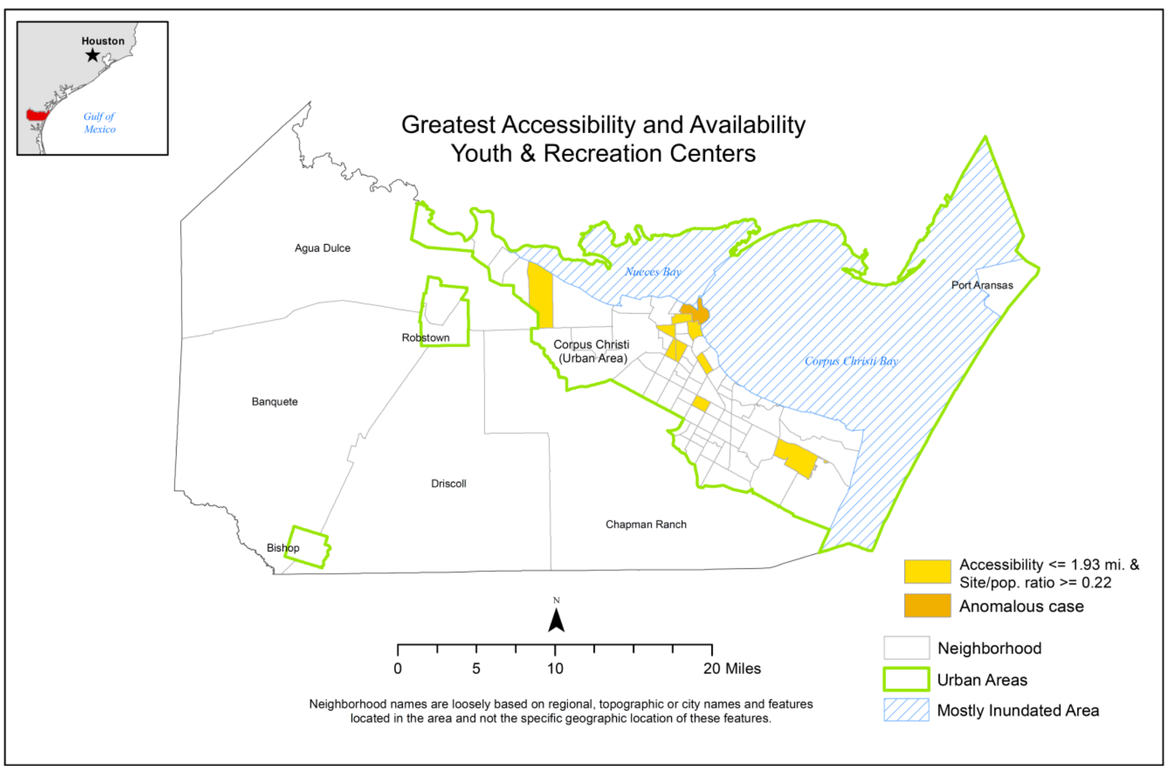


Figure 4.36 Greatest spatial accessibility and availability of youth and recreation centers, Nueces Co., TX

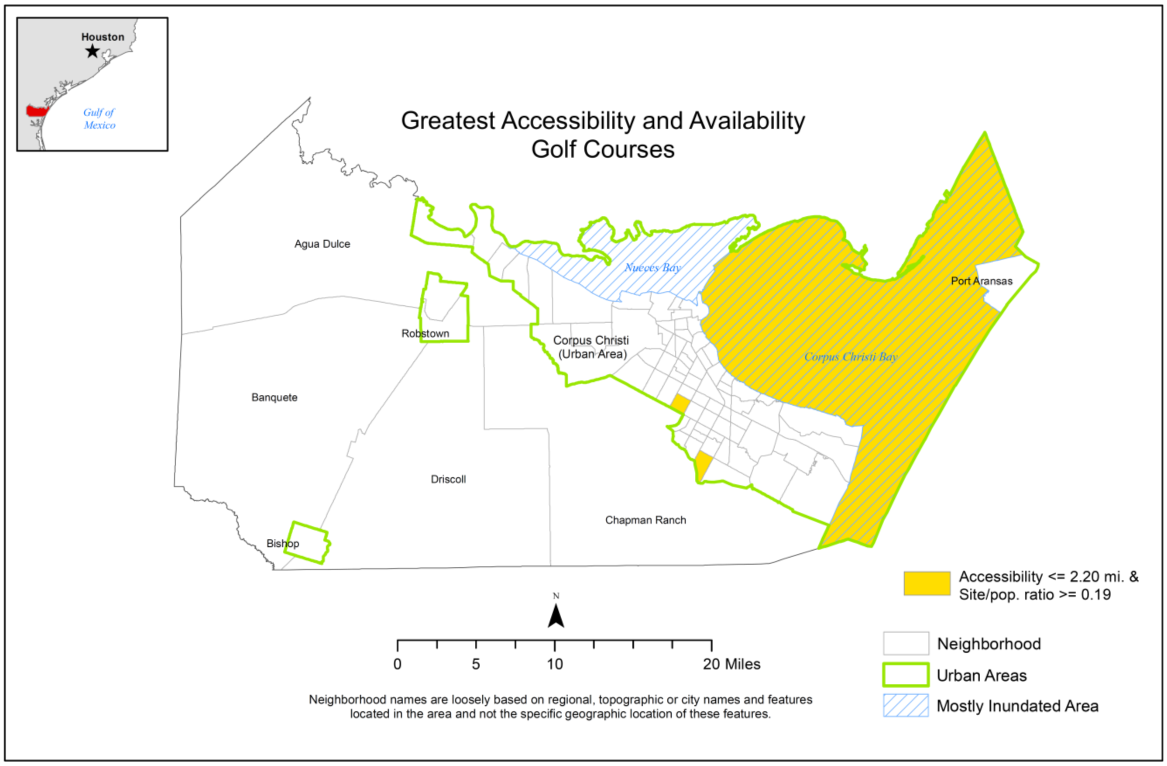


Figure 4.37 Greatest spatial accessibility and availability of golf courses, Nueces Co., TX

4.2 MODELING SOCIOECONOMIC AND SPATIAL RELATIONSHIPS THAT DRIVE SPATIAL ACCESS TO NEIGHBORHOOD physical activity sites IN NUECES COUNTY, TEXAS URBAN AREAS

Pearson's Correlation Coefficient was calculated for spatial accessibility to the nearest physical activity site in 76 neighborhoods in Nueces County, Texas urban areas against all variables chosen from the general socioeconomic categories shown in Table 4.2. These variables include % Household Income by County population and by Race / Ethnicity (Hispanic or white), % Education by Gender and by Race/ Ethnicity and % Transportation by Race/ Ethnicity. The variables for the category % Race were excluded as it likely that they would have caused multicollinearity problems with other variables in regression analysis because these variables also account for Race/Ethnicity. The three socioeconomic variables with the strongest correlation to spatial accessibility for All physical Activity Sites were used to create the Independent Variables that were used in the Ordinary Least Square Regression (OLS) Model to further examine the relationship between spatial access to physical activity sites and socioeconomic factors. In addition, three spatial variables were used in the model.

Table 4.2: Socioeconomic Data Categories

1. % Household Income (Total Population, Nueces)	7. % Education (Male, Total Population, Nueces)
2. % Household Income (Hispanic)	8. % Education (Female, Total Population, Nueces)
3. % Household Income (White)	9. % Education (Hispanic, Male)
4. % Transportation (Hispanic)	10. % Education (Hispanic, Female)
5. % Transportation (White)	11. % Education (White, Male)
6. % Race (Total Population, Nueces)	12. % Education (White, Female)

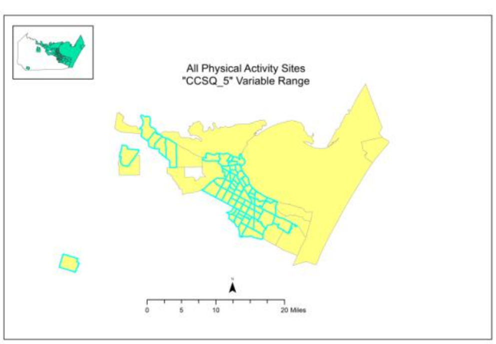
Table 4.3: Variables used in Ordinary Least Square Regression

Variable Type	Variable Name	Variable Description
Independent	NUEDU_MN	% Females with grade 12 but no diploma & % Females with Associate's degrees
Independent	NUINR_MM	% Earning $35,000 - 59,999
Independent	HIINR_MM	% Earning $40,000 - 99,999 (Hispanic)
Independent	ALLPA_NORMA	(No. physical activity sites/ Total Population) * 1000
Independent	BI_AREA	Neighborhoods ≤ 3^2 miles
Independent	CCSQ_5	Neighborhoods ≤ 5^2 miles
Dependent	ALLPA_CC76	Spatial accessibility to physical activity sites in the Corpus Christi urban area

Table 4.4 shows the results for the OLS model. The Jarque Bera test statistic is large and not statistically significant, indicating that the model is not biased and that the residuals are normally distributed. This result is supported by the histogram (Figure 4.43), which resembles a Gaussian curve and scatterplot of model residuals (Figure 4.45), which appear randomly distributed. In addition, a Spatial Autocorrelation test confirms that the residuals are randomly distributed (Figure 4.47). The Multiple R^2 value of .50 implies that the model explains about half of the variability in the Dependent Variable, ALLPA_76 which represents accessibility to All physical activity sites in the Corpus Christi urban area. Because the Koenker (BP) test statistic is significant, only the Robust probabilities are reliable. The Robust Probabilities show that the Spatial Variables, ALLPA_NORM, BI_AREA, and CCSQ_5 exert strong influence in the model, effectively eclipsing any statistical significance of the three socioeconomic variables NUEDU_MN, NUINR_MM, and HIINR_MM. The variable ALLPA_NORMA variable is a ratio comprised of the total number of physical activity sites within a neighborhood divided by the neighborhood population multiplied by 1000 and is visually expressed in the Distribution map series in Section 4.1. Increase in spatial access is associated with increase of neighborhoods where the number of PA sites is large enough to accommodate the size of the population. In this model, ALLPA_NORMA is positive, indicating that as the number of Physical Activities Sites grow to accommodate the size of the neighborhood population, spatial access also increases. This is an expected outcome. It effectively means that that the more physical activity sites there are the shorter the travel distance (e.g. increase in spatial accessibility) to the nearest Physical Activity Site.

The next two significant variables are also spatial in nature. The variable BI_Area shows the number of neighborhoods that are less than or equal to 3 square miles in area while the variable CCSQ_5 represents the number of neighborhoods that are less than or equal to 5 square miles (Figure 4.38). Although both variables depict the size of neighborhoods, the difference in the number of neighborhoods captured by these two variables creates a situation whereby these variables effectively represent distinct spatial relationships and are therefore providing different spatial information. Thus, CCSQ_5 could be providing information about *large vs. small* neighborhoods whereas the BI_Area variable could be interpreted as *inner city vs. outer city*. This view seems to be supported by the fact that both these variables exist in the model without causing multicollinearity problems as indicated by the low Variance Inflation Factor (VIF). Both Variables are negative. Since both are spatial regime variables (or dummy variables), where 1 = inner city neighborhoods and 0 outer city neighborhoods, in the case of BI_Area, the negative coefficient could be interpreted to mean that inner city neighborhoods have shorter distances (e.g. greater spatial accessibility) to the nearest Physical Activity Site which is reasonable given that the majority of physical activity sites are located in the Corpus Christi urban area on nearly all the Location maps in Section 4.1. The CCSQ_5 variable also has a negative coefficient, where small neighborhoods received a value of 1 and larger sized neighborhoods received a value of 0. This could be interpreted to mean that smaller neighborhoods tend to have shorter travel distances (e.g. have greater spatial accessibility) to the nearest Physical Activity Site compared to larger neighborhoods. Again this is corroborated with both Location and Accessibility maps in Section 4.1. From results in Section 4.1, neighborhoods that occupy large areas do not contain as many physical activity sites compared to neighborhoods that occupy small areas.

The same variables were run with Parks as the Dependent Variables with similar results. This is not surprising given the fact that Parks account for 66.8% of the entire dataset. The Jarque Bera test statistic is still large and not significant while the Koenker (BP) statistic is significant (Table 4.5). Therefore using the Robust Probabilities, Table 4.5 shows that the same three spatial variables are significant. However, the Multiple R^2 and Adjusted R^2 show that this model is explaining about 3% less of the variation in spatial accessibility compared to when all of the Physical Activity Sites are present.



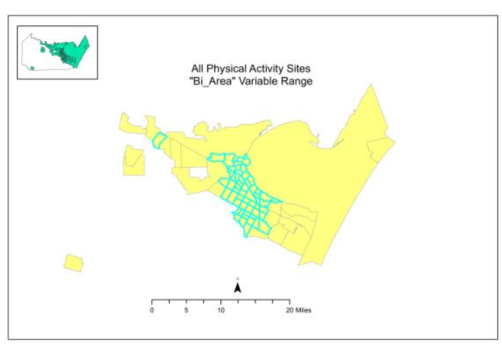


Figure 4.38 Comparison between spatial variables used in OLS model for All Physical Activity Sites, Corpus Christi, urban area

Table 4.4: Ordinary Least Square Regression (OLS) Diagnostic Results for All Physical Activity Sites, Nueces Co., TX, Urban Areas

Input Features:	CC76_OLS_proj2	Dependent Variable:	ALLPA_CC76
Number of Observations:	76	Akaike's Information Criterion (AICc) [d]:	1204.415387
Multiple R-Squared [d]:	0.505141	Adjusted R-Squared [d]:	0.462110
Joint F-Statistic [e]:	11.738958	Prob(>F), (6,69) degrees of freedom:	0.000000*
Joint Wald Statistic [e]:	42.964279	Prob(>chi-squared), (6) degrees of freedom:	0.000000*
Koenker (BP) Statistic [f]:	21.858651	Prob(>chi-squared), (6) degrees of freedom:	0.001284*
Jarque-Bera Statistic [g]:	5.666533	Prob(>chi-squared), (2) degrees of freedom:	0.058820

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	1794.445596	347.109309	5.169684	0.000002*	361.983961	4.957252	0.000005*	--------
NUEDU_MN	-8.132279	17.702456	-0.459387	0.647405	16.628708	-0.489051	0.626361	1.174546
NUINR_MM	15.214031	11.557482	1.316379	0.192405	11.410216	1.333369	0.186799	1.288013
HIINR_MM	-8.649794	7.251702	-1.192795	0.237035	6.638253	-1.303023	0.196901	1.537705
ALLPA_NORM	310.795165	81.718106	3.803260	0.000309*	135.543267	2.292959	0.024900*	1.070867
BI_AREA	-450.364541	197.893857	-2.275788	0.025964*	181.893619	-2.475978	0.015741*	1.659491
CCSQ_5	-987.155038	262.134369	-3.765836	0.000349*	287.066724	-3.438765	0.000999*	1.668206

Table 4.5: Ordinary Least Square Regression (OLS) Diagnostic Results for Parks, Nueces Co., TX, Urban Areas

Input Features:	CC76_OLS_proj3	Dependent Variable:	PARKS_CC76
Number of Observations:	76	Akaike's Information Criterion (AICc) [d]:	1215.156674
Multiple R-Squared [d]:	0.478539	Adjusted R-Squared [d]:	0.433194
Joint F-Statistic [e]:	10.553411	Prob(>F), (6,69) degrees of freedom:	0.000000*
Joint Wald Statistic [e]:	44.577310	Prob(>chi-squared), (6) degrees of freedom:	0.000000*
Koenker (BP) Statistic [f]:	12.679390	Prob(>chi-squared), (6) degrees of freedom:	0.048419*
Jarque-Bera Statistic [g]:	5.298528	Prob(>chi-squared), (2) degrees of freedom:	0.070703

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	2165.069344	372.525726	5.811865	0.000000*	405.625424	5.337608	0.000001*	--------
NUEDU_MN	-0.709744	18.998684	-0.037358	0.970305	18.060144	-0.039299	0.968763	1.174546
NUINR_MM	6.621526	12.403757	0.533832	0.595176	12.059774	0.549059	0.584740	1.288013
HIINR_MM	-10.517542	7.782694	-1.351401	0.180984	6.938255	-1.515877	0.134124	1.537705
ALLPA_NORM	270.189993	87.701758	3.080782	0.002967*	134.277786	2.012172	0.048107*	1.070867
BI_AREA	-508.121995	212.384257	-2.392465	0.019460*	209.151244	-2.429448	0.017726*	1.659491
CCSQ_5	-1006.614530	281.328658	-3.578073	0.000642*	306.234652	-3.287069	0.001598*	1.668206

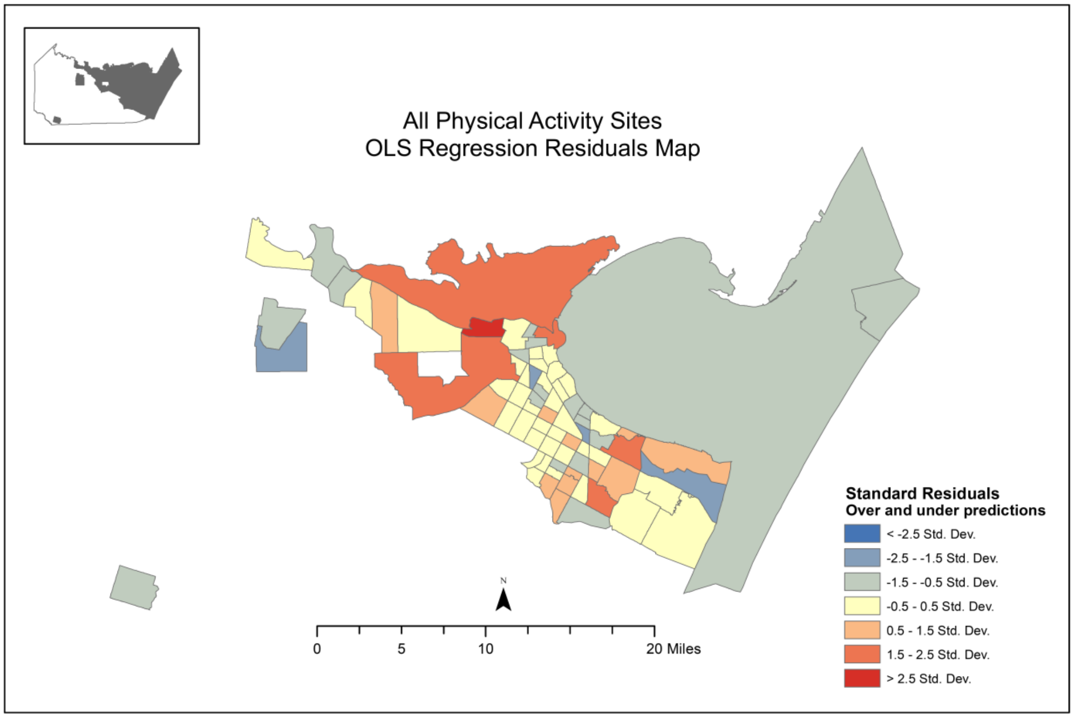


Figure 4.39: Ordinary Least Square Regression (OLS) Residual Map for All Physical Activity Sites, Nueces, Co., TX, Urban Areas

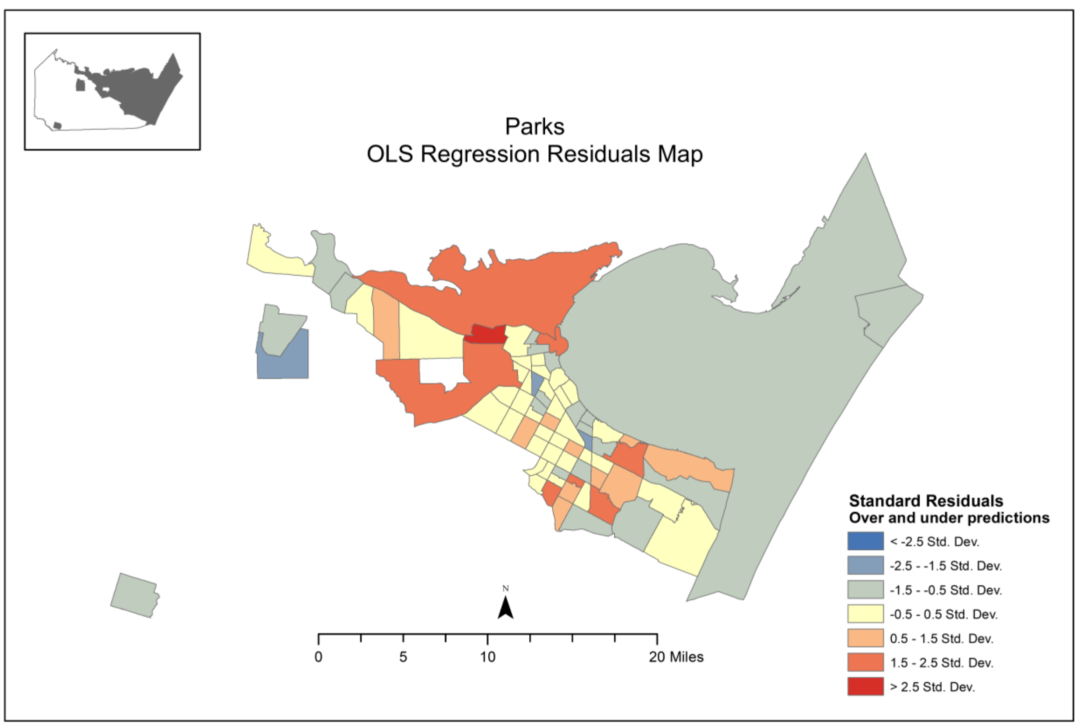


Figure 4.40: Ordinary Least Square Regression (OLS) Residual Map for Parks, Nueces, Co., TX. Urban Areas

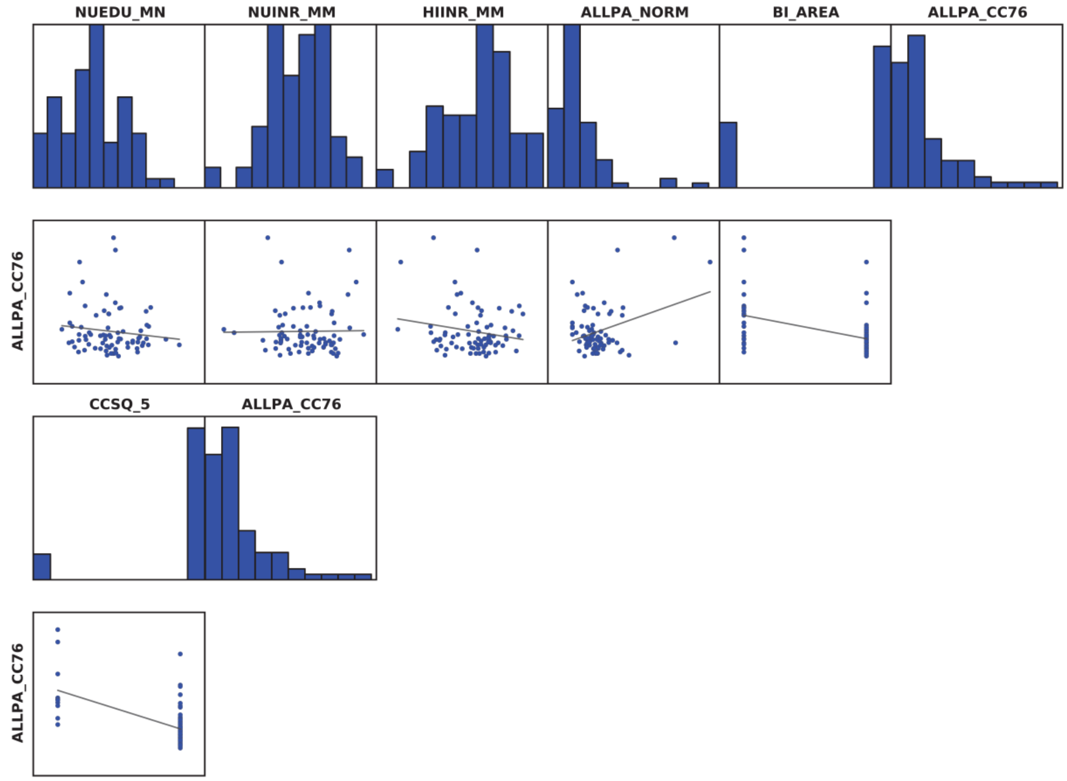


Figure 4.41: Histogram and Scatterplot of OLS Variable Distribution for All Physical Activity Sites, Nueces, Co., TX, Urban Areas

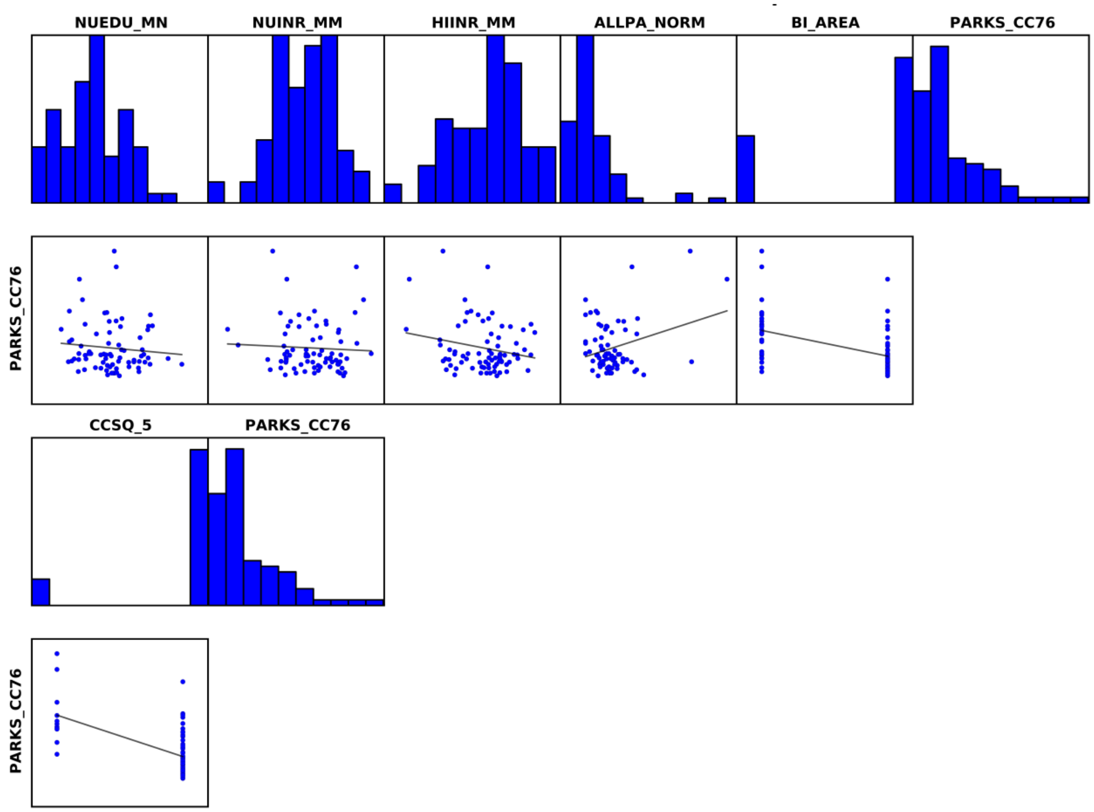


Figure 4.42: Histogram and Scatterplot of OLS Variable Distribution for Parks, Nueces, Co., TX, Urban Areas

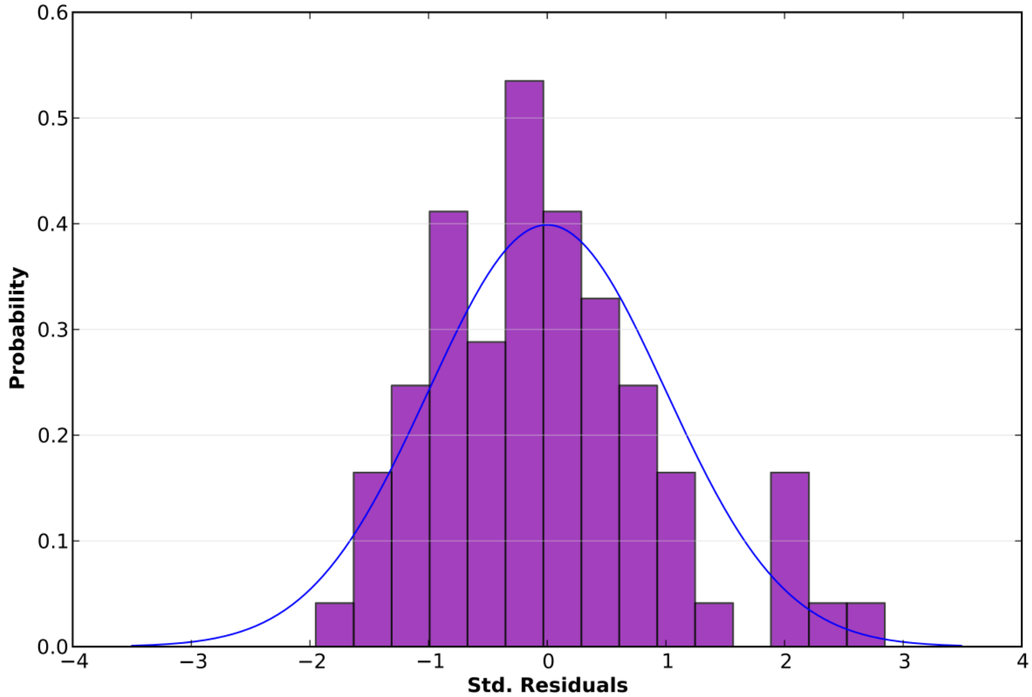


Figure 4.43: Histogram of OLS Regression Standard Residuals for All Physical Activity Sites, Nueces Co., TX, Urban Areas

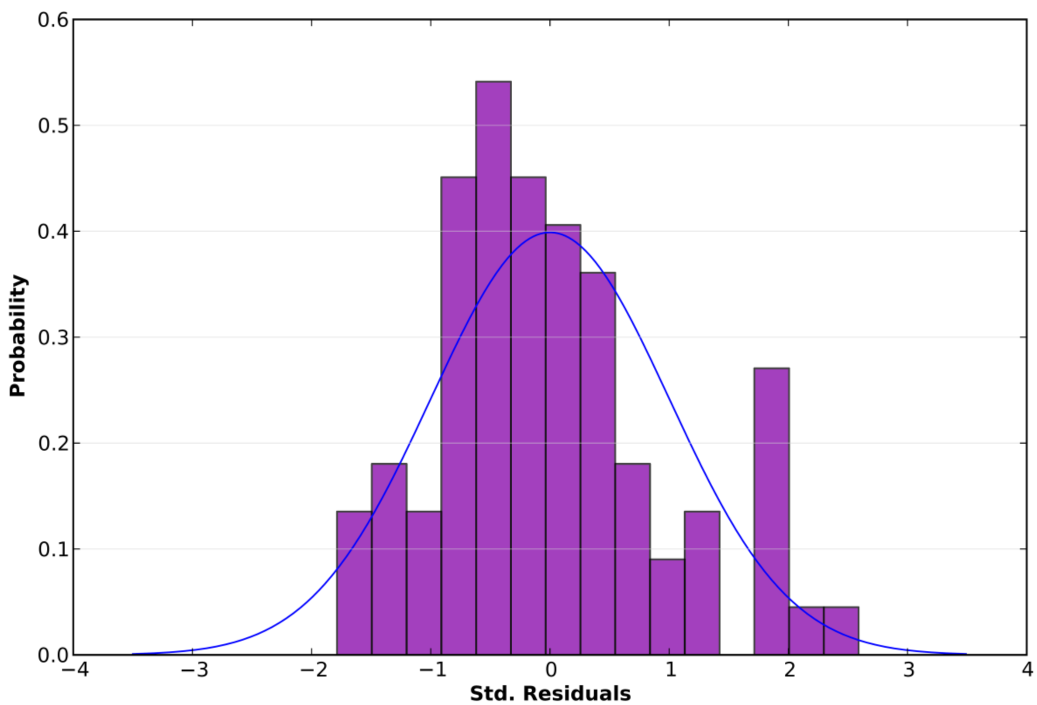


Figure 4.44: Histogram of OLS Regression Standard Residuals for Parks, Nueces Co., TX, Urban Areas

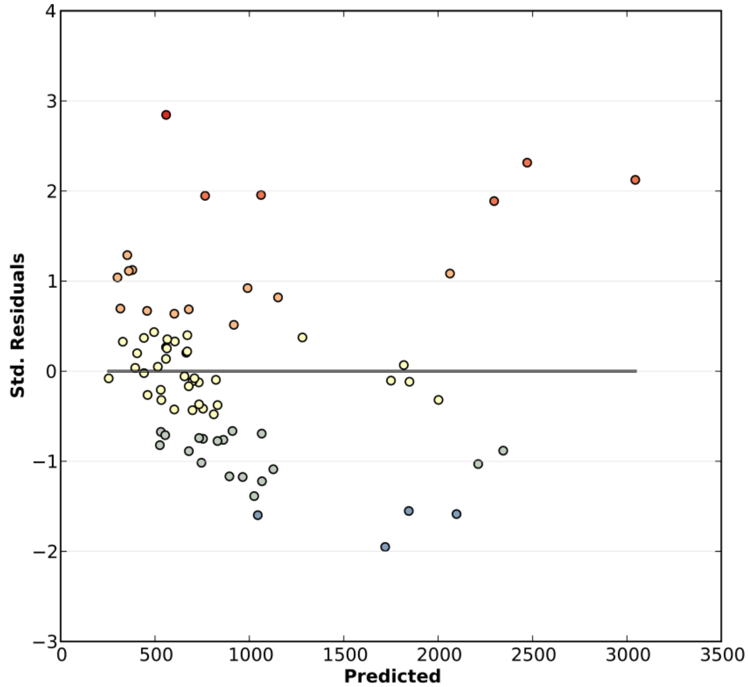


Figure 4.45: Scatterplot of OLS Regression Standard Residuals for All Physical Activity Sites, Nueces Co., TX, Urban Areas

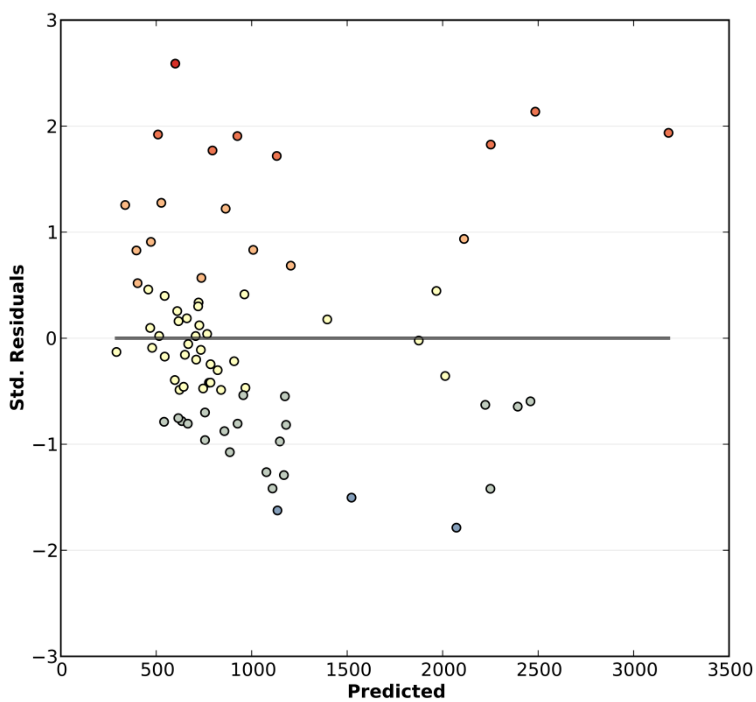
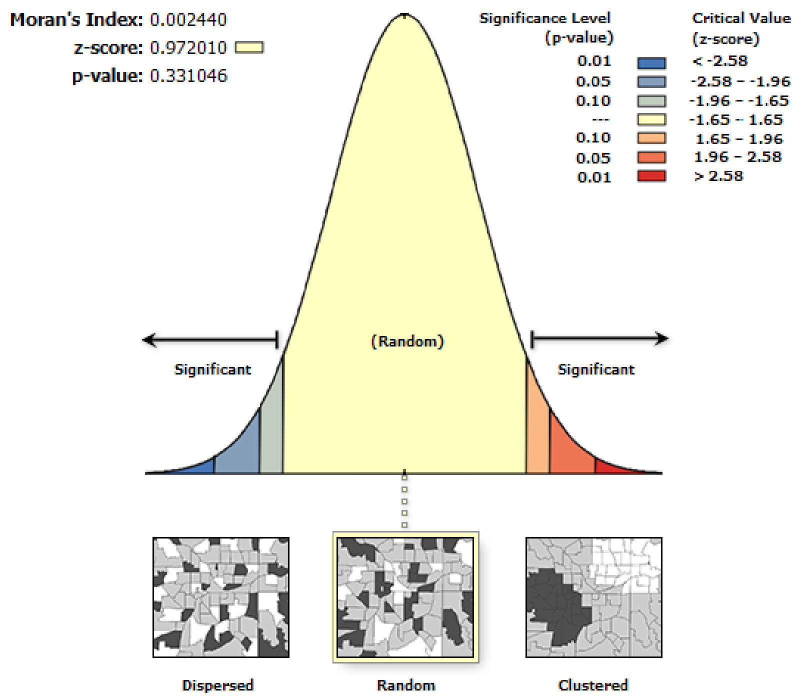


Figure 4.46: Scatterplot of OLS Regression Standard Residuals for Parks, Nueces Co., TX, Urban Areas



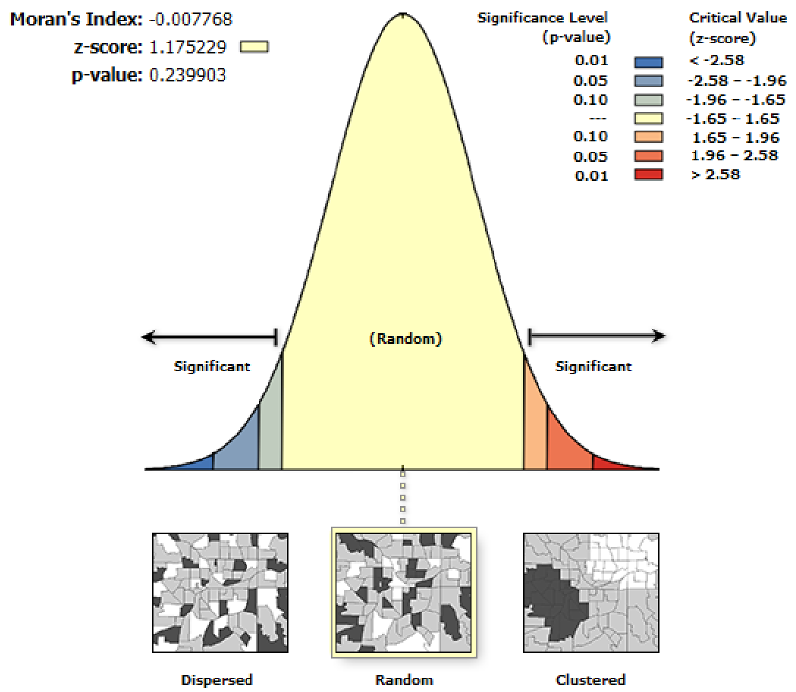
Global Moran's I Summary

Moran's Index:	0.002440
Expected Index:	-0.013333
Variance:	0.000263
z-score:	0.972010
p-value:	0.331046

Dataset Information

Input Feature Class:	OLS_CC76_ALLPA_Mod2
Input Field:	RESIDUAL
Conceptualization:	INVERSE_DISTANCE
Distance Method:	EUCLIDEAN
Row Standardization:	False
Distance Threshold:	26613.728993 Meters
Weights Matrix File:	None
Selection Set:	False

Figure 4.47: Spatial Autocorrelation (Global Moran's I) Results for All Physical Activity Sites, Nueces Co., TX, Urban Areas



Global Moran's I Summary

Moran's Index:	-0.007768
Expected Index:	-0.013333
Variance:	0.000022
z-score:	1.175229
p-value:	0.239903

Dataset Information

Input Feature Class:	OLS_CC76_Parks_Mod1
Input Field:	RESIDUAL
Conceptualization:	INVERSE_DISTANCE
Distance Method:	EUCLIDEAN
Row Standardization:	False
Distance Threshold:	0.249276 Degrees
Weights Matrix File:	None
Selection Set:	False

Figure 4.48: Spatial Autocorrelation (Global Moran's I) Results for Parks, Nueces Co., TX, Urban Areas

4.3 VARIABLES ASSOCIATED WITH BODY MASS INDEX (BMI) IN THE CORPUS CHRISTI URBAN AREA, TEXAS

Socioeconomic and spatial variables were created from the combined data of two surveys – the "Diet, exercise and physical activity environment survey for adult residents of Nueces County" and the "Neighborhood Food Environments and Disparities in Persons with Diabetes in Nueces County." The average age of respondents for this study is 46, the eldest participant being 83 and the youngest being 18 with a standard deviation of 15. The average BMI is 33. According to the Center for Disease Control and Prevention (CDC), the normal BMI range for a healthy adult is between 18.5 – 24.9 while a BMI greater than 25 is considered overweight and a BMI greater than 30 is considered obese. In order to determine if there is an association between accessibility to physical activity sites and obesity in neighborhoods within the City of Corpus Christi, 8 variables were created from survey data. Table 4.7 displays other statistics for variables that were considered in this study. It shows that the survey is heavily biased toward women who account for 71.4% of survey respondents. More than half those surveyed have been told by a doctor or other health professional that they have diabetes or sugar diabetes. Regarding other health statistics, only 17.8% of the survey had a normal BMI of between 18.5 - 24.9. Moreover, 26.0% are overweight (BMI between 25.0 - 29.9) and 55.4 % have a BMI of 30 or greater and are therefore obese by CDC standards. Altogether 81.5%, well over half the survey respondents, are overweight or obese because they have a BMI equal to or greater than 25. Regarding economic status, when asked which income level best represented their total household income from all household members during the past 12 months nearly half, 45.8%, reported earning less than $29,999. Further, 29.2% reported earning $30,000 – 59,999 and 24.9% reported earning more than $60,000.

In terms of spatial accessibility, most participants live within half a mile of the nearest Physical Activity site and 28.3% live less than a quarter mile from the nearest Physical Activity site. In order to ascertain whether there is an association between BMI, accessibility to physical activity sites and socioeconomic variables, Pearson's Correlation was calculated for 8 categorical variables that were created from survey responses. Participants were asked to respond to the following statements concerning the physical activity environment of their neighborhoods.

Table 4.6: Variables used in correlation analysis for Corpus Christi, TX

Variable Name	Variable Description
Diabetes	Reported being told by a doctor or other health professional that they have diabetes or sugar diabetes
Male =1	Gender
BMI	Body Mass Index
Hispanic	Hispanic ethnicity
HH_Income	Household income
Hood_PA	Perception that neighborhood offers many opportunities to be physically active
Hood_Walk	Percepton that in neighborhood it is easy to walk to places
Hood_Crime	Perception that neighborhood is free form crime
Hood_TRANS	Percepton that public transportation in neighborhood is adequate
Access_mi	Individual spatial accessibility PA sites

The strongest correlations with BMI are the variables HH_Income (r = -0.172) and Hood_Walk (r = -.117). Thus, as BMI increases, household income tends to decrease. Similarly, as BMI increases, the number of people who perceive that it is easy to walk to places in their neighborhood decreases. Other relationships such as Hood_PA (r = -.003), Hood_Crime (r = -.079), and Hood_TRANS (r = -.014) and are not as strong but also have a negative correlation with BMI. Thus, as BMI increases, the number of people who reported that their neighborhood is *free from crime*, reported that public transportation was adequate and reported that their neighborhoods offered many opportunities to be physically active all decreased. Two variables, Hispanic (r = .034) and Access_mi (r = .007) have a weak but positive correlation with BMI. This means that BMI increases with being of Hispanic ethnicity and distance to the nearest Physical Activity site (e.g. accessibility to PA sites worsens).

Other notable relationships are the strong, positive correlation between Diabetes and BMI (r = 0.382). This means that as Diabetes increases, BMI also tends to increase. This finding corroborates the strong linkage to being overweight/ obese and having type II diabetes that is often reported in health literature. There is also a relatively strong negative correlation between the variables Diabetes and Hood_Walk (r = -.110) This means that that the number of people who felt that it was easy to walk to places fell as the number of people with diabetes increased. There are also strong positive correlations between the variable Hood_PA with respect to the variables Hood_Walk (r = .267) and Hood_Crime (r = .285) respectively. This means that as the number of people who feel that their neighborhood offers many opportunities to be physically active increases, the number of people who perceive that it is easy to walk in their neighborhoods and those who say that their neighborhoods are free from crime also increase. The variable Hispanic had the highest correlation with Access_mi (r = -.112), distance to physical activity sites decreases as the Hispanic ethnicity increases. This implies that greater numbers of Hispanic residents are associated with greater accessibility to physical activity sites.

There also seems to be a strong positive correlation with the variables HH_Income with respect to Hood_Crime (r = .219) and Hood_PA (r = .135). This means that household income increases with the number of people who perceive that their neighborhoods are safe and the number of people who felt that their neighborhoods offer many opportunities to be physically active.

In general, Hood_TRANS showed a weak correlation to most variables and the relationship is especially weak with respect to accessibility to physical activity sites. This weak correlation helps to explain why the inclusion of transportation variables produced biased results when the Dependent Variable is accessibility in the OLS regression models in Chapter 4, Section 2. Interestingly, Hood_Walk has a strong positive correlation with Hood_TRANS (r = .127). This means that the number of people who perceive that their neighborhoods are safe increases with the number of people who perceived that public transportation in their neighborhood is adequate. So, again this goes back to the neighborhood environment (e.g. good sidewalks) actually encouraging people to get out and walk).

Table 4.7 Descriptive Statistics for combined "Diet, Exercise and Physical Activity" Survey and "Neighborhood Food Environments in Persons with Diabetes" Survey

Variable	Mean	Median	Mode	Std. Dev.	Max.	Min.
Age*	46	49	56	15	83	18
BMI	33	31	29	8	67	17

* Age calculated for 399 of 465 survey participants used for this analysis.

Data Statistics	#	%
Male	133	28.6
Have diabetes or pre-diabetes	262	56.3
Obesity		
Total overweight or obese	379	81.5
Underweight	3	0.6
Normal weight	83	17.8
Overweight	121	26
Obese	258	55.4
Household (HH) Income		
% HH Income < $29,999	213	45.8
% HH Income $30,000 - 59,999	136	29.2
% HH Income > $60,000	116	24.9
Accessibility		
% Live < .25 miles of nearest PA site	132	28.3
% Live within .25 - .49 miles of nearest PA site	179	38.4
% Live within .50 - 1 mile of nearest PA site	114	24.5
% Live > 1 mile of nearest PA site	40	8.6
Total no. of participants	**465**	

Table 4.8 Results for Correlation among 10 Socioeconomic Variables

	Diabetes	*Male = 1*	*BMI*	*Hispanic*	*HH_Income*	*Hood_PA*	*Hood_Walk*	*Hood_Crime*	*Hood_TRANS*
Diabetes	1								
Male = 1	-0.037782859	1							
BMI	0.382095271	0.016000058	1						
Hispanic	0.082844712	-0.028331494	0.034287816	1					
HH_Income	-0.007163656	-0.019014727	-0.172459283	-0.11697005	1				
Hood_PA	-0.008590609	0.0279148	-0.003200135	-0.129196901	0.135429829	1			
Hood_Walk	-0.11043709	0.058695734	-0.117825737	0.029574825	-0.002287909	0.267374223	1		
Hood_Crime	-0.031881252	0.032597341	-0.079586209	-0.154848865	0.219097697	0.285052556	0.174721278	1	
Hood_TRANS	0.014253687	0.006095099	-0.014257613	0.048621097	-0.047437328	0.092206238	0.127868645	0.004031796	1
Access_mi	0.005001042	0.052828111	0.007243304	-0.112387516	-0.020165276	-0.077472665	-0.060597542	0.021426743	-0.002520793

CHAPTER FIVE
CONCLUSION AND FUTURE WORK

In 2010, Men's Health Magazine gave the City of Corpus Christi the title "Fattest City in America." How could a city of less than 350,000 and containing over 200 parks, more than 100 non-park recreation and exercise facilities as well as year-round access to Gulf coast beaches be so disproportionately impacted by obesity and diabetes? Three research questions were formulated in order to investigate the answer to this question. The first step was to determine the physical activity environment of Corpus Christi and surrounding areas by visualizing and analyzing the spatial accessibility of physical activity (PA) resources in Nueces County, Texas. Corpus Christi is the county seat of Nueces County. A total of 338 physical activity sites comprised of 226 parks and 112 non-park activity sites were used to conduct this study. Non-park physical activity sites were further partitioned into four groups (sports and fun sites, fitness sites, youth and recreation Centers and Golf Courses). Non-park PA sites included discrete locations where physical activity can be undertaken including public and private swimming pools, sports fields, athletic organizations, tennis courts, bowling allies, skating rinks, gyms, health studios, instructional fitness centers, YMCAs, senior centers and golf courses. Three series of thematic maps - Location, Distribution and (Spatial) Accessibility were created for each of the seven groups of physical activity sites. Site locations were geocoded from street addresses and distribution was determined by dividing the number of physical activity sites within each neighborhood by the total population of the neighborhood then multiplying 1000. Spatial accessibility was measured by finding the travel distance from the areas of highest population concentration to the nearest physical activity Site for all PA Site groups using network analysis.

Location and Distribution maps show that the majority of physical activity sites in Nueces County are located in urban area neighborhoods. In some cases, travel distances to the nearest physical activity Site in peri-urban areas were nearly double those of urban area neighborhoods. In this study, there were only 4 peri-urban neighborhoods compared to 77 urban neighborhoods; yet the average travel distance for peri-urban areas was 7.5 miles compared to 0.6 miles in urban areas. Due to extreme disparity in area, number of physical activity sites and spatial access to PA Sites between peri-urban and urban areas, peri-urban areas were excluded from statistical analysis in Research Question Two. About 38% of Nueces County neighborhoods are within less than .5 miles of where the majority of the neighborhood population lives; 37% travel less than 1 mile to the nearest physical activity site and 89% of county neighborhoods have a travel distance of less than 1.5 miles to the nearest physical activity site. The Spatial Accessibility and Location maps make it clear that for residents living in peri-urban areas, especially Banquete, Driscoll and Chapman Ranch, it is necessary to travel outside the neighborhood to access a variety of activity sites such as gyms, recreation centers, golf courses or places that offer instructional courses like yoga, parasailing or Pilates. The results for spatial accessibility to parks was nearly identical to results where all the physical activity sites were analyzed. This is not surprising given that parks comprise 67% of the total PA site dataset. In 38% of Nueces County neighborhoods the nearest park is less than .5 mile from where most of the population resides; in 74% of neighborhoods the nearest park is less than 1 mile from population centers and in 91% of Nueces County neighborhoods the nearest park is about 1.5 miles away from where most people live. Non-park physical activity sites comprised 33% of the PA sites in the dataset of this study. These sites were grouped into 4 categories – Sports and Fun Sites, Fitness Sites, Youth and Recreation Sites and Golf Courses – based on the relative similarity of each activity type.

The Sports and Fun Site group account for 14% of the dataset and is comprised of public and private pools, sports fields, athletic organizations as well as public and private tennis courts. Fun Sites include miniature golf courses, skating/skateboarding rinks and parks, bowling allies and family entertainment centers. In about 23% of Nueces County neighborhoods, a sports or fun site is located less than 1 mile from where most people live; in 54% of neighborhoods the population lives less than 1.5 miles from the nearest sports facility or fun site and 77% of neighborhoods contain population concentrations that live just over 2 miles from the nearest sports or sun site. All Sports and Fun Sites are located in urban areas. Fitness Sites account for

10% of the data and include health studios/gyms as well as sites that offer fitness instruction like Pilates or Yoga. Approximately 49% of Nueces County neighborhoods can access a Fitness Site within 1.5 miles from where the majority of the people in the neighborhood live; in 72% of neighborhoods, residents have access to a Fitness Site that is less than 3 miles away and in 83% of neighborhoods, the majority of the population has access to a Fitness Site that is 3 – 5 miles from where they live. Youth and Recreation Centers account for 6% of the PA Site dataset and include youth organizations such as the Boys and Girls Club of America, the YMCA and senior centers. Youth and Recreation Centers are located less than 1 mile from population centers in approximately 14% of neighborhoods in Nueces County, less than 2 miles in 48% of county neighborhoods and less than 4 miles in 80% of county neighborhoods. All Youth and Recreation Centers are located in urban areas. Finally, approximately 3% of the PA dataset was comprised of public and private 18-hole golf courses. All Golf Courses are located in the Corpus Christi urban area and Port Aransas. In about 10% of Nueces County neighborhoods, the nearest Golf Course was located approximately 1 mile from where the majority of the population lives; in 37% of neighborhoods the majority of the population lives approximately 2 miles or less from the nearest Golf Course and in 63% of county neighborhoods the majority of the population lives less than 3.5 miles from the nearest golf course.

Golf Course spatial accessibility results illustrate an important observation that is echoed in all other spatial accessibility map results. Even when several neighborhoods do not contain Golf Courses, spatial access increases when these neighborhoods are located adjacent to a neighborhood that contains at least 1 Golf Course. This type of contagion effect means that spatial accessibility will often appear to be high (e.g. low travel distance) on Spatial Accessibility maps, but this is no indication that there are enough sites in the neighborhood to accommodate the size of the population. In other words, spatial accessibility alone can only provide a limited view of resource distribution. Distribution maps however, are comprised of a ratio that explicitly accounts for neighborhood size. Combining results from both the Spatial Accessibility and Distribution maps provided a better visualization of resource scarcity. The results indicate that the greatest spatial accessibility *and* availability of physical activity sites is exclusive to urban area neighborhoods. Approximately 42% of Nueces County neighborhoods met the criteria for greatest spatial access and best resource availability when All physical Activity Sites were considered; 33% met the criteria for parks; 27% met the criteria for Non-park PA Sites and 11% met the criteria for both spatial accessibility and availability of Golf Courses.

The spatial accessibility literature consistently shows linkages between neighborhood-level socioeconomic factors and physical activity behavior. In order to determine if these linkages are also apparent within Nueces County Ordinary Least Square (OLS) regression was used to examine the relationship between spatial accessibility to All physical activity sites, socioeconomic variables and spatial factors in Research Question Two. The regression explained about 50% of the factors that influence spatial accessibility in Nueces County urban areas. The three socioeconomic variables used were Female education (2005 – 2009), percentage of households earning $35,000 – 59,000 (2007 - 2011) and percentage of Hispanic households earning $35,000 – 99,999 (2007 - 2011). Results showed that the three spatial variables used in the model were statistically significant while the three socioeconomic variables were not.

Results showed statistically significant relationships with spatial accessibility to All physical activity sites and to Parks. Although the first regression explains about 50% of the variation in spatial accessibility where All Physical Activity Sites was the dependent variable, of the 6 independent variables used in the regression, only the three spatially-relevant variables (e.g. variables that are specifically linked to the geographic location of neighborhoods or physical activity sites) were statistically significant. The first of these spatially-explicit variables can be interpreted as an indicator of the sufficiency of the number of PA sites in a neighborhood to accommodate the size of the neighborhood population and was positively correlated when All Physical Activity Sites were considered. The second spatially-explicit variable captured the spatial relationship between inner city vs. outer city neighborhoods and was negatively correlated with spatial accessibility for All PA Sites. This result could be interpreted to mean that inner city neighborhoods have greater spatial accessibility to physical activity sites, which is a reasonable outcome given that the majority of sites in the study are located in the Corpus Christi inner city area. And finally, the third spatially-explicit variable captured the spatial relationship between small neighborhoods vs. large neighborhoods and was also negatively correlated with spatial accessibility to All PA Sites. This result could be interpreted to mean that smaller sized (e.g. in area) tend to have greater spatial accessibility to physical activity sites than larger-sized neighborhoods in the study. Again, this relationship makes sense when disparity between the larger-sized neighborhoods and smaller-sized neighborhoods are compared on Location, Distribution and (Spatial) Accessibility maps in Chapter Four. Finally, the same spatially-explicit variables were statistically significant for Parks which is not surprising given that Parks account for 67% of the activity sites in the data. However, the parks regression explained about 3% less of the variation in spatial accessibility compared to when all of the physical activity sites are present.

The third objective of the research was to examine the association between spatial accessibility to physical activity sites and obesity in Corpus Christi, Texas. Pearson's Correlation was run for 10 variables derived from two surveys that were combined from adult residents who live in Nueces County, Texas. One survey was targeted to Corpus Christi residents who were diabetic and the other survey was not targeted. Obesity was approximated using Body Mass Index (BMI) obtained from weight and height data acquired from the combined surveys. Approximately 82% of those surveyed were overweight or obese even though 67% of respondents live less than half a mile from the nearest physical activity site. According to the CDC, normal BMI is between 18.5-24.9. BMI greater than 25 is considered overweight and BMI greater than 30 is considered obese. The average BMI for Corpus Christi residents in this survey was 33, which is considered obese by CDC standards. Forty-six percent of respondents reported that their total household earnings over the previous 12 months was less than $30,000. Results from Research Question Three showed little association between BMI and spatial accessibility to physical activity sites. The strongest correlations to BMI were household income, which was negatively correlated, and the participant's perception that it was easy to walk to places within their neighborhood, which was also negatively correlated. Though the associations are much weaker, the number of people who perceived that their neighborhood was free from crime; reported that public transportation was adequate in their neighborhood and reported that their neighborhoods offered many opportunities to be physically active all decreased with increasing BMI. In other words, being overweight is associated with how safe people feel in their neighborhoods, whether public transportation is available in the neighborhood and whether resident's perception that there are many opportunities to engage in physical activity within their neighborhoods. Finally, Hispanic ethnicity showed a weak but positive correlation to BMI.

5.1 CONCLUSION

Results from Research Question Three show that the majority of individuals surveyed live within half a mile of the nearest physical activity site and that 28% actually live within a quarter mile of the nearest site. Similar results emerged from spatial accessibility maps in Research Question One. The result demonstrates that physical activity sites are easily accessible to most Corpus Christi residents. Yet, the overwhelming majority of respondents, 82%, were overweight or obese. The implication, then, is that distance to physical activity sites (e.g. spatial accessibility) alone does not mitigate obesity. Therefore, merely living close to physical activity sites is not enough to encourage the uptake of regular physical activity in Corpus Christi. This conclusion is supported when comparing the neighborhood Distribution and Spatial Accessibility maps from Research Question One. Because spatial access to physical activity sites is impacted by the number of PA Sites located in adjacent neighborhoods, PA sites appear to be highly accessible in urban areas because the nearest PA Sites are very commonly located within one mile of where most people tend to live in the neighborhood. This kind of contagion effect creates a situation whereby neighborhood spatial accessibility is high (e.g. less than 1 mile from densely populated areas) even though some of these neighborhoods contain no sites at all. The Distribution maps, however, take into consideration whether the number of sites within the neighborhood are enough to accommodate the size of the population. This metric is distinct to simply calculating the absolute number of PA sites per neighborhood as the former explicitly accounts for the number of people living within individual neighborhoods and was found to be significantly positively correlated with spatial accessibility to All Physical Activity Sites as well as Parks in Research Question Two. When the Accessibility and Distribution maps are juxtaposed; it is clear that in many cases, neighborhoods that have high spatial accessibility to PA Sites do not score as well on the Distribution map. Further, when both Spatial Accessibility and Distribution were used as a criteria for determining scarcity of neighborhood resources, far fewer neighborhoods and only ones in urban areas, met the criteria for greatest accessibility and availability.

One interpretation of these results is that when there are fewer physical activity sites within neighborhoods, the kinds of physical activity opportunities that they present tend to be less diverse in that there aren't many different kinds of activity sites available. For example, for two small neighborhoods identical in size and population, if one neighborhood contains 2 gyms that impose a membership fee of $100 per month and the other contains a similar gym but also contains a public park with biking trails that is next to the beach, residents in the second scenario may be more likely to engage in physical activity even though in both cases, spatial accessibility to physical activity sites is comparable. The implication is that there may be other barriers to anti-obesogenic behaviors (such as walking, bike riding or swimming) than cannot be explained by lack of spatial accessibility alone. Two of these barriers appear to be:

- Lack of diversity in type physical activity opportunities available;
- Annual household income of neighborhood residents

In fact, these two potentially mitigating factors may be correlated. Results from Research Question Three show that household income is positively correlated with whether people perceived that their neighborhood offered many opportunities to be physically active. One interpretation of this finding is that better off neighborhoods tend to offer more diverse opportunities to engage in physical activity. Further, BMI is negatively correlated with household income and whether residents perceived that it was easy to walk in their neighborhoods. This suggests that when neighborhoods are perceived as being safe and yearly income is higher, residents tend to be thinner, perhaps due to increased physical activity. In addition, household income had a relatively strong positive correlation with whether Corpus Christi residents perceived that their neighborhood was free from crime. This means that as household income increased perception that the neighborhood was safe also increased. Again, crime-free neighborhoods are often associated with wealthier neighborhoods. Two income variables were found to contribute to explaining at least 50% and 48% of the factors that influence spatial accessibility to PA sites and to parks, in Nueces County urban area neighborhoods; although they were not statistically significant. These conclusions support similar findings in the spatial accessibility literature that link neighborhoods with higher socioeconomic status and perceptions of access, safety and aesthetics that impact physical activity behavior (Wilson et al., 2004; Klingerman et al., 2006; Popkin et al.; Loon, 2010).

The number of Hispanic residents who earned $40,000 – 99,999 per year was negatively correlated with spatial accessibility to physical activity sites and parks. This means that as the number of Hispanic residents earning higher incomes increases, the distances to the nearest PA sites decrease (e.g. spatial accessibility improves). Interestingly, the other income variable (those earning between $35,000 – 59,000 across race/ethnicity and gender within Nueces County) showed a positive correlation with spatial accessibility to PA sites and parks – the opposite relationship. Neither of these relationships proved to be statistically significant in the regression models from Research Question Two. The significance of these relationships could have been overshadowed by the strong influence of the spatially-explicit variables in the model mentioned earlier. However, the results of Research Question Three show that there is a relatively strong negative correlation between whether a person self-identified as being Hispanic and a number of other variables including whether they perceived that their neighborhood offered many opportunities to be physically active and whether respondents felt that their neighborhoods were safe from crime.

The take home message is that nearness of physical activity resources (e.g. spatial accessibility) alone has not been demonstrated to effectively mitigate obesity in the City of Corpus Christi nor urban areas in Nueces County as there appear to be other barriers to the uptake of anti-obesogenic behavior. One potential barrier is the lack of diversity in physical activity types within neighborhoods. This potential deterrent to the uptake of anti-obesogenic behaviors in the community and on an individual-level appears to be associated with neighborhood and individual-level income. Research Question One and Three suggest that an array of PA Sites are needed in order to accommodate the needs of the population and this is more important than merely having physical activity resources in close proximity. Income appears to be correlated with whether people perceived that there were plentiful opportunities to engage in physical activity and whether they perceived that their neighborhoods were safe.

There seems to be little dispute that the physical activity environment can influence exercise behavior but this research suggests that if the objective is to encourage more people to be physically active on a community level, thereby lowering BMI and decreasing incidence of Type II diabetes, a more diverse array of fitness opportunities may need to be offered. Neighborhood-level interventions are more effective because they affect more people (Popkin, 2005). Several of the associations between built environment or neighborhood characteristics that have been cited in the literate appear to mirror the case in Corpus Christi. This includes the relatively strong positive correlation between those who had reported being told by a healthcare professional that they had diabetes or pre-diabetes and their BMI.

This study contributes to a new awareness and understanding of the nature of spatial access to physical activity sites in Nueces County. Physical activity sites are places where people can be physically active such as parks, gyms, instructional facilities and YMCAs. These facilities can be public or private, in-door or outdoor, free or fee-imposed. A key benefit of conducting this research has been the ability to characterize the physical activity environment of Nueces County, Texas – an area that has been disproportionately affected by diabetes and obesity. This research also demonstrates the effectiveness of GIS as a tool for analyzing quantitative and qualitative data to determine spatial accessibility of physical activity sites at a neighborhood level.

5.2 RECOMMENDATIONS

Based on the findings of this research study, it appears important to learn as much about individual *and* adjacent communities as possible including demographic and socioeconomic characteristics of neighborhoods to help guide decisions about the type of physical activity opportunities that would best meet the needs of the neighborhood(s) concerned *as well as* surrounding neighborhoods. Questions such as what kinds of physical activities are already here in the community? What kind of PA sites are of interest in this community? What present resources are being underutilized and why? Can the community afford to pay for proposed projects? In addition, special care should be taken to avoid adding redundant physical activity sites to the same area. Thus, if there are already 3 gyms in the local area, it may be more effective to build a public or low cost recreation center that might potentially encourage more people to be physically active. Adding aesthetically pleasing qualities to present sites or building new physical activity sites in or around natural or esthetically pleasing areas like beaches, wooded areas or simply adding interventions to make activities safer could improve people's perception of the safety and value of these physical activity sites and encourage physical fitness; thereby reducing the likelihood of obesity.

5.3 FUTURE RESEARCH

The two surveys used to conduct the analysis for this research contained much more information than was possible to include within the thesis. Because one survey was targeted toward adult residents in Corpus Christi with diabetes and the other was not, it is possible to compare spatial accessibility, socioeconomic and health characteristics between populations that have diabetes and those that do not. In addition, these surveys also make it possible to examine why opportunities to participate in water sports and swimming activities appear to be underutilized in Corpus Christi, a coastal city that offers year-round access to Gulf of Mexico beaches as well as public and private swimming facilities.

REFERENCES

Ambercrombie, L., MPH, Sallis, J. F., Conway, T. L., Frank, L. D., Saelens, B.E. and Chapman, J. E. (2008). Income and racial disparities in access to public parks and private recreation facilities. American Journal of Preventative Medicine, 34(1), 9 - 15.

Billaudeau, N., Oppert, J-M., Simon, C., Charreire, H., Casey, R., Salze, P., Badariotti, D., Banos, A., Weber, C. & Chaix, B. (2011). Investigating disparities in spatial accessibility to and characteristics of sport facilities: Direction, strength, and spatial scale of associations with area income, *Health & Place*, 17, 114-121.

Brabyn, L., and Sutton, S. (2013). A population based assessment of the geographical accessibility of outdoor recreation opportunities in New Zealand, *Applied Geography*, 41, 124 – 131.

Casey, R., Chaix, B., Weber, C., Schweitzer, B., Charreire, H., Salze, P., Badariotti, D., Banos, A., Oppert, J-M. and Simon, C. (2012). Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth, *International Journal of Obesity*, 36, 914-919.

Centers for Disease Control and Prevention, CDC (2013). 1600 Clifton Rd. Atlanta, GA 30333, USA. http://www.cdc.gov/obesity/data/adult.html.

Centers for Disease Control and Prevention, CDC (2012). Texas State Nutrition, Physical Activity and Obesity Profile. http://www.cdc.gov/obesity/stateprograms/fundedstates/pdf/texas-state-profile.pdf, www.dshs.state.tx.us/obesity/NPAOPprogrampage.shtm
Colletti, J., and Masters, M., http://www.menshealth.com/mhlists/metrogrades-fattest-cities/printer.php

Cutumisu, N., & Spence, J. C. (2012). Sports fields as potential catalysts for physical activity in the neighborhood, *International Journal of Environmental Research and Public Health*, 9, 294-314.

Duncan, M-J., Winkler, E., Sugiyama, T., Cerin, E., duToit, L., Leslie, E., & Owen, N. (2010). Relationships of land use mix with walking for transport: Do land uses and geographical scale matter? *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 87(5), 782-795.

Finkelstein, EA; Trogdon, J; Cohen, JW; Dietz, CW (2009) Annual Medical Spending Attributable to Obesity: Payer and Service-*specific Estimates. Health Affairs. 28(5).*

InfoUSA. http://www.infousa.com/us-consumer-database/

Joseph, A., and Phillips, D. (1984). Accessibility and utilization: geographical perspectives on health care delivery. New York: Harper and Row.

Karusisi, N., Thomas, F., Méline, J. and Chaix, B. (2013). Spatial accessibility to specific facilities and corresponding sport practice: the RECORD Study, *International Journal of Behavioral Nutrition and Physical Activity*. 10(48), 1-10.

Kirby J., Liang L., Chen, H., Wang, Y (2012). Race, Place and Obesity: The complex relationships among community racial/ethnic composition, individual race/ethnicity and obesity in the United States. *American Journal of Public Health.* 102(8):1572-1578.

Klingerman, M., Sallis, J., Ryan, S., Frank, L., and Nader, P. (2007). Association of Neighborhood Design and Recreation Environment Variables with Physical Activity and Body Mass Index in Adolescents. *American Journal of Health Promotion*. 21(4):274-277.

Loon (2010). From Society to Behavior: Neighborhood Environment Influences. Obesity Prevention: The Role of Brain and Society on Individual Behavior. Chapter 55. p. 687-698.

Maria P. and Evagelia, S. (2009). Obesity Disease. *Health Science Journal*. 3(3):132-138.

Maroko A., Maantay J., Sohler N., Grady K. and Arno P. (2009). The Complexities of Measuring Access to Parks and physical activity sites in New York City: a quantitative and qualitative approach. *International Journal of Health Geographics*. 8(34):1-23.

Messer, L.C., Laraia, B.A., Kaufman, J.S., Eyster, J., Holzman, C., Culhane, J., Elo, I., Burke, J.G. and O'campo, P. (2006). The development of a standardized neighborhood deprivation index. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. 83(6):1041-1062.

Mitra, R., and Buliung, R.N. (2012). Built environment correlates of active school transportation: neighborhood and the modifiable area unit problem, *Journal of Transport Geography*, 20, 51-61.

Openshaw, S. (1983) The modifiable areal unit problem. Norwick Norfolk: Geo Books.

Oreskovic, N.M., Kuhlthau, K.A., Romm, D., Perrin, J.M. (2009). Built Environment and Weight Disparities among children in high-and low-income towns. *Academic Pediatrics*. 9:315-21.

Popkin, B.M., Duffey, K., Gordon-Larsen, P. (2005). Environmental Influences on food choice, physical activity and energy balance. *Physiology and Behavior*. 86.

Reed, J.A., Ainsworth, B.E., Wilson, DK, Mixon G. and Cook, A. (2004). Awareness and use of community walking trails. *Preventative Medicine*. 39.

Sallis and Glanz (2009). Physical Activity and Food Environments: Solutions to the Obesity Epidemic. *The Milbank Quarterly*. 87(1):123-154.

Sharkey, J.R., Horel, S., Han, Daikwon, and Huber, J.C. (2009) Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of Colonias. *International Journal of Health Geographics* 8:9.

Swaney, J. (2012). Independent Study: Obesity. *ISNA Bulletin*. February, March, April 2012, 9-13.

Vojnovic, I. (2006). Building communities to Promote Physical Activity: A Multi-Scale Geographical Analysis. Geografiska Annaler. *Series B. Human Geography*. 88(1): 67-90.

Weiss, C.C., Purciel, M., Bader, M., Quinn, J. W., Lovasi, G., Neckerman, K. M., and Rundle, A. G. (2011). Reconsidering access: Park facilities and neighborhood disamenities in New York City, *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 88(2), 297-309.

WHO (World Health Organization) (2014). Obesity and overweight. Fact sheet N311. http://www.who.int/mediacentre/factsheets/fs311/en/

Wilson, D.K., Kirtland, K., Ainsworth, B.E., Addy, C.L. (2004). Socio-economic Status and perceptions of access and safety for physical activity. *Annals of Behavioral Medicine*. 28(1):20-28.

Glossary of Terms

Access/ (Spatial) Accessibility – In the context of this thesis, spatial access or spatial accessibility refers to the travel distance between where the majority of the neighborhoods population resides and the nearest Physical activity site.

DataFerrett (Federated Electronic Research, Review, Extraction and Tabulation Tool) – An online data analysis and extraction tool provided by the U.S. Census Bureau used to locate, customize and download federal, state and local data. The tool is located at http://dataferrett.census.gov/

Feature Class – A term used in GIS that refers to the manner in which data are visually displayed in a Geographic Information System (GIS). Feature classes consist of homogeneous collections of geographic feature representations or descriptive properties (most commonly points, lines, polygons and annotations) that have the same spatial representation, a common set of attribute columns (ESRI).

GIS (Geographic Information System) – A data handling system that "integrates hardware, software, and data for capturing, managing, analyzing and displaying geographically referenced information" (ESRI).

Mean Center – In spatial statistics, the mean center identifies the geographic center of a set of features by averaging their X and Y coordinates (ESRI).

Neighborhood – Neighborhoods for this study were represented by U.S. census tracts for neighborhood-level analysis used in Research Questions One and Two. For individual-level analyses in Research Question Three neighborhoods were defined as the area within a 1 mile radius or twenty-minute walk from the respondent's residence for those participating in the targeted Neighborhood Food Environments and Diabetes Survey. For those participating in the Diet, Exercise and Physical Activity Environment component of the survey, neighborhood was not explicitly defined by the study.

Network – A feature class made of lines that represent or model streets, roads and highways.

Network Analysis – A spatial examination of properties that arise from travel along a network such as routing, travel direction, closest facility and service area. Network analysis is used to model real-world travel along a path of connected line segments. An example is (poly)lines that model roads. Network Analyses are assessed in ArcGIS using the Network Analyst extension tool (ESRI)

(Physical) Activity Site - In this research, these refer to places where physical activity takes place such as parks, gyms, pools, golf courses, beaches, sports complex as well as sports fields.

Physical Activity Environment – Describes the discrete (e.g. built environment features such as a gym or natatorium) and continuous (e.g. socioeconomic) characteristics of the geographic space in which households are situated. This environment influences behavior including the decision of whether or not to engage in physical activity at a neighborhood or community level.

APPENDIX

Appendix A: Survey Instrument

DIET, EXERCISE & PHYSICAL ACTIVITY ENVIRONMENT SURVEY FOR ADULT RESIDENTS OF NUECES COUNTY

Texas A&M University – Corpus Christi ⌖Coastal Bend Diabetes Initiative ⌖ Thesis Research

This Diet, Exercise and Physical Activity Environment Questionnaire is for residents of Nueces County and will take about 10 – 15 minutes to complete. Your participation is completely voluntary and you may withdraw at any time. If you come to a question that you do not want to answer please just skip it. All information is confidential. Your responses help us create better access to recreational facilities in our community and we appreciate your participation.

Background and Short Health Section

1. (Other than during pregnancy) have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?
   - ☐ Yes
   - ☐ No
   - ☐ Borderline or pre-diabetes
   - ☐ Don't know
2. Since the survey is about recreational facilities in neighborhood environments, please tell us your address so that we can assign your responses to the appropriate neighborhood. This information is used to conduct this study only; and is kept strictly confidential.

   Street Address____

   City ____

   Zip Code ____
3. What is your gender/sex?

   ☐ Male ☐ Female
4. What is your age as of your last birthday? _________________
5. What is your height

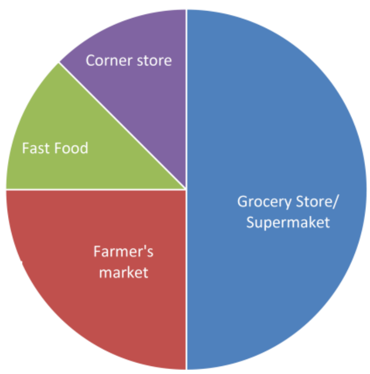
   Feet ______________ Inches _______________
6. What is your weight? ____________________________
7. What race or races do you consider yourself to be? Check all that apply.
   - ☐ American Indian or Alaskan Native
   - ☐ Asian
   - ☐ Black or African American
   - ☐ Hispanic or Latino
   - ☐ Native Hawaiian or Pacific Islander
   - ☐ Non-Hispanic White
   - ☐ Don't know
   - ☐ Other (please specify) ____

1

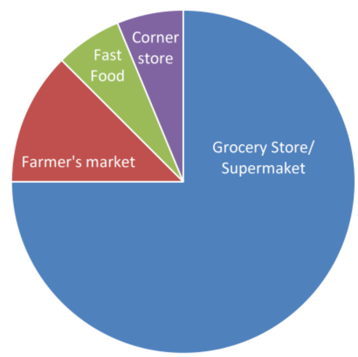
8. Which category best represents your TOTAL household income from all household members during the past 12 months?
   - ☐ Less than $10,000
   - ☐ 10,000 – 29,999
   - ☐ 30,000 – 59,999
   - ☐ Greater than $60,000

9. Which of the following charts best represents your food spending habits? (Circle A,B,C or D)

A



B



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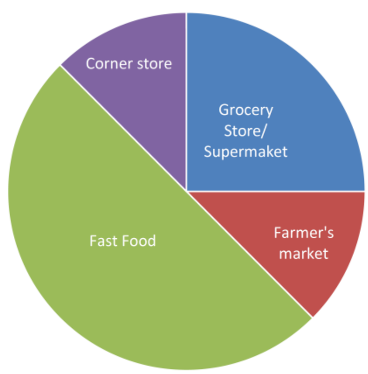

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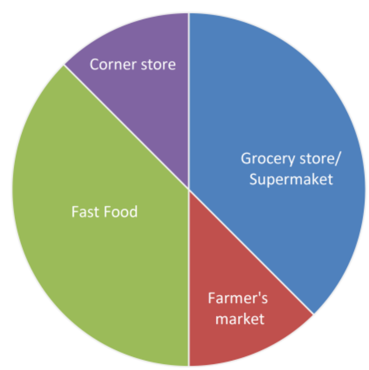


Physical Activity Section

10. Please read the following statements that people have made about their neighborhood and food situation. For these statements, please state whether you strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree.

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
My neighborhood is attractive	☐	☐	☐	☐	☐
My neighborhood offers many opportunities to be physically active	☐	☐	☐	☐	☐
It is pleasant to walk in my neighborhood	☐	☐	☐	☐	☐
There are busy roads to cross when out for walks in my neighborhood	☐	☐	☐	☐	☐
In my neighborhood it is easy to walk to places	☐	☐	☐	☐	☐
My neighborhood is safe from crime	☐	☐	☐	☐	☐
A large selection of fresh fruits and vegetables is available in my neighborhood	☐	☐	☐	☐	☐
The fresh fruits and vegetables in my neighborhood are of high quality	☐	☐	☐	☐	☐
A large selection of low fat foods are available in my neighborhood	☐	☐	☐	☐	☐
Lack of access to adequate recreational facilities is a problem in my neighborhood	☐	☐	☐	☐	☐
There are sidewalks in my neighborhood	☐	☐	☐	☐	☐
Public transportation in my neighborhood is adequate	☐	☐	☐	☐	☐

11. What factors are most important to you when considering whether to participate in physical activity? **Select three.** Then rank them from 1-3 with a ranking of "1" being most important.

Activity	**Rank**
Distance to facility from my neighborhood	
Cost of activity	
Safety of the environment around the recreational activity	
Safety of the activity	
Health benefits of the activity	
Feeling motivated to do physical activity	
The beauty or aesthetics of outdoor parks and facilities	
The weather	

12. Is there a nature trail in or near your neighborhood?
    - ☐ Yes
    - ☐ No
    - ☐ Don't Know

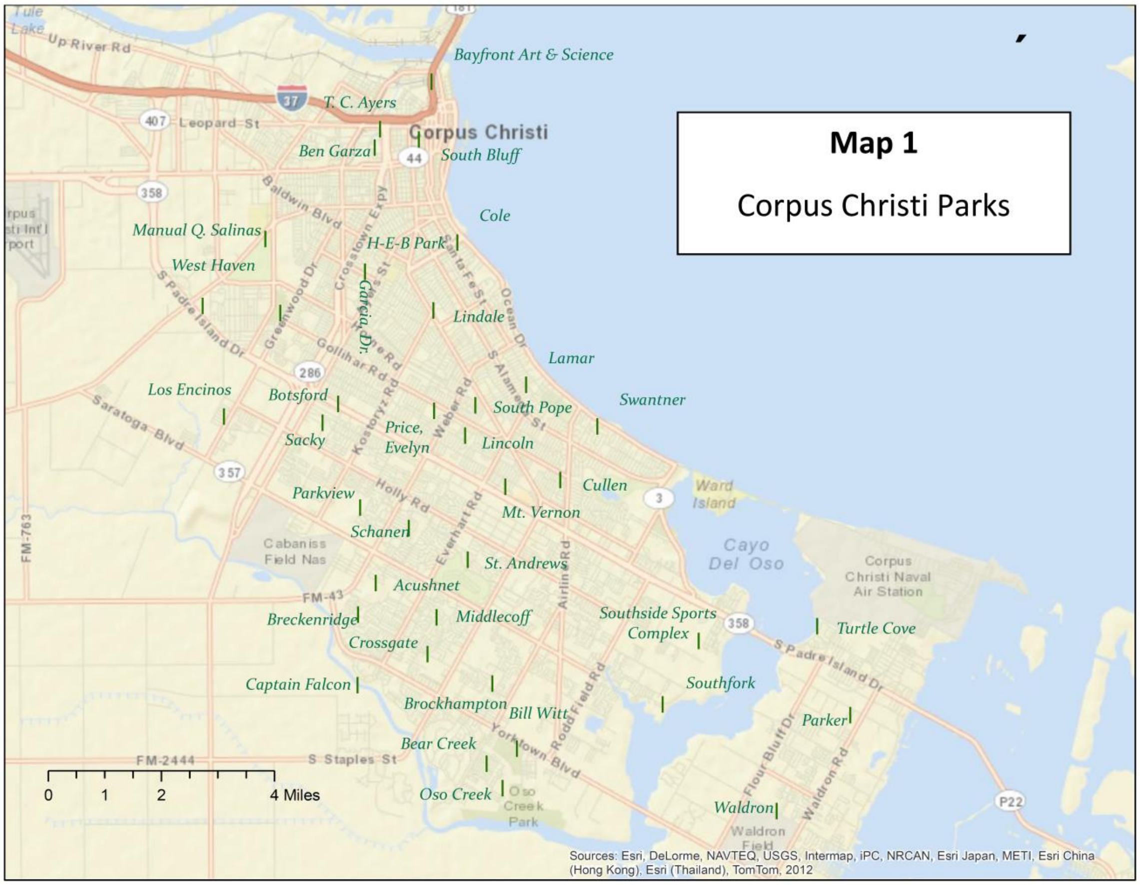
13. Are there adequate facilities for biking in your neighborhood?
    - ☐ Yes
    - ☐ No
    - ☐ Don't Know

14. Do you engage in any of the following beach activities? (check all that apply)
    - ☐ Swimming in the sea
    - ☐ Walking in or near the sea
    - ☐ Team sports on the beach (e.g. volleyball, beach ball)
    - ☐ Surfing
    - ☐ Water skiing
    - ☐ Biking on a trail near the beach
    - ☐ Paddle boarding
    - ☐ Other ____
    - ☐ Do not engage in beach activity

15. If you DO NOT engage in beach activities, please indicate why not (check all that apply)
    - ☐ Beach is too far away from my neighborhood
    - ☐ Beach is too dangerous
    - ☐ Beach is too sunny
    - ☐ Cost of beach activity equipment is prohibitive
    - ☐ Do not know how to swim
    - ☐ No means of getting to the beach
    - ☐ Never thought about it
    - ☐ Other ____

16. Please review Map 1 below to answer questions about parks that you frequent regularly and answer question a-f. **If you do not see your park, please mark the approximate street location of park(s) that you *do* frequent with an "X" on the map to answer questions a-f.**

If you have not visited a park at all within the past 12 months skip to question 17.



a. **Park 1** (Write park name. Add street location if park is not on map)

____

____

b. **Park 2** (Write park name. Add street location if park is not on map)

____

____

c. About how far is your home from **each park?** (add a "✓ " in the appropriate box)

	Park 1	Park 2
1 mile (or less)		
About 2-5 miles		
Between 5 – 10 miles		
Greater than 10 miles		
Don't Know		

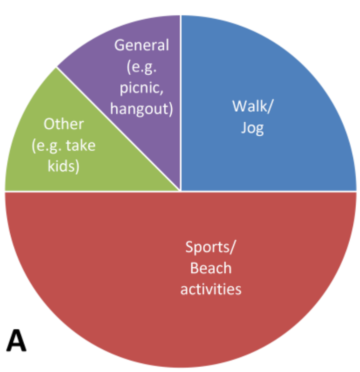
d. How often do you go to **each park?** (add a "✓ " in the appropriate box)

	Park 1	Park 2
Less than once/ month		
About once/month		
2-3 times/ month		
Greater than 3 times/month		
Don't Know		

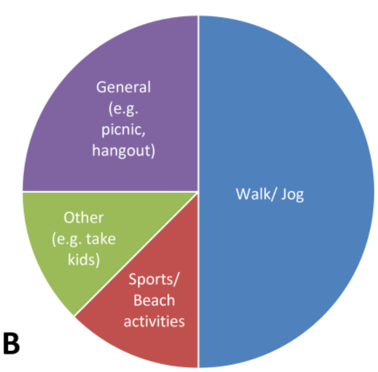
e. What is the usual amount of time spent at the **each park?** (add a "✓ " in the appropriate box)

	Park 1	Park 2
Less than 30 minutes		
About 30 minutes		
About 1 hour		
Greater than 1 hour		
Don't Know		

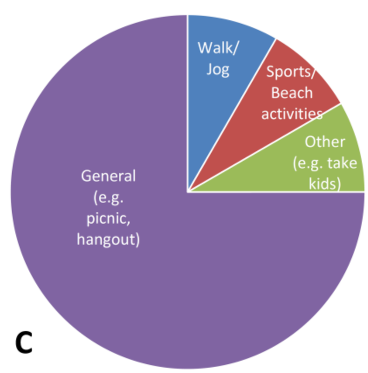
f. Which pie chart best represents activities undertaken at each park? (Circle A, B or C)



A

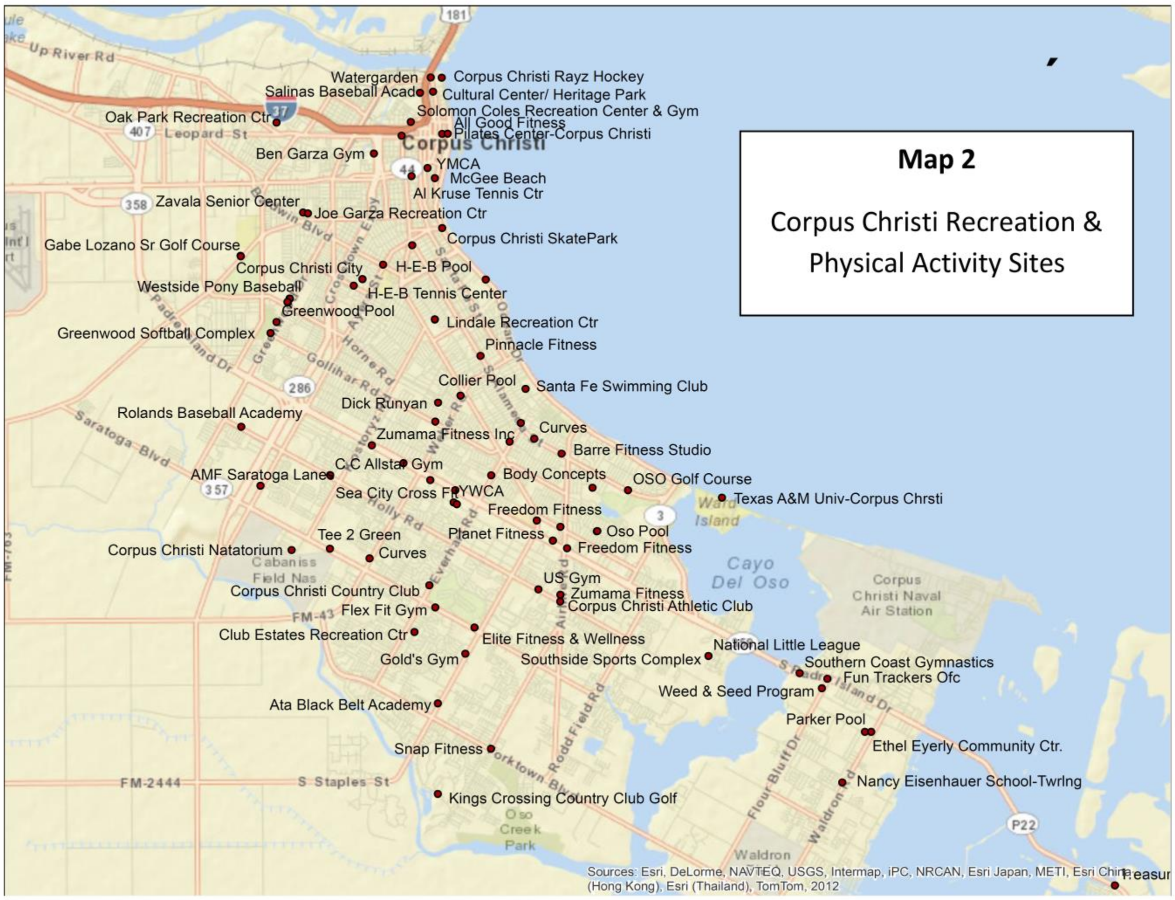


B



C

17. Please use the map to list two NON-PARK recreation and physical activity sites that you frequent regularly and answer questions a-e**. If you don't see your activity site please mark the approximate street location of a site that you *do* frequent with an "X" and answer questions a-e**.



a. **Activity 1** (Write park name. Add street location if activity is not on map)

____

____

b. **Activity 2** (Write park name. Add street location if activity is not on map)

____

____

c. About how far is your home from **each activity**? (add a "✓ " in the appropriate box)

	Activity 1	**Activity 2**
1 mile (or less)		
About 2-5 miles		
Between 5 – 10 miles		
Greater than 10 miles		
Don't Know		

d. How often do you go to **each activity**? (add a "✓ " in the appropriate box)

	Activity 1	**Activity 2**
Less than once/ month		
About once/month		
2-3 times/ month		
Greater than 3 times/month		
Don't Know		

e. What is the usual amount of time spent doing **each activity**? (add a "✓ " in the appropriate box)

	Activity 1	**Activity 2**
Less than 30 minutes		
About 30 minutes		
About 1 hour		
Greater than 1 hour		
Don't Know		

This is the end of the survey. Thank you for your time.