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# Improving the design of golf course communities as wildlife habitats

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# IMPROVING THE DESIGN OF GOLF COURSE COMMUNITIES AS WILDLIFE HABITATS

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# ABSTRACT

Golf course community developments present a unique opportunity to preserve and create wildlife habitat. Golf course management and development industries have become particularly cognizant of their environmental responsibilities in recent times and are responsive to new research. The specific focus of this thesis research is to provide guidance and encouragement for landscape architects designing wildlife habitat areas within golf course community developments. Specifically, I analyze the size, shape, and orientation of a selected number of wildlife habitat areas within the unique context of golf course community land usage. My hypothesis is that the spatial characteristics of a habitat area influence the resulting wildlife habitation. Therefore, designers can influence the habitation of designated wildlife habitat through design decisions. This thesis produces a set of guidelines for the design of wildlife habitat areas within golf course communities in addition to substantiating the importance of incorporating wildlife habitat within large-scale developments, especially golf course communities.

# CHAPTER ONE

## INTRODUCTION AND LITERATURE REVIEW

Over the past five years, an average of 344 golf courses per year have been constructed and opened for business (National Golf Foundation, 2001). With each new golf course completed, an opportunity for an active wildlife habitat is created. Every golf course construction project creates approximately 150 acres of green-space and often leads to development of more acreage. Golf course community developments present a unique opportunity to preserve and create wildlife habitat. Within the general pattern of urban sprawl, large-scale developments (especially developments contingent on green-space creation) can provide answers to the conservation of otherwise displaced wildlife species. Golf course management and development industries have become particularly cognizant of their environmental responsibilities in recent times and are responsive to new research. As a result, information revealed in this thesis could potentially generate a positive environmental impact on thousands of acres of developed land.

During the 1970's, Americans changed dramatically their views on the environment and wildlife (Thomas, 1982). Landscape architects have been major benefactors of America's increased focus on environmental concerns, including wildlife issues. Research by landscape architects in the field of wildlife habitation however, has been quite limited. The reason for this lack of research is the wealth of information available from the scientific community on wildlife and fisheries. However, this information has been developed by the scientific community and does not always meet the specific needs of the designer. This gap in information is waiting to be filled by

landscape architects who feel a responsibility toward wildlife and wish to help other landscape architects provide for unique wildlife demands.

**Research Objective**

The specific focus of this thesis research is to provide technical guidance and encouragement for landscape architects designing wildlife habitat areas within golf course community developments. Large-scale development designers are pressured to develop property to its greatest income potential. This high product yield emphasis requires that designers have assurance and encouragement that all land area decisions, including wildlife habitats, will be productive.

My research reveals that a selected cross-section of wildlife habitation areas is being successfully inhabited by a number of wildlife species. Secondly, I develop a number of useful guidelines to aid in the design of habitat areas. Specifically, I analyze the size, shape, and orientation of a selected number of wildlife habitat areas within the unique context of golf course community land usage.

Four golf course communities within southern Louisiana were selected and their wildlife habitation areas critically observed. These field observations were analyzed in comparison to a number of spatial statistics derived from aerial photographs of the same wildlife habitat areas. My hypothesis is that spatial statistics of the habitat area influence the resulting wildlife habitation. Consequently, designers can influence the habitation of designated wildlife habitat through design decisions.

A detailed statistical analysis was used to prove correlations that exist between the spatial characteristics of specific wildlife habitat areas and their observed wildlife habitation. A resulting set of guidelines is produced to communicate the relationships

between design decisions and resulting habitation of designated wildlife habitat within golf course communities. The guidelines translate scientific proof into information readily accessible by the designer.

**Golf Courses and Wildlife Habitat**

**Figure 1. Wildlife Habitat at The Bluffs on Thompson Creek**

Wildlife habitation and conservation on golf courses is a narrow field, but one that has received increased exposure recently. The primary cause for this recent publicity is the work of Audubon International, Audubon International founder Ronald G. Dodson, and the United States Golf Association. The United States Golf Association (USGA) teamed with Audubon International in 1993 to form the Audubon Signature Cooperative Sanctuary Program's certification program for golf courses. The certification has become well known by both golf course industry personnel and avid golfers. The program seeks to honor golf courses and other developments that meet a number of environmental guidelines. Among the specific environmental concerns of these guidelines is increased wildlife habitation. The requirements for designation in this program are not simple. The initial charges alone for Audubon International consulting and registration of an 18-hole golf course development are approximately $50,000. The golf course developers and owners who subscribe to this program not only pledge devotion to environmental standards but also put their money behind that pledge.

Ronald Dodson is the founder and current president of Audubon International. However, Dodson's connection to wildlife and golf courses extends far beyond his association with Audubon International. He is a leading researcher, expert, and appriser of wildlife habitat within the golf course. He is personally responsible for creating the Audubon Cooperative Sanctuary System, which includes programs for schools, homesites, business properties, and golf courses. Dodson also created the Audubon Signature Cooperative Sanctuary Program designed for properties in the planning and design stages of development. This program recognizes the development of properties, especially golf courses, which meet a number of planning guidelines and adhere to the regulations of environmental experts.

Ronald G. Dodson is the single-most dominant advocate for the increase in wildlife habitation within golf courses and golf course communities. Dodson's most significant publication, *Managing Wildlife Habitat on Golf Courses*, divulges the basics of his philosophies and information in the golf course wildlife habitat field. He describes what he feels the roles of various members of the golfing community are in terms of the environment and wildlife. He also describes the important historical relationship between golf and the environment. Finally, he advises on some specific wildlife habitation accomplishments and showcases golf courses whose actions deem them as models of environmental stewardship.

Another notable researcher in the field of golf course wildlife habitats is Scott W. Gillihan. His recent publication, *Bird Conservation on Golf Courses*, is a true textbook for golf industry personnel who desire to act beneficially for and be educated about bird life habitation. Gillihan is well versed in the current research and information available

about wildlife habitation. He has taken this opportunity to apply these wildlife concepts to the context of the golf course and golf course communities. Gillihan's specific interest and knowledge about bird life contributes positively to this task, as birds dominate the wildlife scene in most golf courses.

Gillihan writes at length about the spatial characteristics of wildlife habitation areas, or patches, as he refers to them. He stresses the importance of considering habitats at the landscape level of planning, during the initial conceptual layouts of a golf course development. He explains how different routings of a golf course will shape the preserved habitat areas. In this endeavor, he tends to show his wildlife bias. He compares the varied routings weighting the concerns of bird habitat equal to all other concerns of a golf course development combined. I would argue that wildlife habitation concerns need to be viewed in concert with a complex of other issues (topography, vegetation, housing developments, hole orientation, access, clubhouse location, etc.).

The size, shape, and orientation of wildlife habitation areas are also discussed in *Bird Conservation on Golf Courses*. Scott Gillihan writes without wavering that large areas are much better than small areas and, therefore, small areas should be merged to create single large areas. His reasoning is that merging smaller habitats eliminates edge areas where disturbance occurs. He also sites a study that modeled total bird species as directly related to the logarithm of the patch size area, i.e.

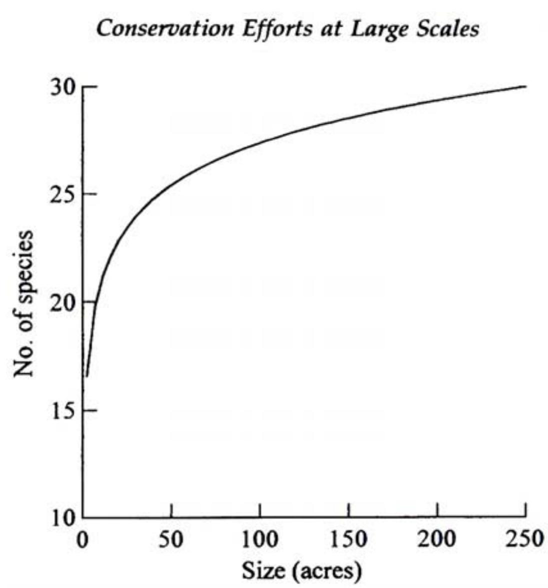



**Figure 2. Bird Species vs. Habitat Size (Source: Gillihan, 2000)**

total bird species increase dramatically in small patch areas and then level off as the patch size increases above fifty acres. Gillihan goes on to explain that edge habitat favors common and predator species and should not be the goal of wildlife managers. He therefore contends that wildlife areas should be large, circular, and have relatively smooth perimeters to minimize edge habitat. Smooth, regular perimeters are most important along the southern edge where sunlight and heat increase the width of edge habitat. Additionally, corridors of at least 30 yards in width are beneficial, especially riparian corridors along streams. He advises that human disturbances should be minimized by routing activity away from preserves and buffering specific habitat locations. One hundred feet of buffer setback between golfers and specific habitat locations is considered minimal. Finally, he discourages viewing property boundaries as habitat boundaries because wildlife obviously will not.

**Golf Course Design Theory**

**Figure 3. The Bluffs on Thompson Creek**

The field of golf course design and development has never been one of well-established education and principles. Those skilled at the art of golf course design are more focused on practicing their skill than teaching it. Because the field is also quite competitive, experienced designers often carefully guard their skills instead of sharing them. A number of well established

golf course designers have, however, taken the time to impart their skills to the next generation of golf course designers.

Dr. Michael J. Hurdzan is perhaps the contemporary golf course architect most committed to sharing his skill as a designer through education. He is a past president of the American Society of Golf Course Architects and has designed over 150 new courses in North America. He routinely speaks at conferences on turfgrass, golf, and land planning throughout the country. He is also well published. Besides contributing to golf industry books as an expert, his *Evolution of the Modern Green* and *Golf Course Architecture: Design, Construction & Restoration* are well respected.

Hurdzan's *Golf Course Architecture: Design, Construction & Restoration* is the premier text on golf course development and strategy. He describes in detail both the practice of golf course architecture and construction (skills, technologies, routines, methods, innovations, etc.) and the theory (philosophies, ideals, concepts, expert opinions, etc.). The theory portion of Hurdzan's book is what truly sets his publication apart. He imparts bundles of knowledge that he has gained through a lifetime of mentoring and practicing. He often writes that a specific skill will take a hundred times to master or that 30 years of practice will be needed to master this skill, but his thoughts and advice seem to get students a head start. He also speaks with clarity about a number of truly great golf courses that he has created. Devil's Pulpit, Devil's Paintbrush, Cook's Creek, Widow's Walk, and Westwood Plateau are among Michael's greatest exploits. Hurdzan also writes with great experience about the necessary tools and technologies of practicing this art. Unfortunately, wildlife habitat within the golf course is only

mentioned as preservation of critical environmental zones and as proof of golf's environmental benefits. The selection and design of these habitat zones is not discussed.

Geoffrey S. Cornish is another golf course architect who has been instrumental in handing down design principles to the next generation of golf course designers. He has been designing golf courses for over fifty years and has more than 200 golf courses of his design in the United States and Canada. He is an often-quoted expert and has co-authored several books. His publications with Ronald Whitten, *The Golf Course* and *The Architects of Golf* have won him numerous awards from the golf community. *The Golf Course* gives an insight into golf course architecture that had never before been captured. Cornish intrigues golfers about the importance of golf course architects in the role and history of the game. There is no question that his writing raised the level of respect and credibility given to golf course architects.

Cornish's most recent collaboration with Robert Muir Graves, *Golf Course Design*, reestablishes him as a leader in the education of golf course design and construction. These two inspiring golf course architects, along with a grand assemblage of industry experts, describe every aspect of golf course development from history and design, to construction and turfgrass, to business and financing. The result is an incredibly informative, albeit sometimes cumbersome, look into the golf course development industry. Most helpful in this work are the numerous case studies from the co-authors' careers that are divulged and evaluated. The inclusion of technical information from various expert contributors also makes the work a valuable reference. In fact, golf course wildlife expert Ronald G. Dodson contributes to Cornish's section on wildlife habitat. Discussion of the topic focuses on providing the four essential elements

of food, water, cover, and range for local wildlife species. Cornish contends that the most important spatial quality in locating wildlife habitat is proper interspersion of these four critical elements so that wildlife species do not have to travel too far to contact them. The importance of selecting appropriate vegetation to encourage and sustain wildlife is also discussed.

A number of other golf course architects have attempted publications to impart their golf course design knowledge but generally without the effort and writing expertise as those previously discussed. A number of publications on golf and golf course development date back to the 1920s. The advice available in these texts has inspired many contemporary designers. However, only some of the advice seems to have stood the test of time. The following quotation, by the man who invented the term "golf course architect," serves as an example:

> Hills on a golf course are a detriment. Mountain climbing is a sport in itself and has no place on a golf course. Trees in the courses are also a serious defect, and even when in close proximity prove a detriment.
> *Scotland's Gift GOLF*, 1928, by Charles Blair MacDonald (Graves et al., 1998)

Three of the most influential texts, and most difficult to locate, published in the 1920s, are products of top golf course architects. Dr. Alister MacKenzie's *Golf Architecture*, George Thomas's *Course Architecture in America*, and Robert Hunter's *The Links* continue to enlighten and amuse golf course professionals and enthusiasts today. The basis for these books was the adaptation of traditional Scottish links golf to the varied landscapes and increased technologies of America. The strict rules and ideals put forth in these texts make for some good humor as well as valid insight. *The Course Beautiful* is a collection of articles from A.W. Tillinghast that dates back to the same time period. Tillinghast is the self-proclaimed Dean of American Golf Course Architects and

makes no subtle recommendations about the ways he believed golf courses should be built and maintained. Unfortunately, environmental and wildlife objectives were beyond the scope and foresight of these early golf course authors.

Other contemporary works detailing the art of golf courses and golf course design are available. Many of these publications appeal because of their coffee table style and glossy pictures. Some, however, contain useful information and insight but are less complete then the works detailed previously. Among the notable are *Golf Course Development and Real Estate* by Muirhead and Rando, and *Golf by Design*, by Robert Trent Jones, Jr. Texts like these are most valuable in that they extend the field of golf course design by focusing their information for a particular audience. Unfortunately, neither of these texts provide valuable information about the inclusion of wildlife habitat.

**Wildlife Habitat Planning**

"All wilderness areas, no matter how small or imperfect, have a large value to land-science." -Aldo Leopold, wildlife biologist

The twentieth century has brought great changes to the world's natural environments. Human population has increased rapidly and the exploitation of natural resources is all too common. It is primarily an increased urbanization of our nation, however, that has left the rest of nature's species searching for quality habitat. As human populations continue to grow and more land is taken for human use, planning for wildlife habitation becomes increasingly critical.

**Figure 4. Deer on Golf Course**

The ultimate aim of planning for habitats is the conservation of associated wildlife species (Morrison et al., 1992). Therefore, ideal habitat planning would be done individually for each wildlife species. However, because wildlife species do not exist in seclusion, we must plan wildlife habitats to benefit wildlife species as a whole.

Wildlife habitation research is a field of inquiry based almost solely on observation of wildlife species. Therefore, the facts are constantly under scrutiny and theories are continually evolving as new and better methods of observation are employed. The benefits of edge habitat were once considered advantageous but more recently edge habitat has been considered destructive. The disturbance of fragile inner forest species was once overlooked because elevated populations of edge habitat regions were more visible. Therefore it is critical to assess only the most recent theories and information regarding wildlife behavior.

Two experts in the current working theories of wildlife behavior have applied these theories to golf course wildlife habitat. Ronald G. Dodson and Scott W. Gillihan have unique interests in this relatively narrow field and have led the way for others like myself to quantify and specify their efforts. After closely studying the works of Adams, Morrison, Peek, and others from within the wildlife management field, I find little fault with Dodson and Gillihan's applications. However, I will make a few additions in the areas of ecological landscape planning and wildlife study techniques. The most current techniques for wildlife population studies were used in this study after being gathered from a number of sources. These techniques are described in the following chapter.

Planning habitat for wildlife of differing needs within a scheme of varied land uses is never simple. An early requirement for planning with wildlife is to identify pre-

existing habitats and determine their relative value for wildlife (Adams, 1994). Habitat for endangered species, threatened species, regionally limited habitat, highly populated habitat, and exceptionally species diverse habitats (in that order) should receive planning priority. As many of these zones as possible should be designated as core reserves, with minimized impact and maintenance. These core reserves should also include access to all four critical elements of water, food, cover, and range. Ideally, these core reserves should be surrounded by rings of increasingly intense development. Low-level, environmentally oriented activities first, low-level developments of primary land use, like housing, second, and higher-level land use developments last.

A short discussion of edge habitat and overall wildlife habitat size is needed. Wildlife experts, including Lowell Adams, consider edge habitat as the first 328 feet (100 meters) bordering a habitat change. This statistic renders all habitats of less than 10-acres useless to birds and other species requiring forest interior habitation, non-edge habitat. However, the relative size of most golf course community developments generally restricts reserve areas to less than 10-acres in any one place. When larger core reserve areas are possible, they are highly encouraged. However, the smaller, less extraordinary reserve areas are not without consequence. The size, shape, and orientation of these smaller areas have important impacts on their usage. Finally, soft habitat edges are a highly encouraged and effective method of minimizing the detrimental effects of edge habitat (Adams, 1994). Soft edges are created when vegetation blends adjacent land uses. These types of vegetative plantings are both easily attained and highly encouraged within golf course community developments.

# CHAPTER TWO

## METHODOLOGY

Studying real-world situations poses great difficulties because numerous uncontrollable factors are constantly at work. Researchers attempt to establish cause-effect relationships but are never certain that the complete situation is being understood. The alternatives to studying a real-world situation are to create a study model situation or to manipulate other's work. I decided this thesis was an opportunity to study real-world situations because of the potential for unique success. Success in this endeavor would be to uncover new, unique information about wildlife behavior within golf course settings. True success would then be the application of this information by future designers to benefit wildlife, people, and golf.

The methodology I undertook was a hands-on experimental approach. I decided that by conducting my own specifically targeted physical experimentation, I could achieve the most informative results. I would physically determine what levels of success a number of confined wildlife habitats were experiencing. First, I selected a number of golf course communities within which to conduct my experimentation. Second, I delineated a number of wildlife areas within each golf course community. I then needed to assimilate two sets of data: the first set being a representative population of wildlife within each area, and the second set being a group of statistics describing the size, shape, and orientation of each area. Finally, I compiled the physical findings with the area statistics for analysis and evaluation.

**Golf Course Community Selection**

The process of selecting golf course communities required that they meet the needs of my research and that they not strain my limited time and resources. I needed to select golf course communities that were within a distance I could readily access. I decided on a 150-mile radius within which to limit my search. I also wanted golf course communities that had been designed to include natural areas for the preservation of local plant and wildlife communities. A golf course community that is highly manicured from property line to property line would not produce any wildlife areas for my study. This eliminated most golf courses designed and built before 1970, when ecological concerns were much less pronounced. This requirement, however, was less limiting than one may imagine. For example, one golf course community I selected contained natural areas only within the railroad right-of-way and bayou edges.

A representative variety of golf course communities was also important in this selection process. I chose golf course communities from both rural and urban settings, as well as golf course communities developed on both properties where land was abundant and where space was limited. Representatives from each of the major golf course operation sectors were also sought out. These sectors include: publicly owned-publicly accessible, privately owned- publicly accessible, and privately owned-privately accessible. I also chose to represent varied plant and geological communities in order not to restrict the results of this research to a specific ecologic community. A last restriction of my search was permission for my study from the management of each golf course community. Luckily, management within the golf course community has become very welcoming toward ecological information and improvement. Finally, the availability of

recent aerial photography of the community was a requirement to gain area statistics consistently among all study sites.

The best results from this study would occur from selecting a large study sample and studying each golf course community at length. However, the nature of this project limited my study to choosing four representative golf course communities and studying each over several days. The following four golf courses were chosen because of their adherence to my objectives and restrictions both individually and as a whole: The Bluffs on Thompson Creek near Saint Francisville, Louisiana; Money Hill Golf and Country Club near Abita Springs, Louisiana; The University Club in Baton Rouge, Louisiana; and Santa Maria Golf Course Community in Baton Rouge, Louisiana.

The Bluffs on Thompson Creek

**Figure 5. Arnold Palmer**

The Bluffs on Thompson Creek is located on a 534-acre tract of land eight miles east of Saint Francisville, Louisiana. The development includes an 18-hole semi-private golf course designed by Palmer Course Design Company and opened for play in 1988. The community at The Bluffs includes approximately 250 homesites, a hotel, dining facilities, clubhouse, golf shop, recreation fields, and more. The development is one of the premier golf course developments in the area. The property is located on Thompson Creek within three miles of Oakley Plantation and is officially recognized as an "Audubon Cooperative Sanctuary."

The Bluffs provided a large sample of varied natural areas for my study. It represents the upper-end golf course community type and is located on a very generous piece of property, yet its golf course is open to the public. The large tract of land within which the Bluffs is located and its rural setting dictated which natural areas would be suitable for my study. I eliminated all natural areas from my study that I could not delineate a distinct ecological boundary. Property boundaries do not dictate wildlife movements in the field and therefore were not used. Roadways and development boundaries do however dictate wildlife movement and served as the primary delineated edges. All remaining internal natural areas (delineated boundary within the property boundary) were studied.

**Figure 6. Hole #18, The Bluffs on Thompson Creek**

Money Hill Golf and Country Club

Money Hill Golf and Country Club is located six miles east of Abita Springs in southeastern Louisiana. The development includes an 18-hole semi-private golf course designed by Ron Garl and opened for play in 1997. The

**Figure 7. Hole #14, Money Hill Golf and Country Club**

community at Money Hill features approximately 400 homesites, parks, trails, and recreational facilities. *Golf Digest* ranked the golf course #1 in Louisiana in 2000. The extended property includes a 200-acre artesian spring-fed lake and a large tract of conservation land managed by the Nature Conservancy.

Money Hill provided a recent example of a golf course community built within a prized environmental setting. The extensive housing layout surrounding the golf course community served as a distinct boundary between the outlying preserve areas and interior natural areas. The opportunity for a number of smaller natural areas exists within the development area that is quite extensively manicured.

The University Club

The University Club is a 1200-acre master–planned community located along Nicholson Drive in southwestern Baton Rouge, Louisiana. The development includes a 22-hole (ultimately 27-hole) private golf course designed by Jim Lipe Design Inc. and opened for play in 1998. The community at University Club includes approximately 600 homesites, clubhouse, tennis complex, and dining facilities.

**Figure 8. Clubhouse, The University Club**

The University Club provides a recent example of a golf course community built in a more urban environment where maximum housing yield was very important. The design also balances environmental aspects of the site and its location between the Mississippi River and Bayou Manchac. Natural areas occur within the development generally as buffer zones between golf, housing, and wetlands. The extensive number of

small natural areas within this site required that I limit the areas for study. My trapping resources would not allow me to study every area within this property. I decided to pair each area in the site with another area of similar size and shape and then eliminate one of the areas from my study. In this way, my study encompassed the entire variety of wildlife areas without surpassing the capabilities of my resources.

<u>Santa Maria Golf Club</u>

Santa Maria Golf Club and Community is a master-planned development along Old Perkins Road in eastern Baton Rouge, Louisiana. The development includes an 18-hole public golf course designed by Robert Trent Jones, Sr. and opened for play in 1987.

**Figure 9. Santa Maria Golf Club**

The golf course opened as a private membership-only golf course in 1987, but went bankrupt and sold in 1990. Since that time, it has been publicly owned and accessible by the Baton Rouge Recreation and Parks Commission. The Community at Santa Maria includes approximately 600 homesites, clubhouse, neighborhood parks, fitness center, and dining facilities.

Santa Maria provides a low-end budget example of a golf course community that thrives in a suburban setting and manages to retain some natural buffer areas. The natural areas serve as buffer zones between the golf course and a section of Kansas City Southern Railroad Tracks, Bayou Manchac, and Wards Creek. Maintenance

misunderstandings have eliminated many possible natural areas but those left intact were studied.

**Wildlife Area Selection**

Although I have briefly discussed how natural areas were selected or eliminated in each golf course community, a broader definition of these natural areas is required. This study focuses on definable areas within the golf course community that are relatively unmaintained and generally available for use by local wildlife. “Definable” requires that the area possess distinct flora boundaries within the overall development property line. Roads, housing, golf holes, and wetlands all constitute distinct flora boundaries. “Relatively unmaintained” requires that grasses are mowed or “bush-whacked” no more than once each year. Some of these areas contain extensive shrub and tree-life while other areas do not. Some of these areas have been left untouched since development, others have been planted with locally native flora, and still others have been recently excluded from golf course rough that is mowed at least twice a month. “Generally available for use by local wildlife” requires that human and mechanical interaction is not so clearly overwhelming as to eliminate any wildlife populations.

**Wildlife Indicator Selection**

Once the study areas within each of the four golf course communities were determined, wildlife habitat success needed to be determined. The two prevailing factors in determining the success of wildlife habitat are the population and diversity of local wildlife inhabiting the area. Therefore, my goal was to determine the approximate wildlife population and diversity within each study area. Wildlife habitation success was not dependent on habitation of any particular species, nor was success undermined by

habitation of any "pest" species. Rather than attempting to identify and monitor every organism living within the habitat area, I chose to rely on indicator groups of species. These indicator groups would be evaluated as to their population density and diversity for each habitat area. Then an assumption would be made that the indicator groups could characterize the overall wildlife population and diversity within each area that I studied.

The indicator groups were chosen with the aid of wildlife expert, Professor Michael Chamberlain. Wildlife groups were chosen for their ease in monitoring as well as their accurate representation of the entire wildlife population. The two wildlife groups that were chosen and monitored were small mammals/rodents and birds. Small mammals/rodents included mice, rats, voles, and shrews. Birds included any bird species landing within the habitat area.

**Small Mammal Monitoring**

The methods I used to accumulate data about the small mammal populations are an adaptation from methods used by wildlife researchers to estimate small mammal populations (Ford et al., 1994; Masters et al., 1998; Schnepf et al., 1998). Sherman Live-traps are placed systematically throughout an area and used to capture these nocturnal animals for identification and then release. For population estimation, a number of these traps are placed on a grid and checked for a number of days. In my study, an accurate estimation of the small mammal population was not necessary. Therefore, a simple transect across the length of the wildlife habitat served to evaluate each wildlife area. The longest, generally straight bisector of the wildlife area was used as a simple transect. Traps were placed at 100' intervals with the first trap

**Figure 10. Sherman Live Trap**

being placed 50’ from the wildlife area edge.

Traps were placed at the desired locations, set, baited (with peanut butter and oats), and marked with nearby flagging for subsequent ease in location. Traps were left for one night and checked the following morning. If a small mammal was present in the trap when checked, it was identified to species and marked by toe-clipping to identify the individual mammal. Then the trap was reset, baited and left for another day and night. If a small mammal was not present in the trap, then the trap was returned to its original set, baited position and any disturbances were recorded. Recorded disturbances included frog, bird, ant, large mammal, and human interactions.

**Bird Monitoring**

The methods I used to accumulate data about the bird populations within the wildlife area are a similar adaptation from accepted wildlife study practices (Aigner et al.,1998; Calme et al., 2000; Haselmayer et al., 2000; Poulin et al., 2000). Again, a simple transect along the longest bisector of the wildlife area was used. Bird populations were monitored at points spaced at 300’ intervals along the transect with the first point 150’ from the edge of the wildlife area. At each monitoring point, every bird that could be identified either visually or acoustically was recorded. Both the species of the bird and its approximate location were recorded. Birds that were flushed from the habitat area by my movements were recorded. Fly-overs, or birds that fly over the habitat area but do not land within the area, were not recorded. Also, birds that could be identified from a monitoring point but were not within the habitat area were not recorded.


**Figure 11. American Woodcock**

**Habitat Area Delineation**

Aerial photography of each golf course community is the most important piece of data required to identify and analyze the wildlife habitat areas. All of the study sites are located within southern Louisiana and were recently photographed and made available by Louisiana State University. Once the photographs were retrieved, they were each field verified as to each community's current condition. Although the photographs did not represent the exact condition of the community at the time of the study, photographs were accurate enough to aid in analysis and area delineation. An initial analysis of each site was made using the aerial photography and knowledge of the golf course layout. An initial site visit was conducted to gain information and permission from golf course management. Field observations about topography and plant communities also aided in understanding the aerial photographs. Next, community developers were contacted to retrieve the most recent boundary information on current and proposed community development. Community analysis was then updated using this development information.

With this information and analysis, the entire community could be delineated as to its general uses. Housing developments, future housing developments, maintained golf course areas, water features, and wildlife habitat areas could all be delineated. Once this process of community area delineation was largely complete, a final comprehensive field visit was required. This field visit required that all wildlife habitat areas be double-checked for accuracy in their delineation and condition. The remaining areas within the overall site boundaries were also surveyed to verify accurateness in the overall site analysis endeavor.

**Wildlife Habitat Areas**

In the following section, I will briefly describe each of the wildlife habitat area's position, condition, and outside influences within the golf course community. This section is critical to understanding the complexities involved in this study, and also, to document the many conditions competing with spatial characteristics to influence wildlife habitation in the studied areas. If these competing conditions prove overwhelming in establishing the desired link, this section will be most important.

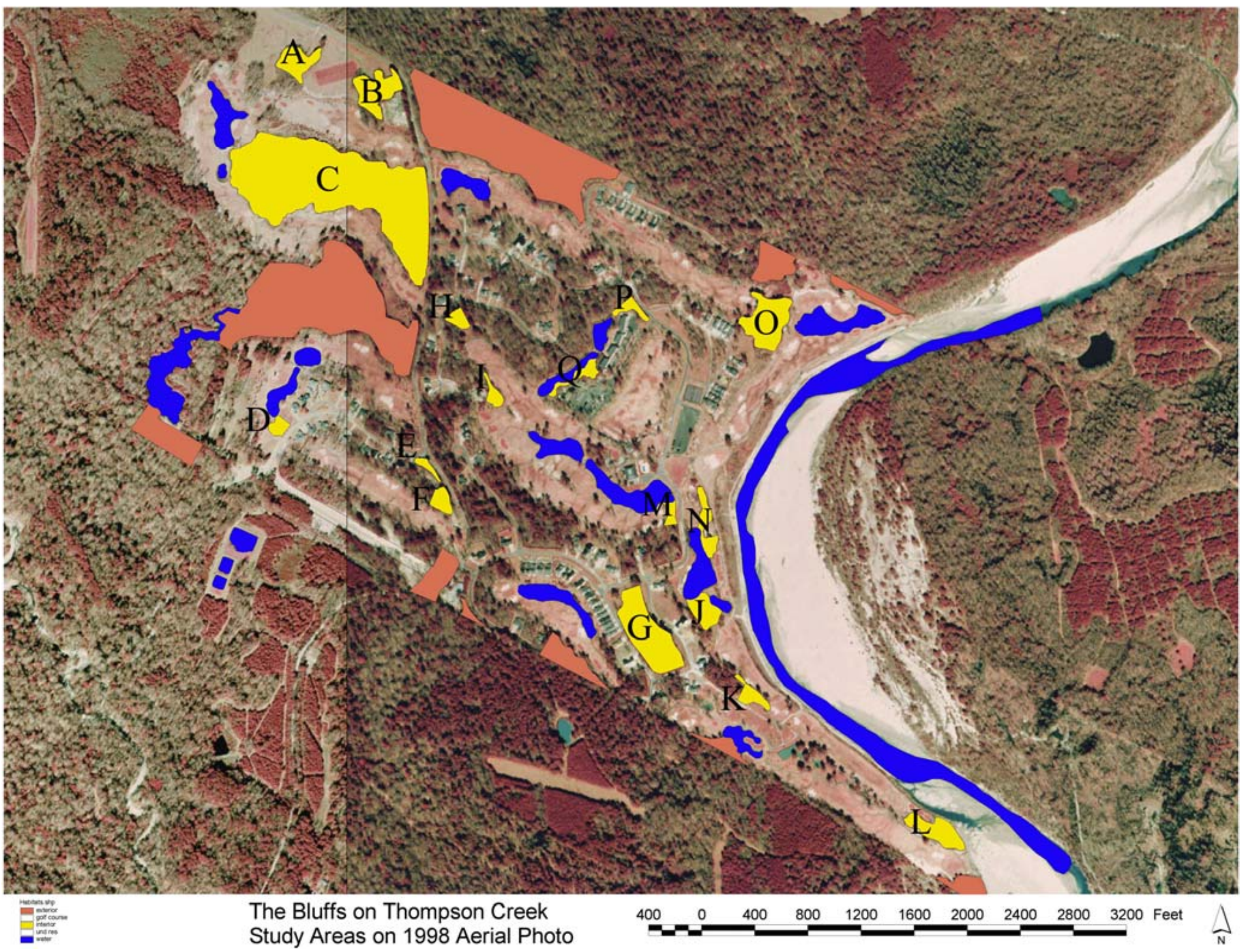



**Figure 12. The Bluffs on Thompson Creek, aerial photograph**

The Bluffs on Thompson Creek

Area A: This area is approximately one acre of predominantly pine forest that sits in the northwest portion of the site near the main entry road. It is forest preserved from before community development but contains unnaturally dense vegetation because of the amount of sunlight available. All along the north and eastern boundaries are open lawn and recreation fields. Along the southwestern boundary the pine forest has been thinned and understory removed as it nears the fairway of golf course hole number fourteen. The recreation fields are underused and the area is set back from the road enough that disturbances are limited.


**Figure 13. Area B, The Bluffs on Thompson Creek**

Area B: Area B is a small pine forest similar to Area A. Area B was however preserved with less care than Area A and contains shade-free zones with very dense understory. The area borders a recreation field on the northwest, entry road on the northeast, and maintenance storage on the southeast. The southwest boundary is again the clearing of understory as it nears golf hole number fourteen. Again, disturbance is limited to the nearby entry road and infrequent use of the ball fields.

**Figure 14. Area C, The Bluffs on Thompson Creek**

Area C: This is the largest area studied on any of the four sites at over 18 acres. This

large section of mixed pine and hardwood forest is well preserved from before construction and remains natural. The area is surrounded by golf holes except on the eastern boundary where it borders maintained lawn near the main entry road. The area is adjacent to two ponds on its western boundary and presumably provides enough range for most local wildlife.

Area D: A one-third acre section of grassland outside the golf course's mowing boundaries. The area is a treeless refuge between tee boxes, a golf course cart path, and a local roadway. Human disturbances are prevalent and cover is very minimal.

Area E: A narrow strip of pineland, approximately 50' in width, preserved between collector and local roadways in the central portion of the site. Vehicular impact is substantial but the vegetation was well preserved during construction. The understory is slightly denser than in a forest area because of the increased sunlight, but some maintenance to control the understory vegetation is evident.

Area F: Only 38' from area E, this wildlife habitat area borders two roadways and fades into hole number six on the southwest side. The area is 0.5 acres of pine forest that was a specific attempt by the golf course architects and community planners to maintain a natural aesthetic for the golf course and housing development. The area is just 500' from maintenance facilities and borders roadways; however the level of disturbance is only moderate.

Area G: This area, too, is a concentrated effort by designers to preserve four acres of mixed pine-

**Figure 15. Area G, The Bluffs on Thompson Creek**

hardwood forest within the housing development of this community. The habitat area encompasses the center of a grand cul-de-sac with houses surrounding the outside of the roadway. The area consists predominately of preserved vegetation and shows of some usage by local residents. A child's play fort and related pathways are primary visible disturbances. The overall disturbance levels are low considering the surrounding roadway and human impacts within.

Area H: A buffer area between the golf course and housing community, this area is approximately the size of a single homesite. The area is situated between the green complex of hole number ten, a Sunrise Village homesite, two local roadways, and the cart path connecting holes ten and eleven. Maintenance also uses a path through the area and stores materials in a portion of the area. The area serves as a visual buffer, but is abused as an environmental and wildlife refuge. The vegetation is preserved pine forest except for about one-third of the area where existing vegetation has been destroyed for maintenance use.

**Figure 16. Area H, The Bluffs on Thompson Creek**

Area I: An area of steep topography bordering hole number ten and filled with dense vegetation. The opposite border of this area is the back of several homesites. Pine trees exist in the area but do not substantiate a pine forest environment. The understory vegetation is thick and makes the topography somewhat difficult to negotiate. Golfers,

nearby residents, and local dogs all frequent the area and cause visible levels of disruption.

Area J: This area is adjacent to two water features and 200’ from Thompson Creek. A mix of pines and hardwoods, the vegetation in this area is some of the most mature on this site. The area is located to the west of hole number one and also borders several homesites. The area is disturbed sparingly by homesite residents and even less frequently by nearby golfers who rarely enter the area.

**Figure 17. Area J, The Bluffs on Thompson Creek**

Area K: Near area J and very similar, this is another valuable preserve of mature vegetation. This area is not adjacent to any water features but is less than 200’ from Thompson Creek. The area borders golf hole number 1, future homesite development, and some open lawn between golf holes. This area receives very little disturbance because of its location, dense vegetation, and steep topography.

Area L: In the southeast corner of the site, this area lies adjacent to Thompson Creek. It is uniquely low and wet with shrubby and grassy vegetation. Golfers do enter the borders of the site but otherwise disturbances are minimal. Golf holes two and three

border the area on the western boundaries while the eastern boundary is the sand pits along Thompson Creek.

Area M: A 60' wide strip of pines preserved primarily as enclosure for the green complex of hole number nine. Maintenance has shrunk this wildlife habitat area to the point that little shelter is available. The area is bordered by a roadway, golf hole, homesite, and water feature near the clubhouse. Disturbances, especially noise, seem quite prevalent because this area is so exposed.

Area N: A fairly steep ridge separating golf hole number one from a park and water feature to the west. The ridge is well preserved from prior to construction and serves as a green buffer, wildlife refuge, and erosion inhibitor. The area is also within view of Thompson Creek. Disturbances, primarily noise, are moderate from both golf hole number one and the neighborhood park.

**Figure 18. Area N, The Bluffs on Thompson Creek**

Area O: A 2.4-acre area of steep topography that generally separates the smaller homesites of Audubon Collection Villas from golf holes sixteen, seventeen, and eighteen. The elevation difference, from top to bottom, within this nine-acre area is more than 80 feet. This mixed pine and hardwood forest remains preserved since construction and is a

valued natural area. Disturbances are minimal and cover is plentiful in this dense area of vegetation.

Area P: Another preserved natural buffer zone, this area helps to hide The Lodge overnight facilities from the view of the community roadway. The lack of dense cover in this area has allowed a thick undergrowth of vines that are very difficult to pass. The area is adjacent to a small pond, hotel, undeveloped homesites, and community roadway. Noise is prevalent in this area related to the hotel and close by parking lots.

Area Q: Similar to Area P, this area separates the same small pond from the golf course cart barn. This cart barn buffer extends from The Lodge west to hole number 10. Noise and other human impact are very evident from workers and the nearby parking lot. A moderate slope toward the pond exists with numerous pines and a thick understory.

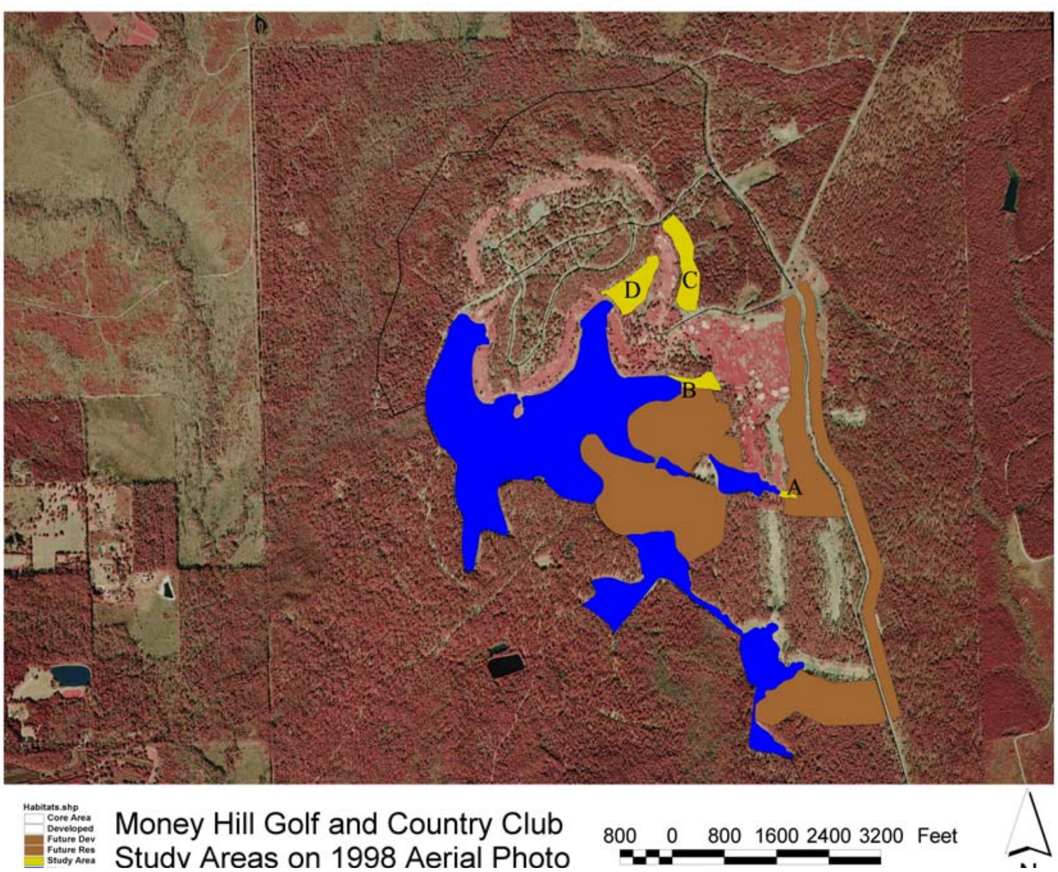



**Figure 19. Money Hill Golf and Country Club, aerial photograph**

Money Hill Golf and Country Club

Area A: A small swale at the edge of the golf course boundary, adjacent to hole number seven, left unmaintained. The area is surrounded by maintained bermuda grass and undeveloped homesites. The area is very exposed but only low levels of disturbance occur due to nearby golfers. The swale maintains some water and drains into an adjacent water feature with a constant water level.

**Figure 20. Area A, Money Hill Golf and Country Club**

Area B: A marshy valley adjacent to the property's largest lake. This low area is a protected wetland between developed and undeveloped homesites. The valley extends from the large lake near the clubhouse up to the number one fairway. Vegetation varies from marshland grasses to pines and hardwoods. Disturbances are low because of the water level and the low level of surrounding uses.

Area C: A nine-acre tract of rolling terrain adjacent to hole number ten. The vegetation is predominately pine forest with understory grasses and some hardwoods. The area is bounded by new development to the east, an existing golf hole to the west, and community roadways on the north and south. Disturbances are high in this area due to the adjacent construction of new housing and a future golf hole.

Area D: An eight-acre low area situated between the clubhouse complex and the housing area entitled Phase 1. The area extends from near hole number ten to hole

eighteen.  The area contains a great number of mature trees, however, open spaces and jagged borders have created a thick undergrowth of vines.  The thick vegetation and wet location keep human disturbance minimal.  The greatest disturbances are the noises associated with the clubhouse and pool complex.

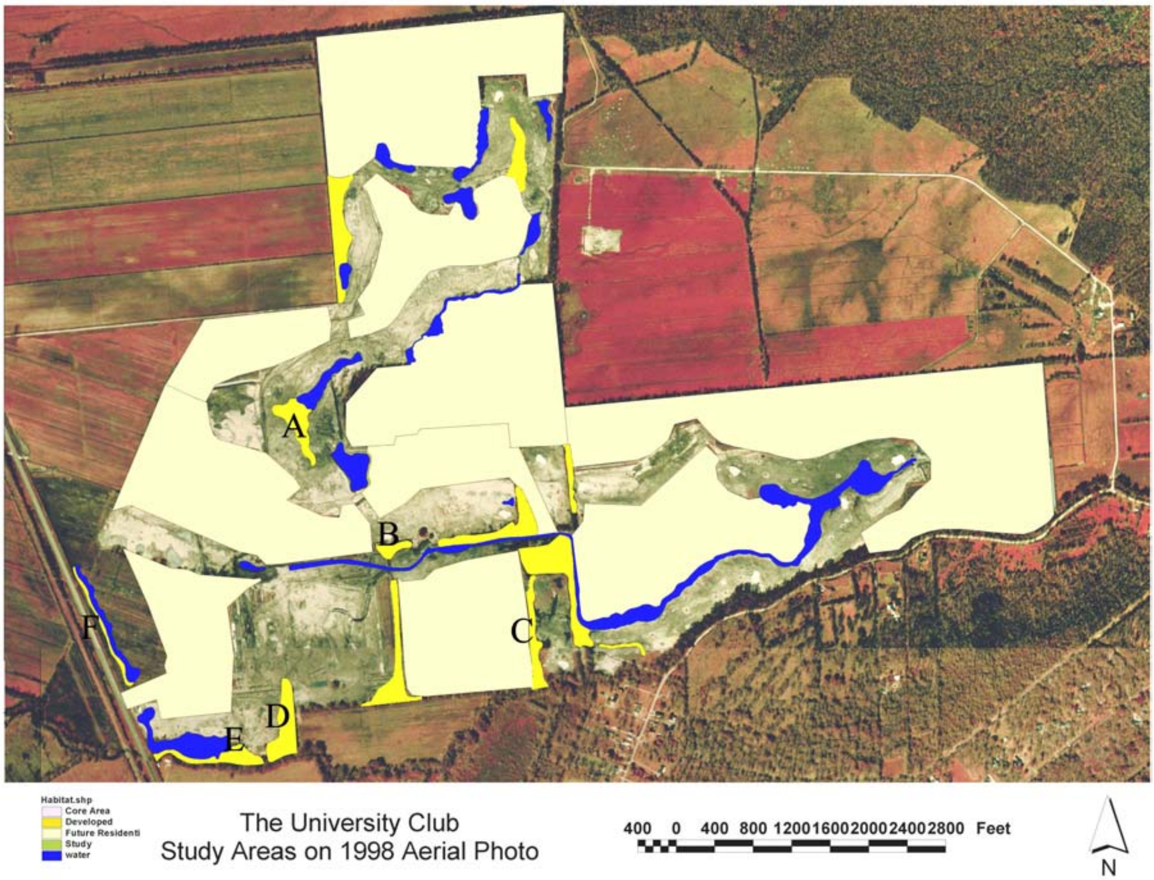



**Figure 21. The University Club, aerial photograph**

<u>The University Club</u>

Area A: A central area within the golf course that has been planted with native grasses and carefully treated to control competition.  The area is also "bush-whacked" twice a year to aid in spot maintenance.  It is truly a designed natural area, intended to separate golf holes and benefit the environment.  It's recent history as a sugar cane field

ensures that no vegetation existed in this area at the time of construction. The area remains open and unprotected with moderate levels of disturbance. As the native grasses become more dominant and maintenance discontinues "bush-whacking," cover and protection will increase.

Area B: A 0.9-acre area between holes one and nine, where mixed vegetation was preserved along a slight ridge, an old field property line. A number of young evergreen trees enclose and protect the area. Disturbances are moderate because of the areas close proximity to the clubhouse parking lot as well as a practice green, tee area, and regulation green.

Area C: This is another preserved property line with preexisting trees. This area is an old depression that drains south into Bayou Manchac. At the northern edge, this area exists as native grasses and cattails within the golf envelope. At the southern edge, the area widens to over 50 feet of established hardwoods and a defined depression. The disturbances in this area are high because of the close proximity of both houses and golf. Management suggested that this wildlife habitation area may be destroyed as more adjoining houses are constructed.

Area D: A low area extending from Bayou Manchac along practice hole number four to the edge of the practice range. Some trees exist along an old fence line but the predominant vegetation is tall grasses and some weedy vines. Disturbances are very low because the area is clearly out of play for golfers and no other developments adjoin.

Area E: This low, wet, humid area exists between the banks that confine Bayou Manchac and the pond of practice hole number three. Vegetation is predominantly tall

grass with numerous pine trees along the boundary banks. Noise disturbances from Highway 30 are moderate but no other development impacts are present.

Area F: A steep embankment that extends the length of the out-of-play side of practice hole number two's curvaceous water feature. The area is vegetated by tall grasses, cattails, and weedy plants that escape the maintenance boundary and create a naturalized embankment. Noise from Highway 30, Nicholson Drive, dominates this area because of its lack of significant cover. A number of recently planted holly trees will help to address this lack of cover. Residents have expressed an interest in maintenance controlling the area, but management does not agree.

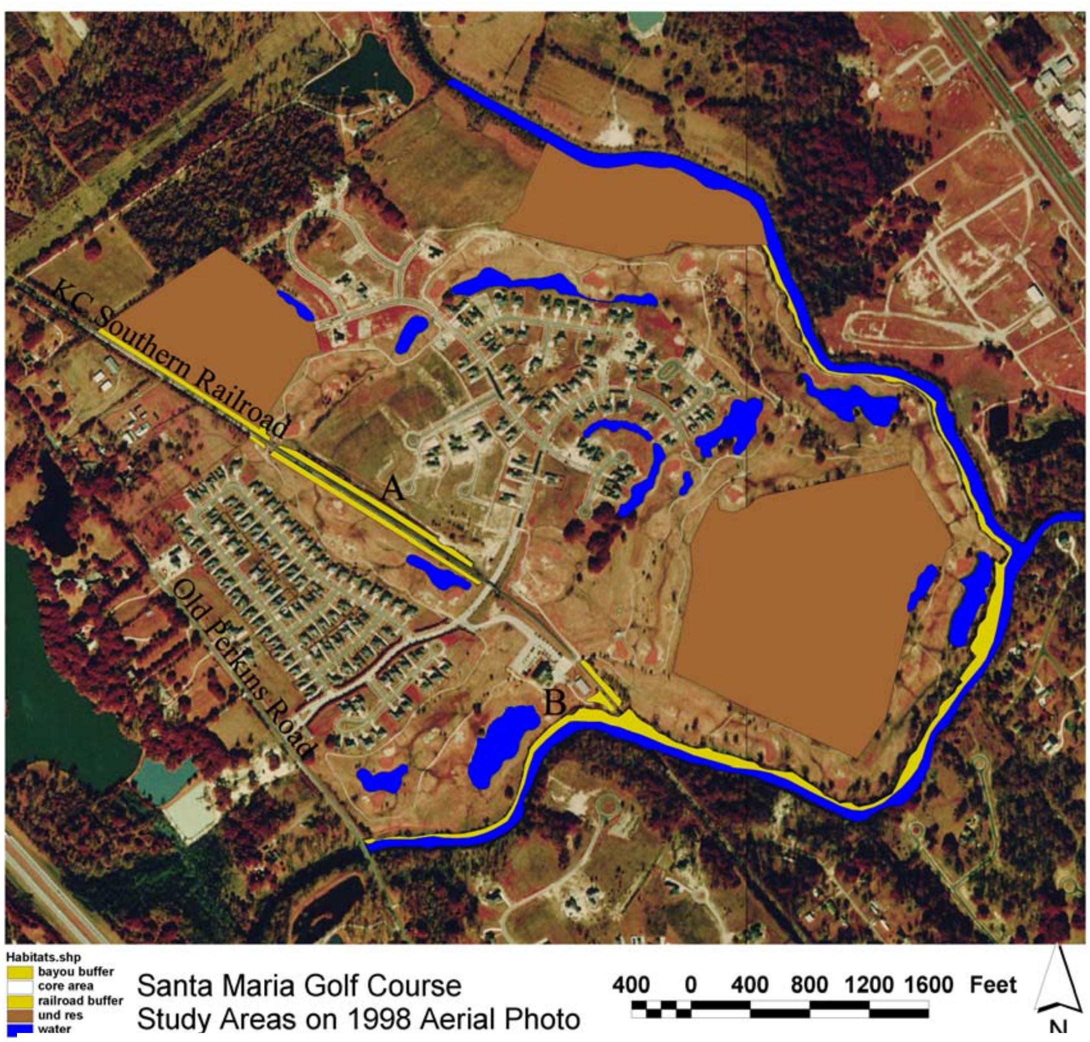



**Figure 23. Santa Maria Golf Club, aerial photograph**

Santa Maria Golf Club

Area A: A buffer zone extending along the entire eastern half of this site. The buffer zone is a preserved wetland bank descending toward Bayou Manchac and Ward's Creek. This buffer varies in width from as little as five feet in some spots to over 100 feet in others. The area is a mix of established swamp vegetation, recuperative vines and grasses, and invading upland species. Limited flooding does occur, but it appears that this natural process has been controlled to the extent that mixed upland species are surviving within the banks of these water channels. Disturbances are surprisingly low in these areas because of the thick understory and the quick drop in elevation along a majority of the boundary. Golf holes predominately separate this wildlife area from the housing development and limit noise disturbance. A typical section of this wildlife habitat area, measuring 1000 feet in length, was examined for the purposes of this study.

Area B: A buffer zone occupying the right-of-way of an active Kansas City Southern Railroad Track that transects the middle of the site from northwest to southeast. The railroad right-of-way is 100 feet in width with the middle 20 feet being occupied by the railroad tracks and adjacent gravel. This leaves approximately 40 feet on either side of the railroad tracks as relatively maintenance free plant life and wildlife habitat. These two wildlife habitat areas extend across the site except for the section between the clubhouse and the driving range. A typical section of this wildlife habitat area, measuring 1000 feet in length, was examined for the purposes of this study.

**Area Statistics**

The wildlife habitat areas were delineated using aerial photography prior to the field study. With the habitat areas delineated, they could be analyzed and compared to

discover spatial characteristics illustrative of their spatial differences. An extension for ArcView GIS, entitled Patch Analyst, was used to estimate a number of descriptive spatial statistics (Elkie et al., 1999)(Environmental Research Systems Institute, 1994). Additional spatial statistics were included to create a more complete description of the habitat's size, shape, and orientation. The spatial statistics were chosen to communicate design characteristics to the designer. Several of these spatial statistics also had shown previous correlation with wildlife populations (Dijak et al., 2000).

The selected spatial statistics were calculated as described below using the delineated habitat areas from the aerial photographs. **Area**, in acres, and **Perimeter**, in feet, were calculated for each wildlife habitat. Then, those two statistics were combined to create an **Edge Density** statistic. **Edge Density** is measured in terms of feet/acre and describes the amount of edge habitat. **Mean Shape Index** is a less intuitive statistic that is used to describe the habitat area's shape as compared to a circle. **Mean Shape Index** is a unitless statistic greater than or equal to 1 where a circle has **Mean Shape Index** of 1. **Fractal Dimension** is another statistic describing each

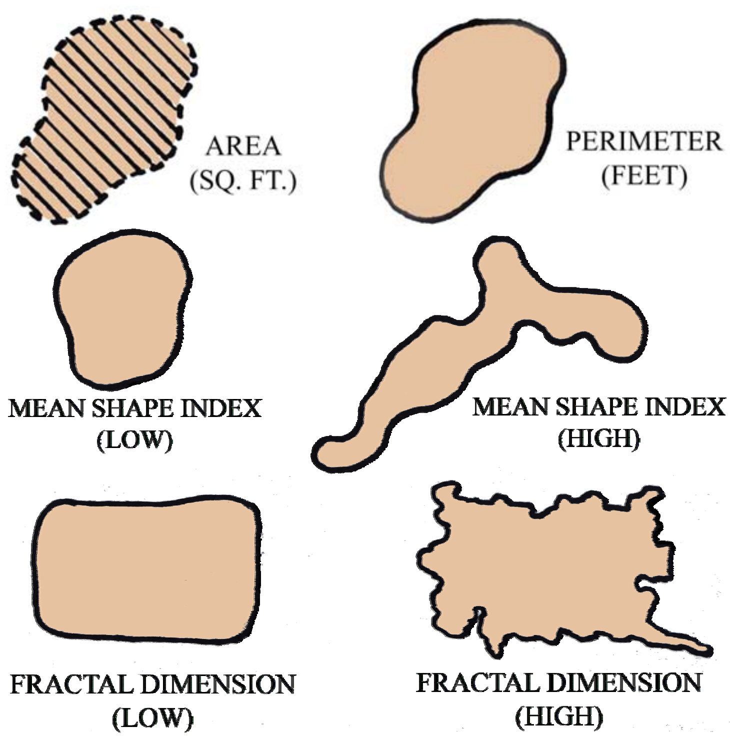



**Figure 24. Spatial Statistic Explanations 1**

shape's complexity. **Fractal Dimension** approaches 1 for shapes with simple perimeters and approaches 2 for shapes with more complex perimeters. **Orientation Angle** is the angle, in degrees, between the wildlife habitat area's major axis and true north. **Orientation Angle** is 0 for habitats oriented directly north-south and 90 for habitats oriented east-west.

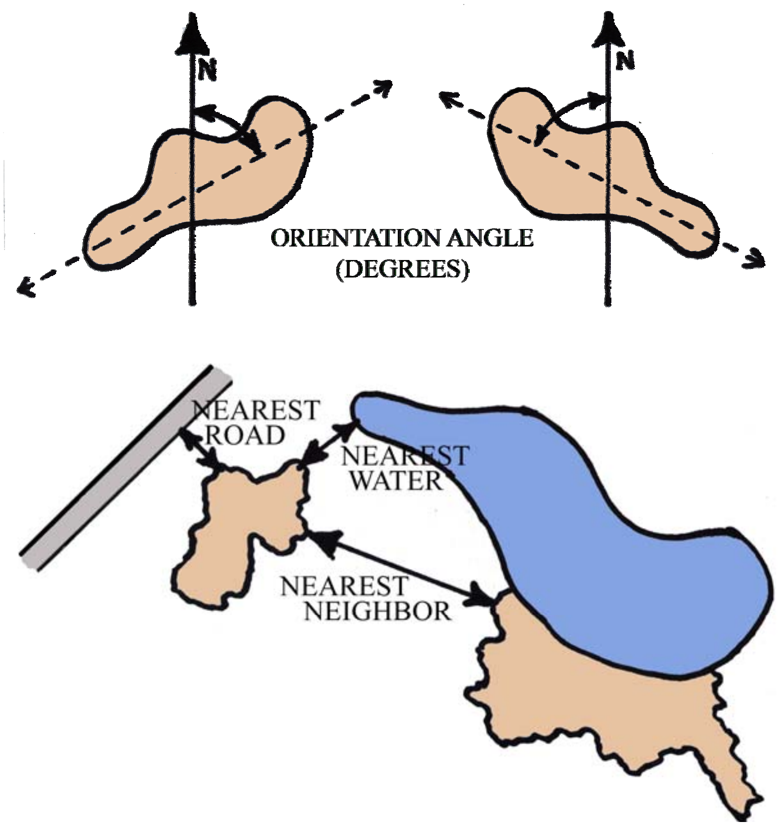



**Figure 25. Spatial Statistic Explanations 2**

**Nearest Neighbor** is a habitat distribution statistic and is equal to the shortest distance, in feet, to the closest wildlife habitat area. The distance is measured from edge to edge. **Nearest Water** and **Nearest Road** are similar statistics measuring the shortest distance to the closest water feature and closest vehicular roadway. Again, these distances are measured from edge to edge and are expressed in feet. Another slightly more complex habitat distribution statistic is labeled **Proximity Index** and describes the amount of wildlife habitat nearby. **Proximity Index** is the sum of quotients, area divided by the square of the neighboring distance, for each habitat with a neighboring distance

less than 1500 feet.  Neighboring distance is the edge-to-edge distance between wildlife habitat areas.

Two other statistics are based on the concept of a core habitat.  A core habitat is the interior portion of a wildlife habitat area excluding a buffer zone around the perimeter of the wildlife habitat area. The buffer zone is described by a given width in feet.  **Core Area** is simply the area of this region, in acres, based upon a given buffer zone width.  **Core Area Index** is equal to the percentage of the habitat's **Area** within the **Core Area**.

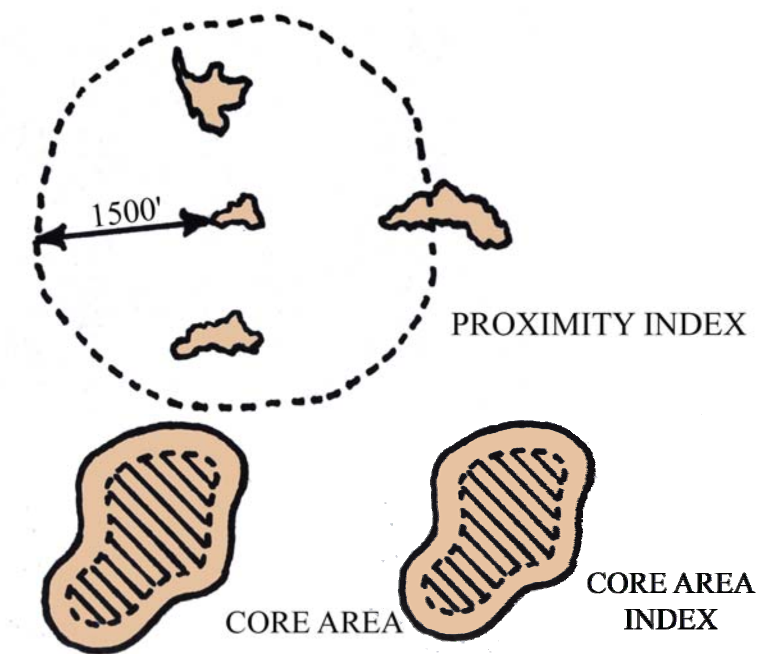



**Figure 26. Spatial Statistic Explanations 3**

# CHAPTER THREE

## INTERPRETATION OF EVIDENCE

Studying real world situations has the best potential for revealing new information about our world, but it also has a high potential for failure. Manipulation of other's work or studying a model situation has a much lower potential for failure because of the lowered risks. It is time to find out if the high risks in my study have been avoided and valuable information discovered. First, the information must be accumulated and interpreted. Second, the results need to be analyzed and assessed based upon the bulk of available information from the fields of wildlife management and golf course design. Finally, others must test the presented results through both further research and implementation to determine its validity.

As both the spatial statistics and field study results have been accumulated, it is time to reveal the results of my study. The results were first assembled from the book of field notes into the large table seen in Appendix A. The small mammal results were listed for each study area and totaled into two statistics. The first statistic, labeled **Mammal ID**, is the average number of small mammal species trapped and **ID**entified per trap night. **Mammal ID** is computed by totaling the number of small mammals caught and identified for each study area, divided by the number of trap nights for each area. Trap nights are simply the number of nights a trap was baited and checked, multiplied by the number of traps. The second statistic, labeled **Mammal ID + E**, is the average number of small mammals **ID**entified plus the average number of mammal **E**vidence instances observed per trap night. Mammal evidence instances are the number of traps disturbed by large mammals. **Mammal ID + E** is computed similarly to **Mammal ID**.

This statistic was established because of the large number of disturbed traps on some sites where very few small mammals were trapped.

The bird results were similarly listed for each study area and totaled into two statistics. The number of birds observed within the study area over the three days was totaled and divided by the number of observation points. This field statistic is entitled **Bird Population Density**. The second statistic is labeled **Bird Species**. **Bird Species** is the number of different bird species observed within the study area over the three days divided by the number of observation points. These four statistics: **Mammal ID**,

| Table 1. Field Statistics | | | | | |
|---|---|---|---|---|---|
| Site | Wildlife Habitat Area | Mammal ID | Mammal ID + E | Bird Pop. Density | Bird Species |
| | | | | | |
| Bluffs | A | 0 | 0 | 2.67 | 3 |
| Bluffs | B | 0 | 0.167 | 2.67 | 4 |
| Bluffs | C | 0.021 | 0.25 | 3.13 | 12 |
| Bluffs | D | 0 | 0 | 1.33 | 3 |
| Bluffs | E | 0 | 0 | 1.33 | 3 |
| Bluffs | F | 0 | 0 | 1.00 | 3 |
| Bluffs | G | 0 | 0.143 | 5.17 | 8 |
| Bluffs | H | 0 | 0 | 1.00 | 3 |
| Bluffs | I | 0 | 0.222 | 2.00 | 4 |
| Bluffs | J | 0 | 0.167 | 2.67 | 4 |
| Bluffs | K | 0 | 0 | 2.67 | 5 |
| Bluffs | L | 0 | 0.067 | 2.33 | 10 |
| Bluffs | M | 0 | 0 | 0.33 | 1 |
| Bluffs | N | 0 | 0.067 | 2.50 | 7 |
| Bluffs | O | 0 | 0.083 | 7.67 | 8 |
| Bluffs | P | 0 | 0 | 4.67 | 7 |
| Bluffs | Q | 0 | 0.222 | 2.67 | 5 |
| Money | A | 0 | 0.111 | 0.67 | 2 |
| Money | B | 0.286 | 0.381 | 5.33 | 10 |
| Money | C | 0 | 0 | 10.25 | 10 |
| Money | D | 0.2 | 0.433 | 8.89 | 9 |
| University | A | 0.048 | 0.048 | 1.17 | 5 |
| University | B | 0.083 | 0.083 | 7.00 | 5 |
| University | C | 0.167 | 0.25 | 2.42 | 8 |
| University | D | 0.3 | 0.367 | 4.78 | 8 |
| University | E | 0.111 | 0.519 | 3.78 | 12 |
| University | F | 0.744 | 0.744 | 0.33 | 3 |
| Santa Maria | A | 0 | 0.259 | 3.56 | 9 |
| Santa Maria | B | 0.037 | 0.259 | 5.33 | 9 |

**Mammal ID + E**, **Bird Population Density**, and **Bird Species** were compiled for each of the 29 study areas and serve as the resultant field statistics of my study.

The complementary set of data for this study is the spatial statistics derived from computer analysis of the study areas. The spatial statistics are described individually at the end of Chapter 2 and many are described in greater detail in *Patch Analyst User's Manual: A Tool for Quantifying Landscape Structure* (Elkie et al., 1999). The statistics also can be categorized into the broader characteristics I described previously as size, shape, and orientation. The size of the study areas is described by it's **Area**, **Perimeter**, and **Core Area**. The shape of the study areas is described by it's **Edge Density**, **Mean Shape Index**, **Fractal Dimension**, and **Core Area Index**. The orientation of the study areas is described by it's **Orientation Angle**, **Nearest Neighbor**, **Nearest Road**, **Nearest**

Table 2. Spatial Statistics

| Site | Wildlife Habitat Area | Area | Perimeter | Edge Density | Mean Shape Index | Fractal Dimension | Nearest Neighbor | Nearest Water | Nearest Road | Orientation Angle | Proximity Index | Core Area (Buffer = 25') | Core Area Index (Buffer = 25') |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (acres) | (feet) | (feet/acre) | (unitless) | (unitless) | (feet) | (feet) | (feet) | (degrees) | (unitless) | (acres) | (%) |
| Bluffs | A | 1.141 | 1083.4 | 949.4 | 1.215 | 1.046 | 293 | 414 | 137 | 78 | 6.052 | 0.599 | 52.46 |
| Bluffs | B | 1.698 | 1517.8 | 893.8 | 1.395 | 1.075 | 293 | 829 | 19 | 71 | 9.562 | 0.910 | 53.62 |
| Bluffs | C | 18.685 | 4974.8 | 266.2 | 1.379 | 1.057 | 302 | 23 | 18 | 63 | 1.348 | 15.891 | 85.04 |
| Bluffs | D | 0.368 | 514.2 | 1398.5 | 1.016 | 1.004 | 966 | 0 | 24 | 46 | 0.011 | 0.129 | 35.21 |
| Bluffs | E | 0.229 | 322.1 | 1404.7 | 1.454 | 1.109 | 38 | 738 | 12 | 52 | 16.197 | 0.008 | 3.51 |
| Bluffs | F | 0.535 | 613.2 | 1146.8 | 1.004 | 1.001 | 38 | 714 | 16 | 12 | 6.94 | 0.235 | 44.02 |
| Bluffs | G | 3.597 | 1818.3 | 505.6 | 1.148 | 1.029 | 223 | 196 | 20 | 28 | 1.188 | 2.604 | 72.40 |
| Bluffs | H | 0.400 | 537.5 | 1342.6 | 1.018 | 1.005 | 302 | 694 | 26 | 39 | 9.088 | 0.145 | 36.31 |
| Bluffs | I | 0.376 | 684.5 | 1818.9 | 1.337 | 1.079 | 338 | 260 | 248 | 18 | 1.611 | 0.101 | 26.76 |
| Bluffs | J | 0.969 | 854.7 | 882.4 | 1.040 | 1.010 | 223 | 0 | 168 | 33 | 3.836 | 0.534 | 55.13 |
| Bluffs | K | 0.583 | 925.7 | 1588.8 | 1.453 | 1.096 | 381 | 166 | 260 | 50 | 1.352 | 0.185 | 31.75 |
| Bluffs | L | 1.356 | 1276.6 | 941.2 | 1.313 | 1.063 | 1298 | 13 | 1855 | 72 | 0 | 0.687 | 50.63 |
| Bluffs | M | 0.288 | 590.3 | 2048.8 | 1.317 | 1.078 | 149 | 0 | 30 | 4 | 2.448 | 0.032 | 11.13 |
| Bluffs | N | 0.843 | 1365.5 | 1620.5 | 1.782 | 1.142 | 149 | 0 | 105 | 7 | 1.658 | 0.235 | 27.92 |
| Bluffs | O | 2.427 | 1539.5 | 634.4 | 1.184 | 1.037 | 667 | 54 | 144 | 24 | 0.04 | 1.659 | 68.36 |
| Bluffs | P | 0.411 | 784.8 | 1907.4 | 1.466 | 1.103 | 354 | 21 | 15 | 75 | 0.418 | 0.074 | 17.92 |
| Bluffs | Q | 0.520 | 1137.0 | 2184.8 | 1.888 | 1.166 | 342 | 0 | 35 | 73 | 0.311 | 0.091 | 17.51 |
| Money | A | 0.538 | 729.2 | 1354.4 | 1.19 | 1.045 | 1790 | 0 | 220 | 74 | 0 | 0.187 | 34.65 |
| Money | B | 2.804 | 2005.2 | 715.1 | 1.434 | 1.077 | 950 | 0 | 155 | 88 | 0.448 | 1.741 | 62.10 |
| Money | C | 9.230 | 3521.7 | 381.6 | 1.389 | 1.062 | 295 | 281 | 54 | 9 | 4.047 | 7.269 | 78.75 |
| Money | D | 7.813 | 2792.8 | 357.5 | 1.197 | 1.035 | 295 | 42 | 252 | 48 | 4.62 | 6.283 | 80.41 |
| University | A | 2.777 | 1984.8 | 714.7 | 1.427 | 1.076 | 1034 | 0 | 497 | 19 | 0 | 1.701 | 61.24 |
| University | B | 0.886 | 947.2 | 1069.5 | 1.206 | 1.046 | 224 | 72 | 71 | 82 | 5.146 | 0.391 | 44.13 |
| University | C | 2.123 | 2676.7 | 1260.6 | 2.2 | 1.174 | 13 | 391 | 160 | 8 | 147.479 | 0.729 | 34.35 |
| University | D | 3.532 | 2132.9 | 603.9 | 1.359 | 1.064 | 45 | 357 | 693 | 4 | 50.541 | 2.372 | 67.17 |
| University | E | 2.335 | 2655.6 | 1137.5 | 2.082 | 1.16 | 45 | 0 | 58 | 89 | 76.057 | 0.997 | 42.73 |
| University | F | 1.021 | 2893.8 | 2833.6 | 3.43 | 1.296 | 745 | 0 | 50 | 27 | 0.183 | 0.000 | 0.00 |
| Santa Maria | A | 6.701 | 12290.5 | 1834.2 | 5.687 | 1.34 | 23 | 0 | 262 | 75 | 24.653 | 1.320 | 19.69 |
| Santa Maria | B | 1.393 | 3393.4 | 2435.4 | 3.443 | 1.286 | 32 | 17 | 45 | 51 | 69.763 | 0.000 | 0.00 |

**Water**, and **Proximity Index**. The size, shape, and orientation of the study areas can also be influenced by statistics outside this categorizing. For instance, the shape of an area with a low **Nearest Road** statistic will often have a regular, straight edge near the roadway. These statistics can also be analyzed, in pairs or groups, to distinguish more about the habitats than would be known individually. For example, study areas with **Nearest Water** equal to zero and a high **Edge Density** are generally associated with specific topographical features such as a bank along a stream or pond.

The general method used for comparing the spatial statistics to the field statistics was to look at each spatial statistic individually. Each spatial statistic was analyzed as the independent variable against the resulting field statistics (the dependent variables). The data was analyzed to evaluate my hypothesis, i.e. the spatial statistics of the habitat area influence the resulting wildlife habitation. In this way, I could determine what effect each spatial statistic has on the resulting level of habitation. I also could determine statistically, whether this witnessed effect was purely coincidental. If not coincidental, with what degree of certainty could I say that a connection does exist between the independent spatial statistic and the dependent habitation statistic?

The relatively low number of habitat areas that were studied precludes the notion that we could pre-determine the success of some future habitat feature. That is, I will not attempt to say to what level of success an individual spatial statistic controls the area's resulting habitation. I will, rather, simply state that spatial statistic "A" has either positive or negative influence upon field statistic (habitation) "B." I will discuss in some cases what the evidence indicates in terms of habitation barriers or advantageous situations but this is purely conjecture. It is my hope that future researchers will extend a

similar study over a much greater number of habitat areas. Then, said researcher may actually be able to deduce to what level the spatial statistics control the results and with what group of spatial statistics habitation levels could be predicted. An example of this type of research, provided by Scott W. Gillihan, was discussed earlier. He reports that bird species' totals in non-specific wildlife habitats are not just positively influenced by greater habitat area, but specifically relative to a multiple of the logarithm of the habitat area. The limited nature of my research precludes this type of accurate prediction within golf course habitat areas.

The habitation results were plotted as the dependent variables against each spatial statistic. Microsoft Excel was used both to plot this data and to determine the linear relationship that represents the data. Finally, a correlation coefficient was determined for each compared set of data. The correlation coefficient describes the strength of association between the variables, assuming a linear relationship. Two points about the conclusions drawn hereafter must be made. First, high correlation does not automatically conclude causation between the two variables. A number of other influencing factors may relate the two variables without one causing the other. Second, correlation coefficients describe an assumed linear relationship, which may not exist. For example, it has already been cited that others conclude a logarithmic relationship between bird species totals and the area of non-specific wildlife habitats.

The importance of the conclusions that follow should be held in context to the above assumptions, however, the conclusions must not be ignored. Strong relationships have been discovered between certain spatial statistics and observed habitation levels. The correlation between these sets of statistics is best measured by the degree of

confidence by which we can say that a linear relationship between the two sets of data does exist. Or conversely, to what degree of confidence we can reject the hypothesis that no relationship between the spatial statistic and the field statistic exists. Through a rather simple statistical procedure based upon the number of habitation areas that were studied, we can establish these degrees of confidence. Because 29 golf course habitat areas were studied, a correlation coefficient of 0.3113 is needed to state that we are 95% assured a linear relationship exists between these two elements. A 95% level of confidence is

Table 3. Correlation Coefficients

| | Area | Perimeter | Edge Density | Mean Shape Index | Fractal Dimension | Nearest Neighbor | Nearest Water | Nearest Road | Orientation Angle | Proximity Index | Core Area | Core Area Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mammal ID | 0.0141 | 0.1049 | 0.2211 | 0.2798 | 0.3804 | 0.0889 | 0.1533 | 0.0100 | 0.1015 | 0.1549 | 0.0071 | 0.1020 |
| Mammal ID + E | 0.2102 | 0.3506 | 0.1612 | 0.4459 | 0.5163 | 0.0520 | 0.2865 | 0.0200 | 0.1158 | 0.3050 | 0.0071 | 0.0224 |
| Bird Population Density | 0.4053 | 0.2189 | 0.4740 | 0.0332 | 0.0819 | 0.2025 | 0.1755 | 0.0480 | 0.0656 | 0.0245 | 0.3899 | 0.5298 |
| Bird Species | 0.6255 | 0.5028 | 0.4067 | 0.2445 | 0.2241 | 0.1453 | 0.3330 | 0.2510 | 0.2005 | 0.3253 | 0.5568 | 0.4581 |

Key
95.0% Confidence if r>0.3113
97.5% Confidence if r>0.3671
99.0% Confidence if r>0.4295
99.5% Confidence if r>0.4703

generally acceptable, depending on the type of work, for establishing a relationship but I will give a range of levels for a more complete understanding. A 97.5% level of confidence is established with correlation coefficient 0.3671, 99% confidence with 0.4295, and 99.5% confidence with 0.4703.

**Habitat Size**

The positive relationship between wildlife habitation and habitat *Area* is the most widely accepted and obvious habitat design characteristic. Gillihan suggests a logarithmic relationship between **Area** and **Bird Species** (Gillihan, 2000). My study data and linear analysis suggests a strong positive linear relationship. The relationship has a correlation value of 0.6255, the strongest correlation value in this study. This level of correlation corresponds to over a 99.5% confidence that a positive relationship between habitat **Area** and **Bird Species** inhabiting the area does exist. The data also assures a

strong relationship between habitat **Area** and Bird Population Density, a 0.4053 correlation value and over 97.5% confidence level.  Logically, it corresponds that certain bird species will require habitats of greater area and that larger habitats will have less

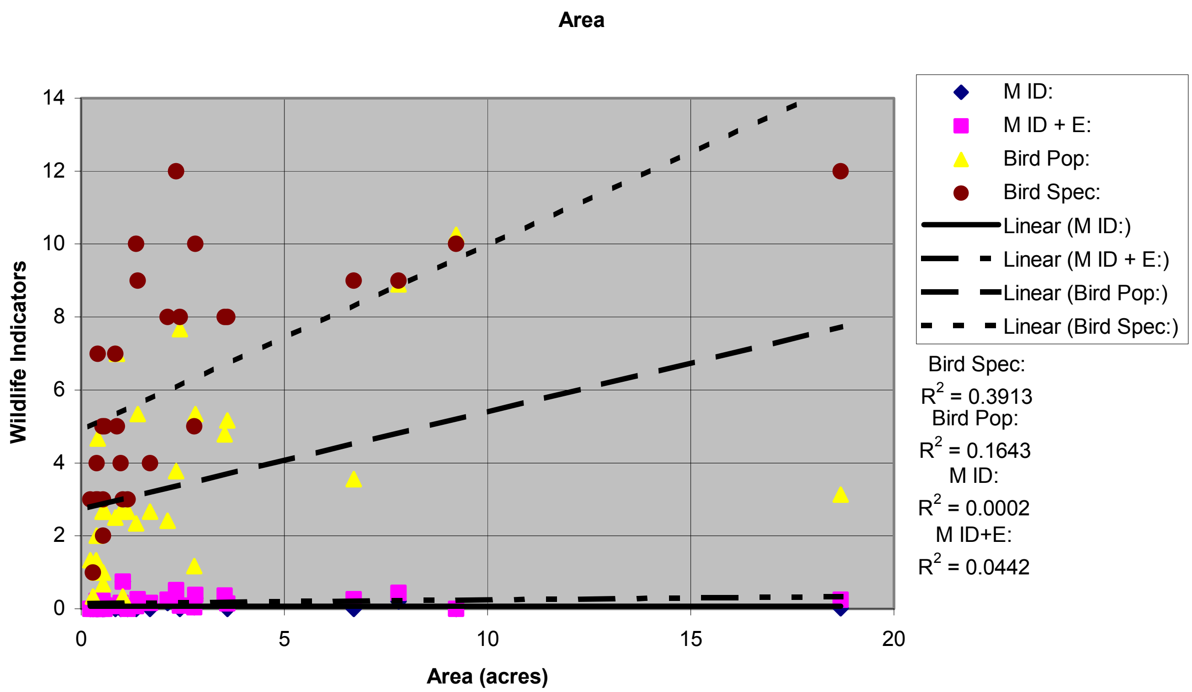
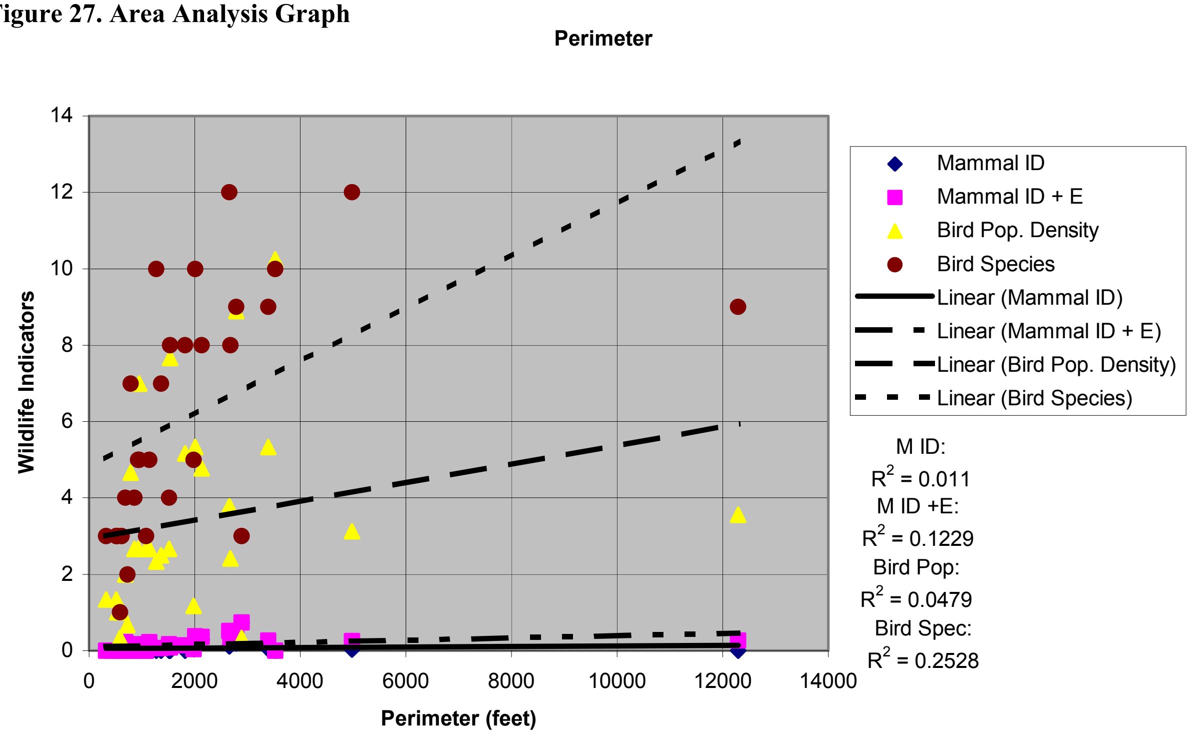



**Figure 27. Area Analysis Graph**



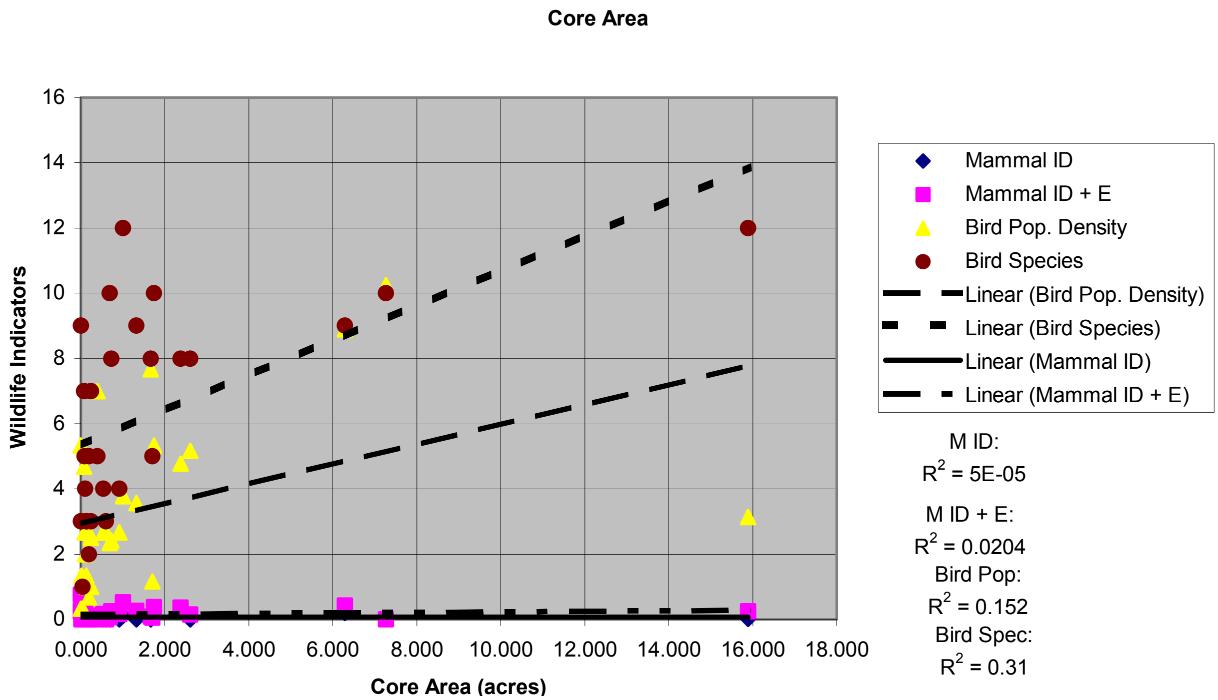



**Figure 19. Core Area Analysis Graph**

disturbance and greater population density. The mammal population statistics do suggest positive relationships with greater habitat **Area**, but without the high confidence that these relationships truly exist (r = 0.2102 and r = 0.0141).

The second spatial statistic describing habitat size is **Perimeter**. A habitat's **Perimeter** increases both as the habitat's area increases and as the habitat narrows, becoming less circular. All four field statistics show a positive relationship with increased habitat **Perimeter**. The study data shows very strong positive relationships between **Perimeter/Mammal ID + E** (r = 0.3506, 95% confidence) and **Perimeter/Bird Species** (r = 0.5028, 99.5% confidence). The high **Bird Species** correlation is not surprising given the extraordinary correlation between **Bird Species** and habitat **Area**. The high **Mammal ID + E** correlation is more important in that it indicates small mammals are more likely to inhabit large, narrow habitats.

**Core Area** is the final spatial statistic predominantly describing the size of the habitat. **Core Area** is also highly descriptive of habitat shape because of its elimination

of habitat area in narrow sections. The two bird statistics both show positive relationships with the habitat's **Core Area**. The correlation factors are high, giving confidence levels of over 99.5% and 97.5% to **Bird Population Density** and **Bird Species** respectively (r = 0.5298 and r = 0.4581). These correlation factors are, however, slightly less than those associated with habitat **Area**. This is not to say that the relationship is not as strong, just that this data shows more convincingly that a positive relationship exists with the entire habitat **Area**. The mammal field statistics show virtually no relationship with **Core Area** (r = 0.1020 and r = 0.0224).

**Habitat Shape**

The shape of habitat areas also was proven to be significant in the observed levels of wildlife habitation. **Edge Density** is an interesting statistic because it affects mammals and birds differently. Mammals are positively affected by increased **Edge Density** while birds are negatively affected by increased **Edge Density**. The edge habitat resulting from increased **Edge Density** decreases interior habitat area enjoyed by bird populations. Mammal populations, however, benefit from the increased length of habitat/golf course boundary associated with increased **Edge Density**. The very strong correlation factors observed with the bird statistics indicate that they are the most important (r = 0.4740 and r = 4076). Logically as well, it corresponds that low **Edge Density** habitats with greater interior habitat would be good for wildlife, especially human-sensitive bird species. The negative relationship between **Edge Density** and **Bird Population Density** has maximum

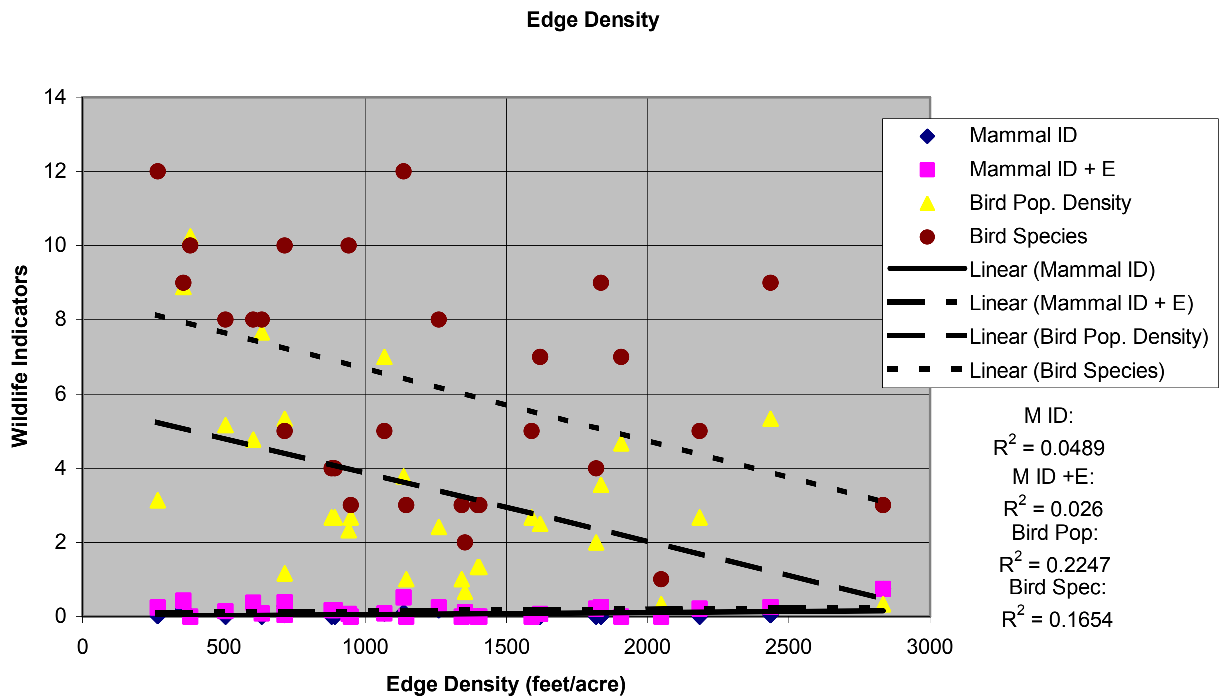



**Figure 30. Edge Density Analysis Graph**

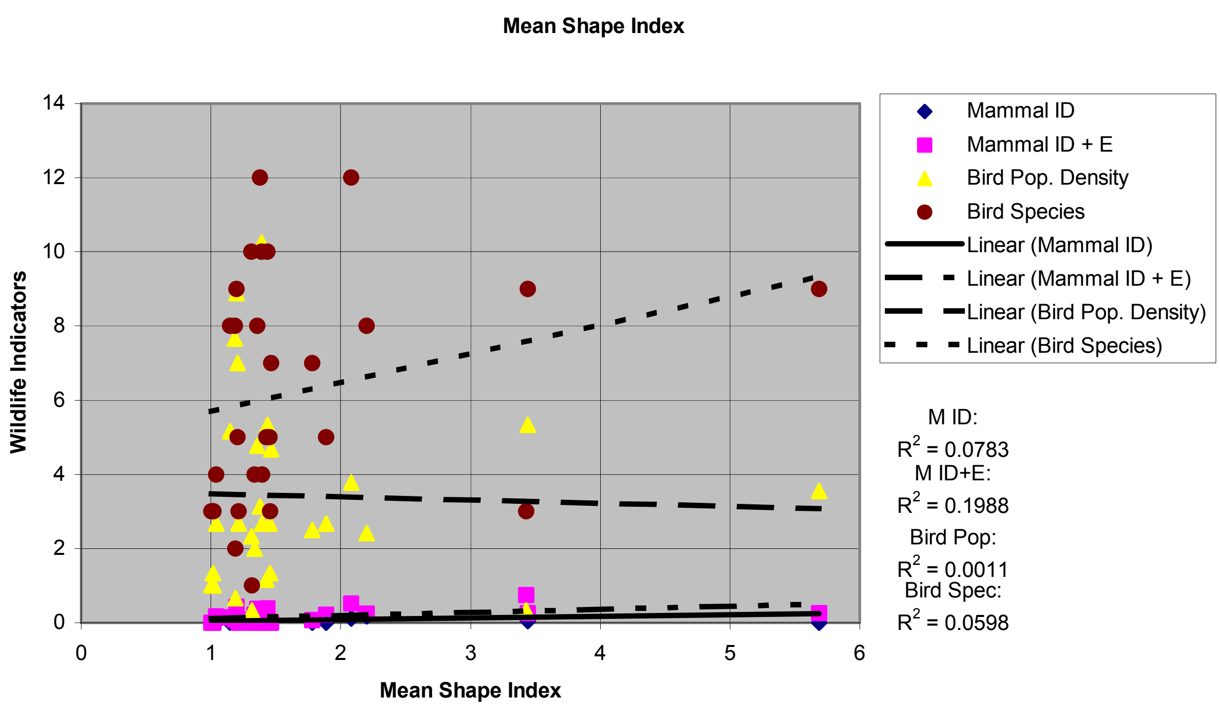



**Figure 31. Mean Shape Index Analysis Graph**

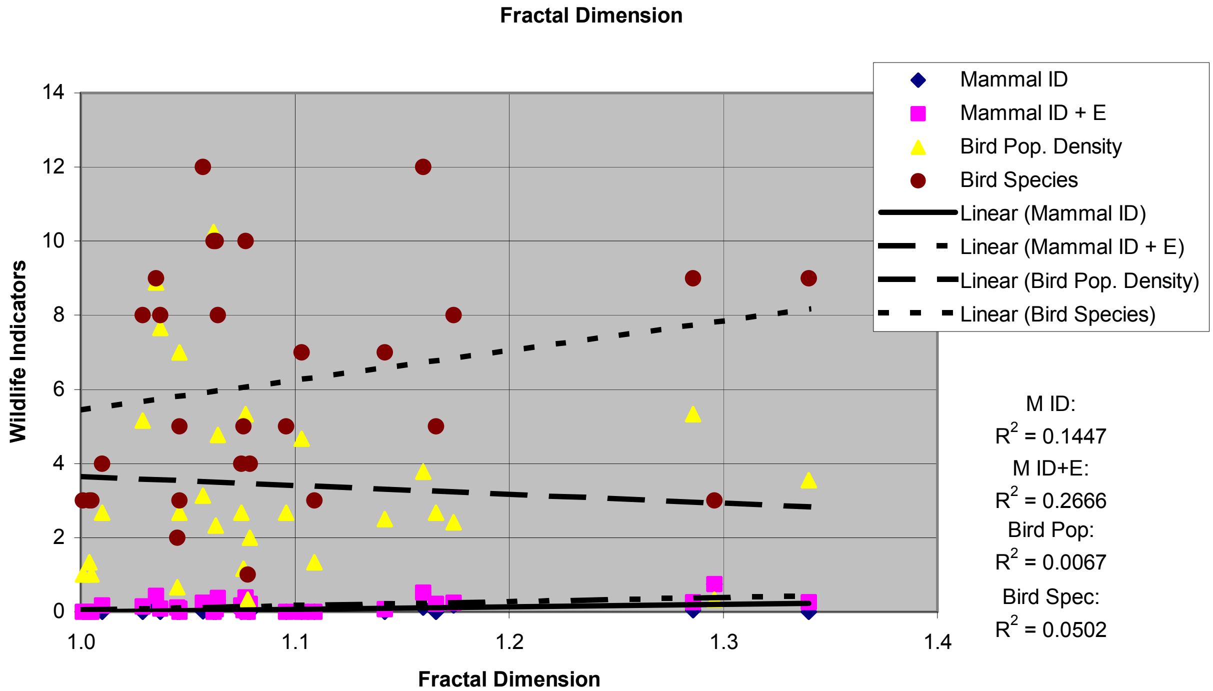



**Figure 32. Fractal Dimension Analysis Graph**

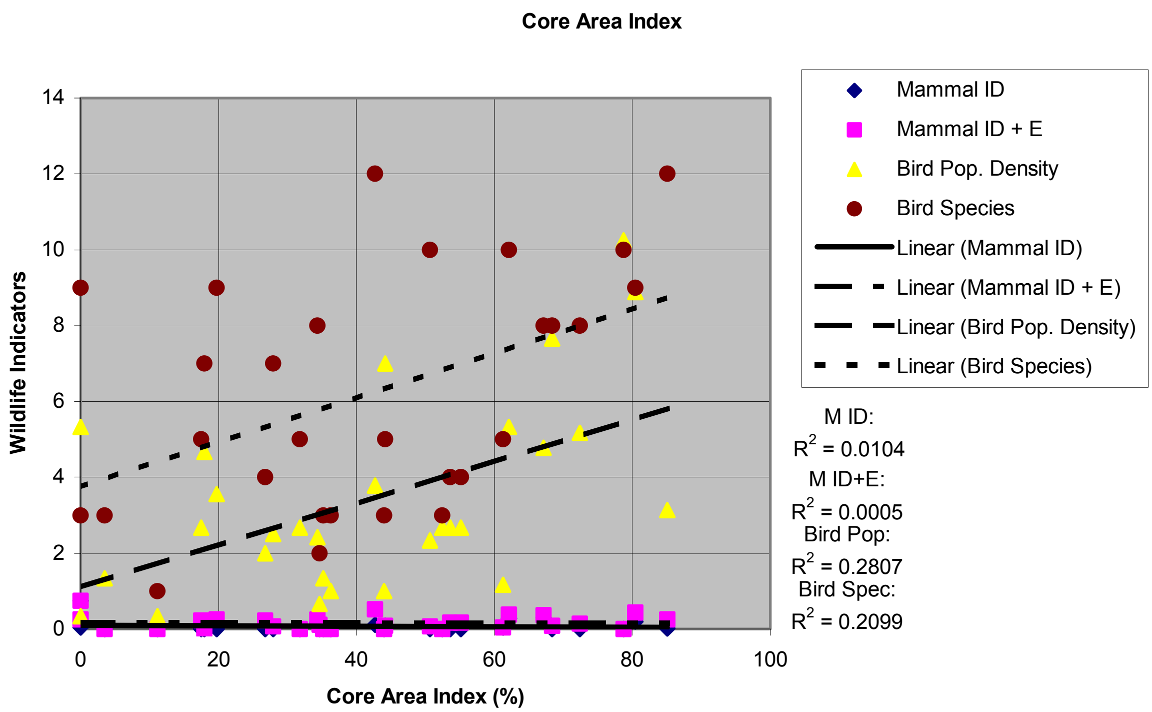



**Figure 33. Core Area Index Analysis Graph**

confidence of 99.5%, **Edge Density** and **Bird Species** has a confidence of 97.5%. The relationship also suggests that habitats will experience zero bird population when **Edge Density** reaches levels above 3500 feet per acre. Habitats with Edge **Density** below 1200 feet per acre show consistently strong **Bird Population Density** and **Bird Species** statistics.

**Mean Shape Index** measures the habitat shape's variance from a circle and shows a positive relationship with the wildlife field statistics. The mammal field statistics show the greatest correlation with the **Mean Shape Index** (r = 0.4459 and r = 0.2798). The **Mammal ID + E** and **Mean Shape Index** statistics have a 99% confidence level that a positive relationship truly exists. A positive relationship with **Mean Shape Index** advocates habitat shapes that differ from circular. None of the other field statistics have a 95% confidence level. The **Bird Population Density** statistic actually shows a slightly negative relationship with **Mean Shape Index**. The bird statistic relationships with **Edge Density** seem to contradict the mammal relationship with **Mean Shape Index**, but not necessarily.

**Fractal Dimension** is another shape statistic that shows strong correlation with the mammal field statistics (r = 0.3804 and r = 0.5163) and little correlation with the bird indicators (r = 0.0819 and r = 0.2241). **Mammal ID + E** and **Mammal ID** have 99.5% and 97.5% confidence levels respectively of a positive relationship with the habitat's **Fractal Dimension**. Only **Area** and **Edge Density** statistics have multiple confidence levels of 97.5% and higher. A positive relationship with **Fractal Dimension** advocates habitat shapes with more complex perimeters. The bird statistics show very little correlation with **Fractal Dimension**, similar to relationships with **Mean Shape Index**.

**Core Area Index** is the percentage of habitat within the **Core Area** and shows a strong relationship with both bird field statistics (r = 0.5298 and r = 0.4581). The data conveys with over 99% confidence that both **Bird Population Density** and **Bird Species** statistics have a positive relationship with the increasing portion of habitat within the core habitat area. This correlates logically that the more habitat area that is buffered from outside disturbances, the more birds and bird species will inhabit the area. The mammal field statistics show virtually no relationship with the **Core Area Index** (r = 0.1020 and r = 0.0224).

**Habitat Orientation**

The orientation statistics describe the habitat's orientation with other habitats, positive and negative influences, and the golf course community. **Orientation Angle** describes the variation of the habitats central axis from a North-South direction. **Orientation angle** does not show a strong correlation with the field statistics (r = 0.1015, r = 0.1158, r = 0.0656, and r = 0.2005). However, it is noteworthy that all of the field statistics indicate a preference for East-West oriented habitats. **Bird Species** has the strongest correlation and is intriguing enough to suggest future study.

**Nearest Neighbor** is one of three statistics measuring the shortest distance between the habitat perimeter and a specific feature. **Nearest neighbor** measures to the nearest habitat area and corresponds negatively to three of the four field statistics. That is, the wildlife field statistics decrease as the distance to the nearest neighboring habitat increases. Although these results logically fit, the correlation numbers are not

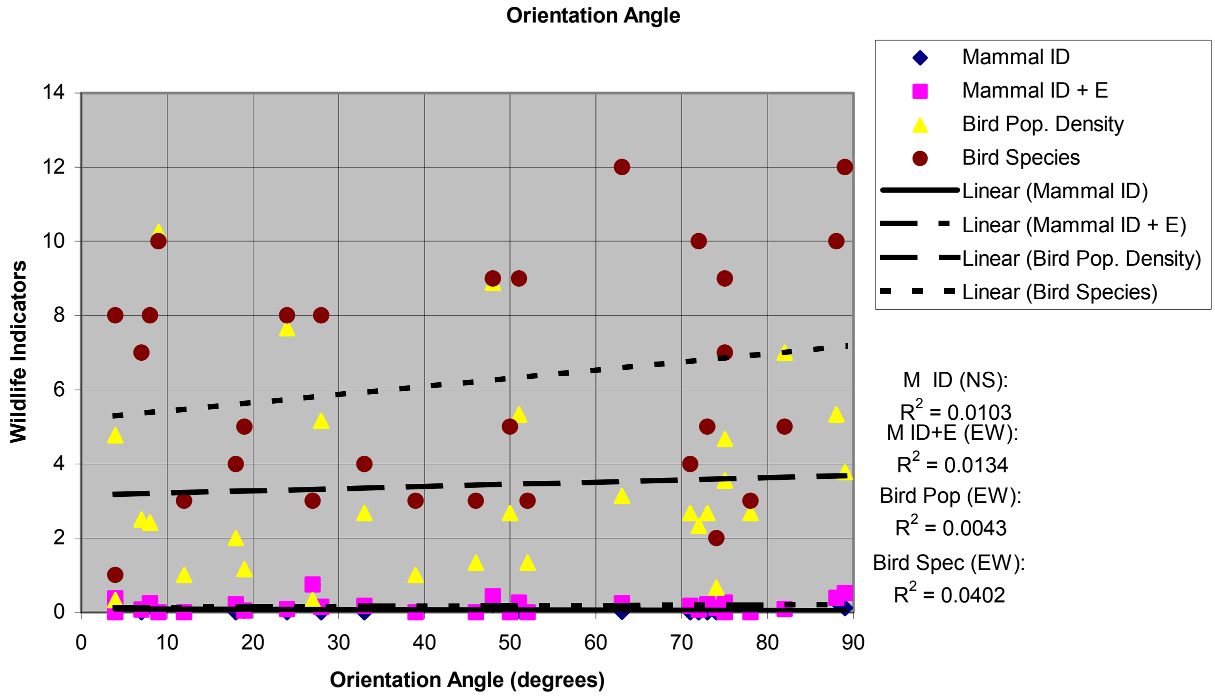



**Figure 34. Orientation Angle Analysis Graph**

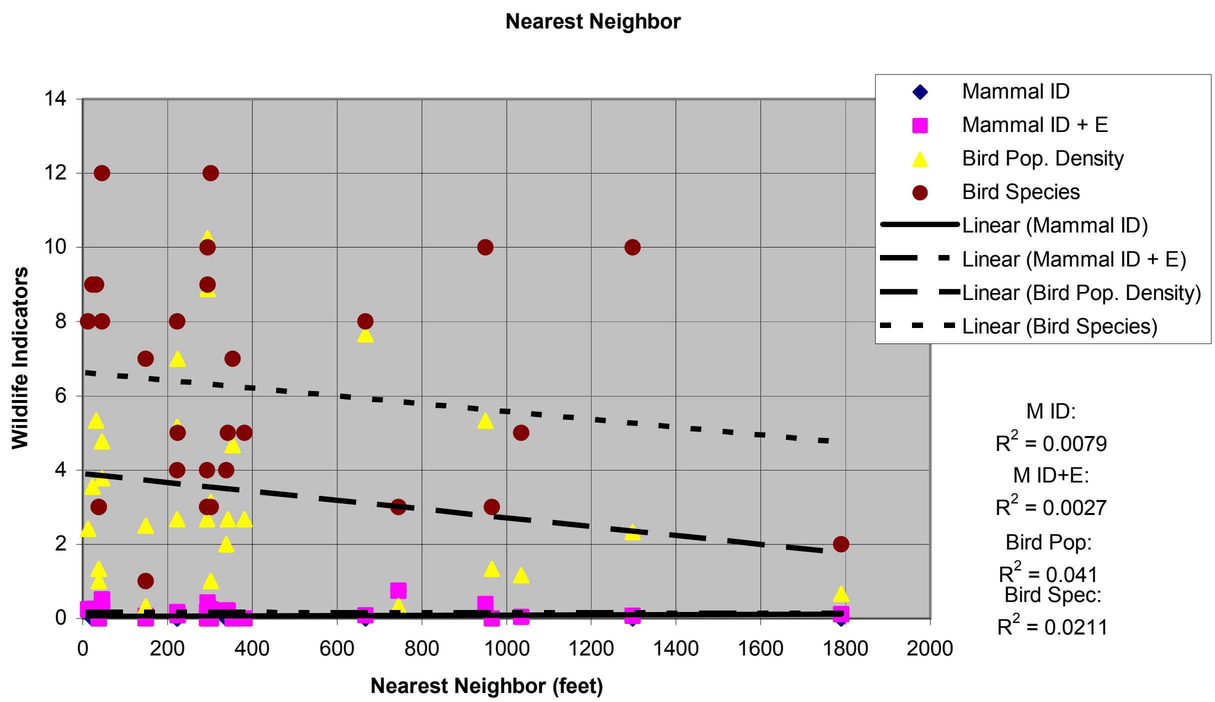



**Figure 35. Nearest Neighbor Analysis Graph**

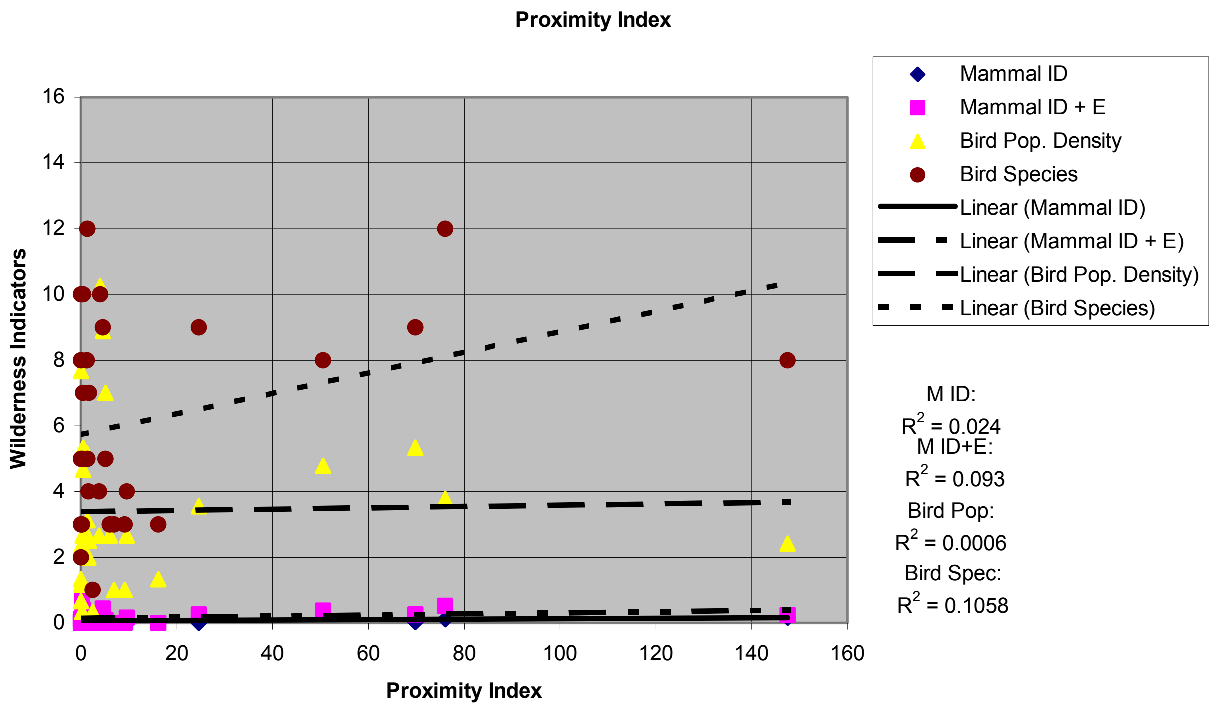



**Figure 36. Proximity Index Analysis Graph**

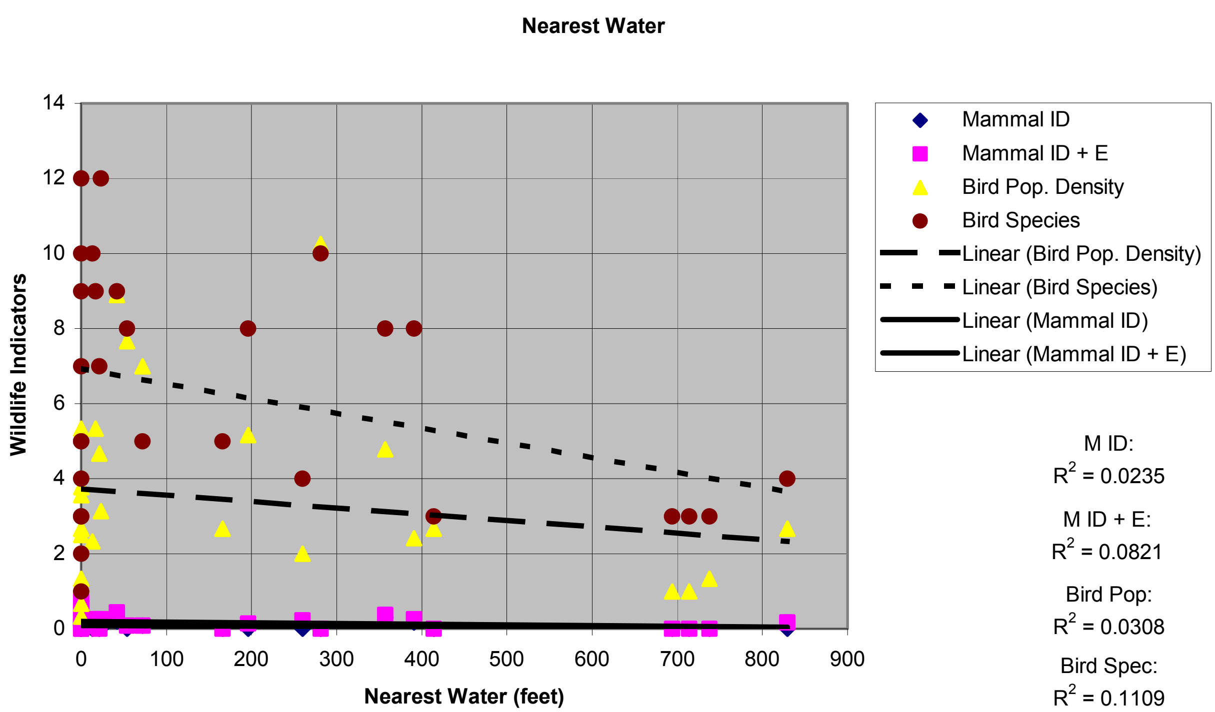



**Figure 37. Nearest Water Analysis Graph**

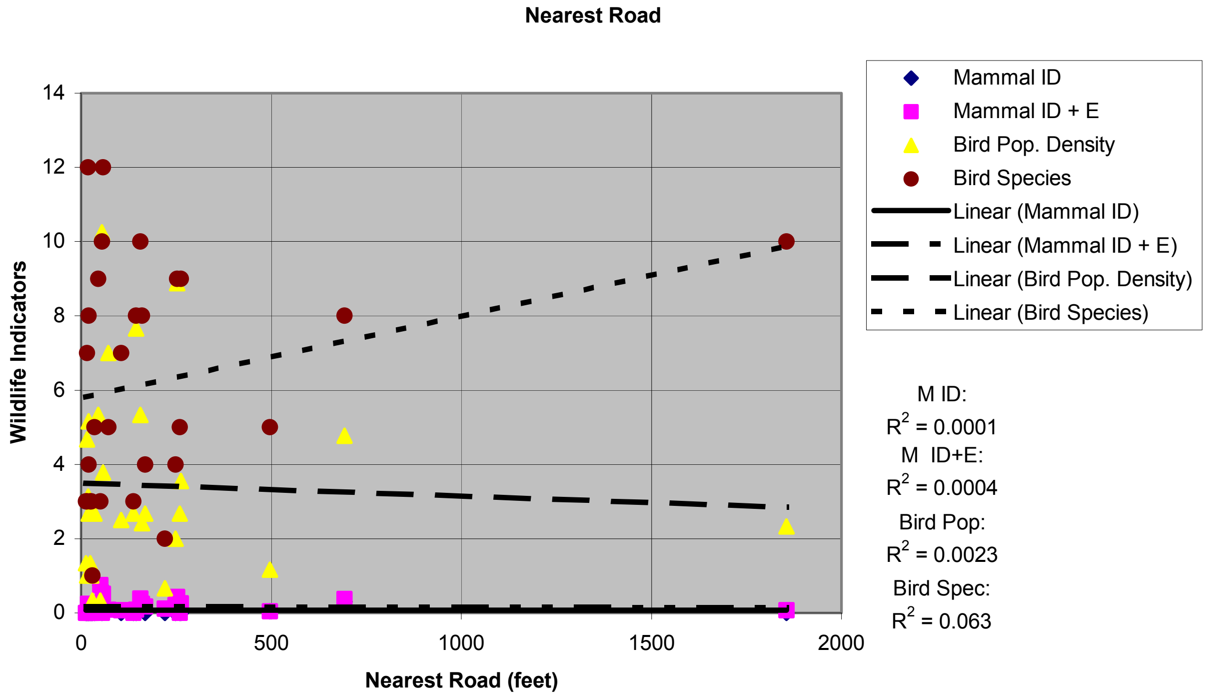



**Figure 38. Nearest Road Analysis Graph**

conclusive. The **Bird Population Density** statistic has the highest correlation with **Nearest Neighbor** (r = 0.2025).

Another attempt to quantify the benefit of other nearby wildlife habitat areas is **Proximity Index**. All four field statistics showed a positive relationship with **Proximity Index**, i.e. as the size and immediacy of other habitat areas increases, the wildlife habitation increases. The correlation between **Proximity Index** and **Bird Species** meets the 95% confidence level and **Proximity Index/Mammal ID + E** falls just short (r = 0.3253 and r = 3050). These correlations seem to prove both that nearby habitat areas do positively influence habitation and that **Proximity Index** is a slightly better predictor of this influence than the simpler **Nearest Neighbor** statistic.

The **Nearest Water** statistic has similar correlation with both the bird and mammal indicators. As the distance to the nearest water feature increases, all four

wildlife field statistics decrease. The correlation between **Nearest Water** and **Bird Species** is the greatest of the four, a 95% confidence level ($r = 0.3330$). The correlation between **Mammal ID + E** and **Nearest Water** is also strong but not at the 95% confidence level ($r = 0.2865$). Water is one of the four requirements for wildlife habitation (water, food, cover, and range) and one would have logically assumed a strong correlation. Further study would most likely continue to prove this correlation.

The **Nearest Road** statistic tests correlation between habitat and a common disturbance. The only wildlife field statistic that shows a correlation with the **Nearest Road** statistic is **Bird Species**. This seems to prove that of the golf course community wildlife inhabitants, certain bird species are the most affected by human disturbance. This fits very closely with the guidance given by golf course bird expert Scott Gillihan about the importance of avoiding edge habitat and providing buffer zones between birds and humans. The correlation with **Bird Species** was, however, insubtantial at $r = 0.2510$ and the other field statistics showed little or no correlation to variation in the **Nearest Road** statistic.

**Unique Observations**

In addition to the correlation between many of the paired statistics, a number of additional inferences can be made from the field data attained in this study. It is important to attain as much information from this study data as possible, even if predetermined methods of analysis called for conclusions to be made from the statistical analysis above. If the sightings of individual birds or observation of their behavioral habits suggests additional conclusions, this information must not be ignored.

Thirty-nine species of birds were observed within the 29 habitat areas of the four golf course communities studied.  All bird species are assigned a continually updated "Partners in Flight Conservation Priority Score" of between 1 and 30, with a score of 30 being the highest priority species for conservation.  The scores are based on the health of the species' overall population.  The Partners in Flight organization established and updates this system to help conservationists focus their energies on the bird species that need help the most.  The United States federal government gives a special protective status to wildlife species that are in imminent danger of extinction, identifying these species as "endangered."  The federal government also protects species, which could become "endangered" in the near future, by identifying them as "threatened."  None of the 39 species observed in this study are listed as endangered or threatened species.  In fact, 35 of the 39 species are currently assigned low conservation priority scores, between 1 and 15.  It should be expected that the most common bird species with healthy populations would be observed most often.  When bird species of a less than healthy population are observed it is particularly important to note and encourage the type of habitats that foster them.

The four species with a high priority conservation score that were observed are the Brown Thrasher, Veery, American Woodcock, and Red-headed Woodpecker.  Brown Thrasher and Veery species are both assigned conservation scores of 17 and are dependent upon habitats containing dense shrubs and understory.  Neither species requires large habitat areas and similar habitats are

**Figure 39. Red-headed Woodpecker**

presumably available at a great number of golf courses with moderately-sized habitat areas and dense undergrowth. The Brown Thrasher was observed in a habitat area of approximately one-half acre, adjacent to wetlands with relatively high disturbance levels (Area Q at The Bluffs on Thompson Creek). The Veery was observed in the largest habitat area studied, Area C at The Bluffs on Thompson Creek.

The American Woodcock and Red-headed Woodpecker species are both assigned conservation scores of 18 and require habitats widely available in golf course communities. The American Woodcock enjoys moist woodlands and wetland areas, types of habitat often constructed during golf course community development. This species was observed in a constructed pond between golf holes at the University Club. The Red-headed Woodpecker is perhaps the most important of the four species listed above because it was observed with such great frequency and in three of the four golf course communities. Red-headed Woodpeckers are found in open forest and scattered tree situations common in golf course communities. Their reliance on large-diameter dead trees for nesting and competition with European starlings has caused a decline in their habitat area and overall population (Scott, 1983). Golf course communities that allow snags, dead trees, and other potential cavities to stand will continue to enjoy this attractive species and aid in its conservation. A similar species, the Red-cockaded Woodpecker, is protected as an endangered species and is known to inhabit many golf course communities in the Carolinas.

Three additional observed species, the Pileated Woodpecker, Red-shouldered Hawk, and Belted Kingfisher, deserve particular note because of their general habitat requirements. The Pileated Woodpecker was observed, on several occasions, within

relatively small study habitat areas. This species is often thought to require large stands of mature forest. Gillihan suggests the Pileated Woodpecker requires a patch of forest habitat at least ten acres in size. Most of the habitat areas where I observed the Pileated Woodpecker were much smaller than ten acres. The Pileated Woodpeckers' repeated observation suggests that golf course communities may be able to provide for bird species in habitat areas smaller than what is normally required. This also hints that habitat patches may be viewed as interconnecting when existing together within a single golf course development. The Pileated Woodpecker also has shown to be one of many bird species that are becoming increasingly tolerant of human encroachment (Scott, 1983).

**Figure 40. Red-shouldered Hawk**

The Red-shouldered Hawk and Belted Kingfisher are two species noted for their sensitivity to human disturbance. Both of these species also are inclined to inhabit small ponds and wetland areas (Scott, 1983). Golf course developments often create small ponds and wetlands adjacent to designated habitat area. These types of small wetlands may be the key to providing for bird species who generally avoid human encroachment. Both the Red-shouldered Hawk and the Belted Kingfisher were observed in wetland associated habitat areas near the outer boundary of the golf course community development.

Of the 39 bird species observed in this study, most were common species with healthy populations. The few species with high conservation scores and lower overall populations tell us more about the habitats that were studied. Thirty-six of the thirty-nine

species observed are included among the species known to nest and inhabit in the study region, according to Partner's in Flight (Gillihan, 2000). The other three species have been previously known to migrate and winter in this region of Louisiana, a southern coastal area of the continent of North America. Because the study took place in the winter months, a few observances of these migrating birds are to be expected. The observance of these species does, however, emphasize the importance of bird migration. Wildlife habitat design must consider species that will use the habitat areas during specific seasons and migration as well as year-round inhabitants.

Complete lists of the birds identified within each golf course community are listed below with an indication of how many of each species were observed:

**The Bluffs**
American Crow (many)
Blue Jay (many)
Brown-headed Cowbird (few)
Brown Thrasher (one)
Canada Goose (many)
Carolina Chickadee (one)
Carolina Wren (one)
Chipping Sparrow (many)
Common Grackle (many)
Common Yellowthroat (few)
Downy Woodpecker (few)
Eastern Kingbird (few)
Eastern Starling (few)
Eastern Wood Peewee (one)
Field Sparrow (few)
Great Blue Heron (few)
Great Egret (one)
Great Horned Owl (one)
Hairy Woodpecker (few)
House Sparrow (many)
Killdeer (one)
Mourning Dove (few)
Northern Cardinal (few)
Northern Mockingbird (few)
Northern Flicker (few)
Pileated Woodpecker (few)
Red-shouldered Hawk (one)
Red-winged Blackbird (few)
Red-headed Woodpecker (many)
Summer Tananger (few)
Veery (one)
White-breasted Nuthatch (one)
White-throated Sparrow (many)

**Santa Maria**
American Crow (few)
Blue Jay (many)
Common Grackle (few)
Eastern Kingbird (one)
Eastern Starling (few)
House Sparrow (few)
Mourning Dove (few)
Northern Cardinal (many)
Northern Mockingbird (few)
Red-winged Blackbird (few)
Veery (few)

**University Club**
American Crow (many)
American Woodcock (one)
Belted Kingfisher (one)
Blue Jay (many)
Carolina Chickadee (few)
Common Grackle (many)
Downy Woodpecker (one)
Eastern Phoebe (one)
Eastern Starling (few)
Great Blue Heron (one)
Great Egret (few)
House Sparrow (many)
Mourning Dove (many)
Northern Cardinal (many)
Pileated Woodpecker (one)
Red-winged Blackbird (many)
Song Sparrow (few)
Warbling Vireo (few)

**Money Hill**
American Crow (many)
American Robin (few)
Belted Kingfisher (one)
Blue Jay (many)
Cedar Waxwing (one)
Chipping Sparrow (many)
Great Blue Heron (few)
Great Egret (one)
Mourning Dove (many)
Northern Cardinal (many)
Pileated Woodpecker (few)
Red-headed Woodpecker (many)
Red-winged Blackbird (few)

The small mammals observed in this study are widespread species and provide little insight about the studied habitats. Three species of small mammals were trapped and identified in the small mammal portion of this study. The White-footed Mouse, Cotton Mouse, and Hispid Cotton Rat are all known to inhabit the southern Louisiana region in large numbers. The Cotton and White-footed mice are very similar animals and inhabit primarily wooded and brushy areas. Both species can swim and climb trees as well as negotiate the ground. They feed on nuts, seeds, and fruits, in addition to a number of insects. In autumn, these mice will store caches of nuts and seeds in a bird nest or abandoned burrow (Whitaker, 1996). This supply of collected food may have lowered trapping success in my study, especially at The Bluffs on Thompson Creek, which was observed in the month of October. The three remaining sites were observed in November and December when stored food supplies were likely lower. The Hispid Cotton Rat is a larger rodent that consumes primarily green vegetation and occasionally insects or young birds. The cotton rat is one of the world's most prolific mammals. Its enormous reproductive potential is kept in check by its many predators, which include birds, reptiles, and other mammals. Their primary habitat is grassy and weedy fields but they were often observed in more forested areas. Cotton rats also are known to occur in great numbers in thick vegetation around

**Figure 40. White-footed Mouse**

**Figure 41. Cotton Mouse**

**Figure 42. Cotton Rat**

ponds or marshes (Whitaker, 1996). All three species of mammals are primarily nocturnal and are members of the *Sigmodontinae* subfamily.

The total numbers of mammals observed by species and golf course community site are as follows; 45 White-footed mice (38 at University Club, six at Money Hill, and one at The Bluffs), ten Cotton mice (five at University Club, and five at Money Hill), and eight Cotton rats (six at University Club, one at Money Hill, and one at Santa Maria.

The results of this study strongly suggest that spatial design of wildlife habitats does affect the ensuing habitation of the area. Most of the spatial statistics showed virtually undeniable evidence that correlation does exists between them and the observed wildlife habitation in the field. The subsequent chapter will attempt to refine the results of this study and coordinate them with the existing knowledge available from wildlife experts and golf course designers. The individual results, however, are the base for the following conclusions and are the essence of new information provided by this study. The results also substantiate that a number of existing theories about wildlife habitat and habitation, formed by various wildlife management and golf course design experts, hold true in golf course community settings.

# CHAPTER FOUR

## SUMMARY, CONCLUSIONS, AND GUIDELINES

A number of spatial-habitation correlations were successfully identified by this study and discussed in the previous chapter. But what does it all mean? What use are these correlations? Most importantly, is this everything we need to know to design successful wildlife habitat areas within golf course communities? While this study does not provide all the answers, not even to this very specific task of designing wildlife habitat within golf course communities, it does validate that many existing wildlife habitation theories apply to the specific environment of golf course communities. This study also identifies some new spatial characteristics that show direct relationships with these specific wildlife habitation areas.

Wildlife habitation areas should be as large as possible to inhabit the greatest number and variety of habitat species. This is the most logical, simple and widely accepted spatial characteristic regarding wildlife habitation areas. This relationship was also proven by this research study. The **Area** statistic correlated strongly with increasing bird population and species variety. The golf course community setting did not alter the generally accepted relationships between habitat size and bird populations. **Area**, **Perimeter**, and **Core Area** all showed very strong positive relationships with bird habitation. These relationships seem to suggest wildlife habitats within golf course communities have few unique tendencies in term of size.

The mammal statistics do, however, point to a unique relationship between size characteristics and habitats within golf course communities. The mammal statistics have no positive relationship with **Area** or **Core Area** of the habitats. That is, mammal

populations show no tangible increase in relative abundance when habitat area increases. The mammals do show a positive relationship when habitat *Perimeter* increases. An assumption that mammal populations benefit from an interaction with the more manicured areas of golf course communities can be made. The mammals seem to inhabit the edge habitat adjacent to the greater golf course community. Although the reasons for this cannot be substantiated, it is likely that the mammal populations enter and exit the habitat areas in search of food and water, both of which are easily accessible on the golf course. The mammals are also likely to enjoy the increased food and cover provided by dense understory vegetation along the habitat's perimeter. Finally, the mammal's nocturnal behavior tends to separate them from the daytime disturbances of nearby human populations.

A number of conclusions can be made about the size of designed habitat areas from this study. First, the larger the area is the better. Not only should habitat areas be designed as large as possible, but smaller habitat areas should be condensed into larger areas. Larger areas have proven better for bird populations and diversity, while mammals show no preference to multiple small areas or single large areas. **Perimeter** positively affects bird variety and mammal populations while **Core Area** positively affects bird population and variety. **Perimeter** and **Core Area** generally work against each other; however, the habitat's boundary should be altered if either statistic can be significantly increased without greatly decreasing the other. For instance, a perfectly rectangular area would be more beneficial with a curvilinear perimeter. The effects of this relationship also will be important when analyzing the shape statistics.

The shape statistics studied are more unique to this study and less predictable. The first statistic is a direct result of the two size statistics of **Area** and **Perimeter**. **Edge Density**, the resultant quotient of **Perimeter** divided by **Area**, was proven to negatively affect both bird population and variety. The optimum **Edge Density** for bird statistics was below 1200 feet per acre. Areas with very large **Edge Density**, over 1200 feet per acre, are long and narrow. Generally, condense areas with a curvilinear perimeter have only moderate **Edge Density** and would seem to escape this negative relationship while creating as large of a **Perimeter** as possible. If a long, narrow habitat area exists, or is originally designed, increasing the width as much as possible will positively affect **Edge Density**, **Area**, **Perimeter**, AND **Core Area**.

A very meaningful relationship exists with the spatial statistic titled **Mean Shape Index**. **Mean Shape Index (MSI)** rates the habitat's perimeter shape against a perfect circle. A perfect circle has **MSI** of 1 and **MSI** increases as the habitat's shape differs from that of a circle. Generally, an increase in **MSI** creates an increase in **Edge Density**. However, **Mean Shape Index** has a very different relationship with the wildlife statistics. **MSI** has a proven positive relationship **Mammal ID + E** and no substantial negative relationship with the bird statistics. If landowners or governing agencies have a preference between birds and mammals, a designer could easily concentrate on the more important statistic. This situation will rarely occur and therefore we must attempt to best satisfy both species groups. The object is to retain a low **Edge Density** while creating as large of a **Mean Shape Index** as possible. One option is to create largely regular perimeters on non-circular shapes. Another is to create long, but thick habitat areas. Perhaps more importantly is why mammals seem to prefer non-circular shapes. Non-

circular shaped habitats in this study were often a consequence of a topographical feature such as a wetland, steep ridge, or stream bank. These types of areas are often unsuitable for development, but are preferred by mammal populations, and suitable for many bird species.

**Fractal Dimension** and **Core Area Index** are the final two spatial statistics descriptive of habitat shape and confirm design strategies discussed above. **Fractal Dimension** describes the complexity of the habitat perimeter, increases as the perimeter becomes more complex, and has proven positive relationships with both mammal population statistics. **Core Area Index** is the percentage of total **Area** within the **Core Area** and has proven positive relationships with both bird field statistics. It confirms earlier arguments that mammals would prefer complex boundaries and that bird populations prefer protected, interior habitat. Notably, bird populations have a stronger correlation with total **Area** than **Core Area** or **Core Area Index**. Therefore, **Core Area** and **Core Area Index** should be encouraged but not by eliminating any habitat **Area** outside of the **Core Area** (edge habitat). The habitat boundary, too, should be increased in complexity but not at the detriment of the **Core Area**. Positive mammal reaction to complex perimeter is in reaction to many elements associated with a habitat's complex perimeter. Close association with vegetation, topographic features, the golf course, and water features creates a more complex perimeter while association with roadways and parking lots, for example, does not.

Wildlife habitat orientation within the golf course community is difficult to describe with a single spatial statistic or even a group of spatial statistics. Orientation includes relative placement with other habitats, water features, disturbances, and position

relative to the world. **Nearest Water** and **Proximity Index** statistics were the two orientation spatial statistics proven to affect the wildlife populations living within golf course community habitats. All of the studied statistics showed some logical correlation but often the relationships were quite subtle. Studying a large number of habitat areas would provide an opportunity to prove these more subtle relationships. Additionally, any future studies on wildlife habitat design in golf course communities should concentrate on discovering further orientation statistics and proving their correlation with a habitat's success.

**Bird Species** was the only wildlife statistic to show a high level confidence of correlation with any orientation statistic. This bird diversity statistic represents the wildlife species that are the most difficult to provide acceptable habitat for their habitation. It logically corresponds, therefore, that small differences in the orientation of a habitat will affect habitat-particular bird species the most. Many of the other relationships between orientation and wildlife statistics show some explainable correlation. Further studies would likely give increased confidence as to the existence of these relationships and confirm their reason for use in design.

The two strongest orientation relationships proven in this study were to water features and to additional habitat. Both these relationships seem obvious when pointed out, but are strengthened by statistical proof. Many bird species, especially those who prefer wetland-type habitat, need permanent water features nearby. Wildlife habitats positioned near water features were shown to benefit a richer variety of bird-life. The strongest habitat relationship of any kind was to **Area** and, therefore, it is logical that additional habitat area nearby would have a positive impact. It is notable that **Proximity**

**Index** was a better indicator of positive nearby habitats than was **Nearest Neighbor**. It is important that additional habitats are nearby, within 1000 feet edge-to-edge, and of substantial size. Both of these orientation statistic relationships point to an additional truth about golf course communities. Golf course communities provide an environment in which many species are willing to freely travel about. Wildlife species living in designated habitat areas are willing to travel about the more manicured portions of the property to find water, food, and additional habitat.

Wildlife species positively responded when additional habitat was within 1000 feet and had the strongest relationship with increased habitat area. Wildlife corridors are often described in existing literature as the solution to connecting small habitat areas within an overall human environment. This research suggests that wildlife corridors may not be needed in golf course community situations. None of the golf course communities studied had any kind of corridor system to link habitats and other features providing food or water. Golf course communities seem to provide an environment friendly enough to wildlife in order for them to travel freely throughout the area. This study far from proves these suggestions I make, but does at least promote additional study as to the need for wildlife corridors within green-space dominated developments like golf course communities.

The individual bird species that were analyzed because of the importance of their observation lead us to a few complementary conclusions. Small habitats within golf course communities may have more potential for habitation of particular species than segmented habitat in other urban and suburban developments. To encourage this potential, two specific design decisions should be made. First, higher levels of human

activity such as vehicular roadways, cart paths, practice facilities, and other gathering areas should be separated from designated habitats. The strongest reason for separation is that much of the low-level human activity occurring within a golf course community can be accepted by bird species that normally avoid any human disturbance. Second, small water features and habitat areas should be paired when possible to encourage habitation by wetland species of birds and other mammals. Water features are much more common within golf course community developments than many other types of developments. Designed wildlife habitats should take full advantage of this opportunity. The observed species also illustrate that the golf course community itself can be used as range habitat for some species. Bird species, and other wildlife species, generally requiring a large range for habitation may accept a smaller than normal natural habitat when placed within a larger, human-associated green space. Therefore, species with large range requirements should not be overlooked during the design and implementation of these habitat areas. More generally, the variety of species observed in this study should give credence to the importance and potential of habitat areas within golf course communities.

**Guidelines**

These conclusions must now be assembled into a clear, concise reference list so that designers may incorporate these ideas about habitat spatial design into the overall process of golf course community development. This list incorporates the conclusions made from this specific study with the general knowledge available from the field of golf course architecture. In this way, a habitat design objective, discovered in this study, would not be accepted into this reference list if it did not logically coincide with the accepted objectives of golf course architecture. For instance, I would not suggest that all

18 golf course holes be aligned linearly in order to create long narrow habitats if long narrow habitats of a specific orientation were deemed most successful. The goal is to create successful wildlife habitats beneficial to golf course communities, not at the detriment of golf course communities.

The Wildlife Habitat Design Guidelines for golf course communities are listed in rough order of importance and then followed by a short discussion of each:

1. Design wildlife habitats as large as possible and encompass as much land area as possible. Smaller areas should be consolidated into single larger areas.

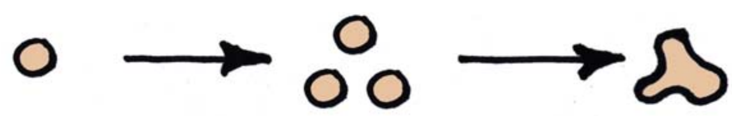


**Figure 43. Guideline 1**

2. Locate wildlife habitats on topographical features such as steep ridges, wetlands, and stream or pond banks.
3. Delineate curvilinear boundaries for wildlife habitats.

**Figure 44. Guideline 3**

4. Locate wildlife habitats adjacent to, or close to, water features.

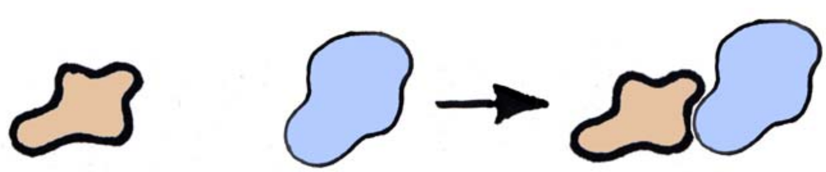


**Figure 45. Guideline 4**

5. Locate wildlife habitats close to additional habitat existing either within or outside of project boundaries.

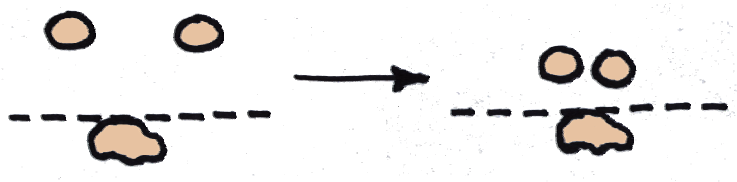


**Figure 46. Guideline 5**

6. Maximize the width, as opposed to the length, of generally long, narrow wildlife habitats.

**Figure 47. Guideline 6**

7. Include any questionable small or narrow areas adjacent to a designated wildlife habitat.

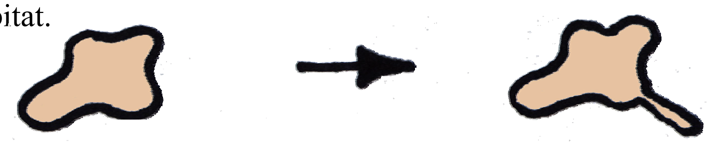


**Figure 48. Guideline 7**

8. Locate wildlife habitats as far away as possible from high-level human activities and disturbances.

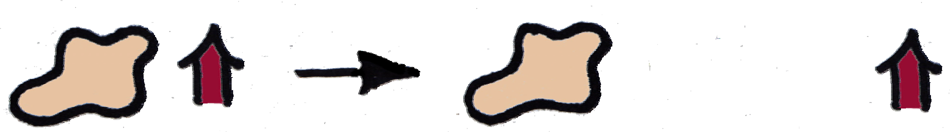


**Figure 49. Guideline 8**

9. When designing for a specific species, do not eliminate the possible use of habitats smaller than the generally accepted minimum.

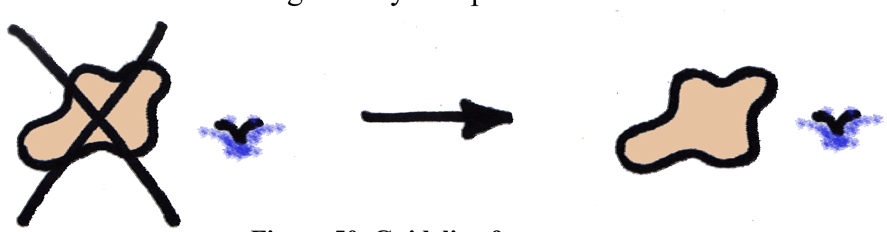


**Figure 50. Guideline 9**

10. When any of guidelines #1-9 are competing, choose the design option that creates the largest total area of wildlife habitat.

Guideline #1 summarizes the most discussed relationship of this study, the more the better. Designated wildlife habitats should be incorporated into every golf course community project and should designate as much land area as possible. This guideline also emphasizes that smaller habitats should be consolidated into single larger habitats as long as this can be done without losing any substantial total habitat area. Guideline #2 promotes wildlife designation of site features often considered unbuildable because of the high associated costs or because environmental statutes prohibit their use. These areas are commonly left over when golf course communities are designed and can be successfully designated as wildlife habitat.

Guidelines #2 and #3 coordinate very easily with current golf course design practices. Guideline #3 advises the best boundaries for wildlife habitats are curvilinear boundaries. A curvilinear boundary also is considered the ideal boundary for a golf hole. This type of boundary provides a calm, natural feel while containing the grassed area playable by golfers. For wildlife, a curvilinear boundary maximizes the *Perimeter* while maintaining maximum interior, core habitat. Wildlife species that enjoy the golf course interaction and those species requiring protected interior habitat benefit from a wavy perimeter.

The location of wildlife habitat amongst additional features is discussed in Guidelines #4, #5, and #8. Guidelines #4 and #5 advise the placement of wildlife habitat close to positive elements of water and additional habitat. Any permanent water feature provides a necessary element of survival and a required habitat-type for certain species.

Additional habitat in close proximity and of sufficient size provides supplemental food and range. This supplemental range makes habitation of a larger variety of wildlife species possible and allows for greater populations of wildlife. Guideline #8 recommends the separation of wildlife habitat from high-level human disturbances. This is particularly important because of the observed tolerance of golfers by several bird species known for their general intolerance of human disturbance.

Designing habitat to encourage use by specific species often influences choices in vegetation establishment and maintenance. This study has shown that several specific species were able to accept smaller than normal habitat areas because of their location within the golf course community. Therefore, Guideline #8 advises that smaller habitats should not be ignored when making supplemental decisions to encourage specific species or species groups.

The relationships of wildlife habitat shape and *Core Area* are central to Guidelines #6 and #7. Guideline #6 describes the most applicable method to increase the *Core Area* of a wildlife habitat. The importance of the habitat's total area should never be forgotten in the pursuit of increasing central core area. This conflict is the subject of Guideline #7. Any additional areas that can be delineated within a wildlife habitat and managed as such increase the habitat's success. Guideline #9 encourages developers and designers to consider small habitats for species which require a large range, because of the benefits from placement within a golf course community. Many species will consider the golf course viable range habitat and travel freely through and within it. Therefore, decisions about maintenance and vegetation within small habitat areas should consider such species.

The final guideline, #10, refers back to the first. Though the guidelines are to aid in design of wildlife habitat size, shape, and orientation, the most important habitat feature is their existence. The greatest proportion of a development property that can be devoted toward wildlife habitat should be devoted toward wildlife habitat.

The results of this study have been analyzed, concluded, reviewed, and assessed. Did the study itself provide the best results possible? How could the study be improved to provide more information to golf course architects and planners about the design of designated wildlife habitats? This study has been very successful in providing strong evidence that a number of design decisions can clearly affect the habitation of designated wildlife habitat areas. The most important decision continues to be the decision to set aside land specifically for local wildlife. This study gives designers a number of clear guidelines about how to position and shape these wildlife habitats within golf course communities. This study also gives designers the confidence that designated wildlife habitats are successfully being inhabited by a number of wildlife species.

A quick review of my methods will summarize the advantages and disadvantages of my research decisions as well as giving recommendations to future research in this area. I believe a more extensive study with a similar methodology could be very valuable. Also, I believe that my thesis research would give an additional study the credibility to seek financial backing. The United States Golf Association sponsors research investigating golf's relationship with wildlife and its habitat. The USGA contributes $200,000 annually to the Wildlife Links Program designed solely for this purpose and administered by the National Fish & Wildlife Foundation (USGA, 2002). Similar studies have received sponsorship of between $25,000 and $45,000 from the

Wildlife Links Program. Scott Gillihan received sponsorship of $43,000 to produce his publication *Bird Conservation on Golf Courses*. This type of sponsorship for research is rarely available and removes any financial impediments from proceeding in this type of research project.

Golf course community selection, the first step of this research project, was very successful. The four, selected golf course communities provided a good variety of wildlife habitats and active wildlife populations for my study. I am very appreciative for the positive responses and information given to me by the management of these four golf courses and their associated residential developments. This research would not have been possible without their cooperation. However, the biggest shortcoming of the research is the relatively small number of study sites and habitat areas that were researched. A similar research project with a great many more study sites would produce irrefutable evidence of the relationships that exist between habitat design and wildlife habitation.

The second step was selecting the habitat areas within each of these golf course community sites that would be studied. The habitat areas that were studied very well represented habitat areas contained within the golf course community. Habitat areas extending beyond the boundaries of the golf course community are assumed to be subject to the same spatial relationships. Any future studies should consider including habitat extending beyond the site. The additional area incorporated in these types of habitats is advantageous. This study proves the very positive relationship with increased size and by pairing on-site habitat with off-site habitat, both habitats are positively affected. Further

study could investigate any additional relationships important to the success of these types of habitat areas.

The wildlife monitoring methods used in this study proved effective. These methods would be recommended for any future studies evaluating the success of fragmented wildlife habitat. Studies in different geographical regions may require altered methods and consultation from a wildlife study expert. The spatial statistics used to differentiate and evaluate the habitats also were effective. A number of strong relationships were identified and a set of valuable guidelines was produced. Aerial photography proved to be valuable as well. Additional orientation statistics may have produced more valuable information. Orientation statistics are more likely to have subtle but important relationships with wildlife habitation. If additional orientation statistics are to be evaluated, a larger sample of habitat areas will be required. Statistics better describing the level of disturbance affecting the habitat area also would be advantageous.

The analysis portion of this study was simple yet effective. Basic relationships were identified as positive, negative, or inconclusive. If a larger sample of sites was studied, more accurate relationships could be identified. With accurate relationships, planned habitat areas could be evaluated as to their potential success. The basic relationships identified in this study simply provide guidelines about positive and negative habitat characteristics.

Although the study methods produced successful results, a number of limitations to this study exist. A more extensive, subsequent study would ideally eliminate many or all of the limitations which restrict the results and conclusions produced by this study. The field study portion of this study was limited geographically and seasonally. The sites

were all located in southern Louisiana and do not well represent the United States or even the southeastern region of the Unites States. The limited geographic range in the study sites also limited the soils, vegetation, and climatic conditions that the study represents. The field study was also limited to the fall season, October to early December. A more complete understanding would be produced by field studies conducted repeatedly throughout the year. The spatial statistics are primarily limited in number. The twelve spatial statistics are far from an exhaustive list of possible spatial study statistics. As more spatial statistics are analyzed, a more complete understanding of habitat design can be conveyed to designers.

There is an additional benefit of a more exhaustive study that would be of great consequence. A study complete with broader sampling and additional spatial statistics would initiate the possibility of habitat success prediction. A number of parameter relationships could be applied to the spatial design of wildlife habitats to predict wildlife habitation populations and diversity. A designer could adjust a wildlife habitat's design and apply a formula to determine the design's impact on future habitation. Wildlife habitation will never be an exact science, but a general model using a number of design parameters would be of great use.

The results of this study are best summarized by the Wildlife Habitat Design Guidelines that it produced. It is my hope that these guidelines will be of use to golf course community designers and planners to produce wildlife habitat more valuable for wildlife populations. This study also will be effective if it spawns additional research in this field. Additional research is strongly recommended because of the availability of financial support and the golf industry's receptiveness to new information.

The guidelines and information produced by this study provides valuable guidance for thousands of acres of golf course community properties. The concepts involved also are applicable to all other types of large-scale land developments. Wildlife is an incredibly valuable portion of our natural world that we continue to invade and disrupt. We must continue to pursue information that will allow human and wildlife populations to live in harmony. The inclusion of wildlife communities in our designs is necessary to sustain the quality of life we all currently enjoy. By including well-designed wildlife habitats in our designs, we will enhance and strengthen the lives of not only ourselves, but our neighbors, our children, and our children's children.

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# VITA

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