Use of Geographic Information Systems and Global Positioning Technology to Map and Study Nesting Trends and Density Dynamics of a Heronry on the Upper Mississippi.

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Abstract

Geographic Information Systems (GIS) were used to examine the nesting behaviors of great blue herons (*Ardea herodias*) and great egrets (*Ardea alba*) in the Mertes Slough area of Pool 6, Upper Mississippi River. Nest trees and nests were located by canoe and locations recorded by use of global positioning system (GPS) technologies. Nesting trees and nests were plotted on a 1989 land cover use dataset for Pool 6 and analyzed spatially with Environmental Systems Research Institute (ESRI™) mapping software. Special attention was given to the explorations of nesting patterns in relation to a recreational canoe path that traverses through the rookery area. This study's findings suggest that the heronry is expanding over time and in the direction of the canoe path; however, herons and egrets show preference for nesting sites in areas 20-30, and 30-40 meters from the canoe path. Explanations are incomplete in explaining these nesting behaviors.

Introduction

Nestled in the backwaters of the Mississippi river, near Winona, Minnesota, lies a heron and egret colony. Every spring, hundreds of great blue herons (*Ardea herodias*) and great egrets (*Ardea alba*) descend upon Mertes Slough, part of the Winona district of the Upper Mississippi River National Wildlife and Fish Refuge. This refuge, with its broad pools, braided channels, wetland and floodplain forests, provides critical habitat for migratory birds. One of the main objectives of this refuge is not only to provide habitat for migratory species, but to monitor species health and populations for the birds protected under the Migratory Bird Treaty Act and the Waterbird Conservation for the Americas Initiative. Herons and egrets fall under both programs as protected species. A critical element of conserving and managing water birds is a comprehensive monitoring program. Waterbird conservation management decisions depend on measuring and evaluating population change as a basis for setting policy, identifying management and research priorities (FWSWS 2003).

The Mertes Slough heronry consists mainly of great blue herons, but is home to great egrets as well. This heronry is of interest to wildlife managers and ornithologists alike because it is the only remaining heronry in the Winona area (Faber 1998, Nelson 2003). Other nesting colonies in the vicinity have been abandoned or reduced to a few pairs of breeding birds (table 1). What caused the abandonment of the other colonies is not known but the loss does raise concern about what the contributing factors might be. Monitoring the health of the Mertes

Table 1. Record of decline for abandoned heron rookeries in the Winona area. Data provided by the FWS.

Colony Name	River Mile Marker Location	Last Nesting Count (# nests)	Last Year Active
Nelson Trevino	761	34	1996
Zumbro River	750.8	172	1995
Witman	737	5	1996

Slough heronry will help wildlife managers better protect vital habitat for these migratory species and may lead to clues about the health of the surrounding habitat. Although the heronry is not easily accessible by foot, it attracts increasing numbers of observers by boat. Since this rookery is one of few remaining in the area, and the birds are sensitive to disturbances, the increasing number of visitors is a concern.

Combining nesting data into a Geographic Information System, the nesting behaviors of the herons and egrets can be analyzed and patterns can be identified in relation to the canoe path that meanders through the colony. Having a record of each nesting tree allows for spatial analysis of results and trends. Objectives for this study were; to create a Geographic Information System (GIS) database of past nesting count data, to provide a description of the heronry, to aid in monitoring the heronry, to identify nesting density hotspots, and to assess the affects of increasing canoe traffic through the heronry on nesting site selection.

Species Background

The great blue heron, *Ardea herodias*, is found in North America from coast to coast, and from Canada to the Gulf of Mexico. This regal bird stands 39-52 inches tall, and has a wingspan of six to seven feet. The great egret, *Ardea alba* (frequently placed in the genus *Casmerodius*) is smaller, standing 35-41 inches tall. The great blue heron and the great egret belong to the order Ciconiiforme, which are wading birds that have long legs, necks and bills. The great blue heron and the great egret, belong to the family Ardeidae, which includes herons, egrets, and bitterns. The fossil record of these extraordinary birds indicates that its genus *Ardea*, has been in existence for at least 14 million years, and has been virtually unchanged (Horton 1999). Of the 80 species of heron known to have existed through geologic time, 60 are still in existence (Horton 1999). The great blue heron is the largest and most widely distributed of the American herons. Throughout the northern range of their habitat, these birds are migratory; returning to their breeding ranges as early as February in some states, and they continue to return through March and April in the more northerly states. Southern species may remain year round. Migration flocks may grow to groups of 40 or more (Palmer 1962). The great blue heron and the great egret are found in many aquatic habitats; streams, rivers, lakes, reservoirs, forested and non-forested wetlands, prairie potholes, ditches, and backwaters. This heron can live in either fresh or saltwater aquatic habitats. Most nesting colonies are found along major

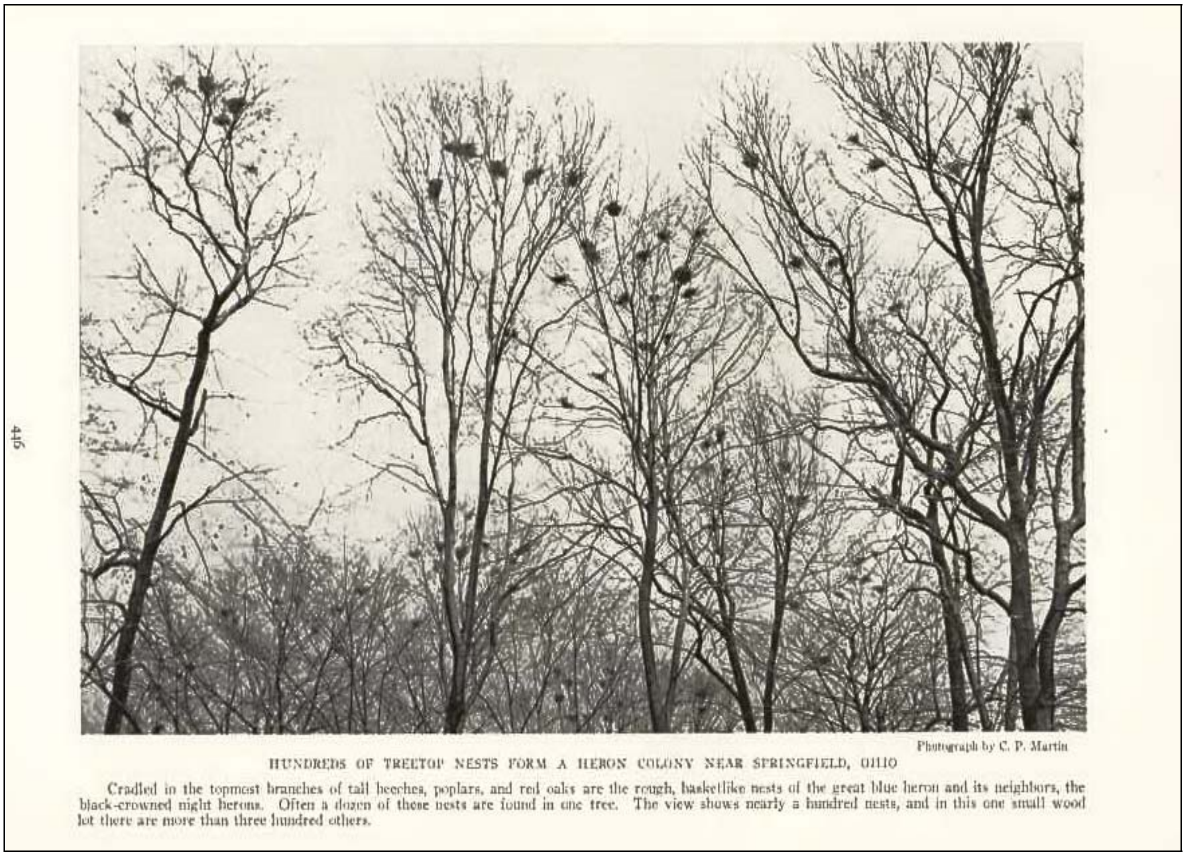

Figure 1. Herons and egrets prefer to nest communally. Photo of a heronry in Ohio from the October 1932 issue of National Geographic, National Geographic Society, Washington D.C.

rivers, nesting in bottomland forest habitat. The principle food of herons and egrets is fish, however, they will eat a wide range of prey. It is suggested that these species will feed on anything they can swallow including, frogs, salamanders, mudpuppies, tadpoles, crustaceans, insects, snakes, and even small rodents. The great blue heron feeds solitarily, and sometimes in groups. Feeding habitat seems to be the limiting factor for nesting selection and colony location has been correlated with the distribution of food resources and habitats (Custer *et al*. 1996).

The nesting sites chosen by these species in different portions of its range are varied; however, there are characteristics common to each of the species everywhere. Herons and egrets are social species, preferring to nest in colonies (Figure 1). The mixed colonies are usually inhabited by a combination of great blue herons, great egrets (*Ardea Alba*) and /or black crowned night herons (*Nycticorax nycticorax*). However, the colonies could contain any combination of these species or may also include; snowy egrets (*Egretta thula*), little blue herons (*E. Caerulea*), tricolored herons (*E. Tricolor*), cattle egrets (*Bubulcus ibis*), white ibis (*Eudocimus albus*), glossy ibis (*Plegadis falcinellus*), or wood storks (*Mycteria americana*) (Spendlow *et al*. 1989). These colonies can vary from a few pairs of birds, to several hundreds (Bent 1926). The male selects the breeding territory, which frequently contains an old nest. This territory will be used for hostile and sexual displays, copulation, and nesting.

There are two main hypotheses about the benefits of colonial nesting. One hypothesis is that colonial nesting is a means of exploiting near by resources more efficiently. The benefits of prey exploitation depend on the patchiness and predictability of the prey. High prey density areas are favorable areas for colonies; this provides shorter travel distance to areas of abundant food sources. Also, there may be increased feeding efficiency that is facilitated by social foraging behaviors (Kopachena 1991). Another benefit of colonial nesting is thought to be an anti-predator adaptation (Forbes 1989). Group vigilance is an anti-predator benefit. When the colony is alerted of a predator, the others may have the chance to cover and protect their nests. Even in the absence of the adults, alarm calls of other colony members cause a response in the young. The nestlings will crouch down in the nest and become still and less conspicuous to predators. Also, by choosing inaccessible colony sites, predation is reduced. An established colony also might provide an informational benefit to a young or naive individual, by providing information about the suitability of a nesting site. Since colonies often shift sites in response to disturbances, an established colony shows that the site is suitable and has conditions favorable for heron feeding and reproduction (Forbes 1989). The net benefit of these advantages will result in favor of colonial nesting.

Nests sites are usually chosen in trees, and usually of the highest location possible. The great egret shows preference for nest heights of slightly lower heights than those of the great blue heron. However, herons and egrets will occasionally nest in low trees, bushes, or even on the ground. Nests are slightly hollow large flat platforms of sticks and twigs. Egrets' nests are similar to that of the great blue heron but are usually not as well made (Bent 1926). Herons and egrets may select nests left from previous years to build and nest upon or they may build an entirely new nest. Nests may vary from 25 to 40 inches in diameter (Bent 1926). Breeding takes place during the months of March through May in its northern range, and November through April in the Southern Hemisphere. After the breeding season, dispersal will occur and a southward migration will follow for much of the United States.

Herons and egrets select aquatic habitats that have clean non-polluted water and are good biological indicators for monitoring the quality of habitats, as their breeding parameters are sensitive to deterioration or contamination that might occur in their preferred habitats. Studies done on herons in the Northwestern United States show that organochlorine residues as well as polychlorinated biphenyls (PCBs) and DDE were found in most of the heron eggs collected. Six brains of great blue herons from Oregon were analyzed and residues of DDE and PCBs were detected in all six. Residues of nine other organochlorines were also detected at low levels (Fitzner et al.1988). Despite their presence, the residues of DDE and PCBs in eggs, tissue, and whole body samples, the levels were below mortality levels, or levels that would interfere with reproductive success. The presence of these chemicals however, may indicate decreased water quality and may be a clue to colony abandonment. Herons and egrets may also vacate a colony if they encounter too many disturbances, loss of food sources, or the deterioration of the rookery due to guanotrophy (Horton 1999).

Study Site History

Saint Mary's University owned Mertes Slough until the late 1980s. The United States Fish and Wildlife Service (FWS) had interest in obtaining the land so Saint Mary's University sold the land to the FWS with the stipulation that Saint Mary's would have perpetual access (Faber 1999). This area is still under ownership of the FWS and is used by Saint Mary's University staff and students for biological study. Both Saint Mary's University and the FWS currently monitors the nesting populations within the rookery and were the contributors of nesting counts for this study.

Nesting counts for the Mertes Slough heronry have been collected on and off since 1977 by either Saint Mary's University or the FWS. GPS points and 1999 nesting data recorded during this study were combined with past nesting counts for analyses of this rookery. Since years lacking tree identification numbers could not be spatially referenced, they were excluded from the GIS portion of this project, but included in the over all population information. Nesting counts for the years of; 1980, 1981, 1982, 1993, 1994, 1995, 1996, 1998 and 1999 include the actual tree identification numbers that can be given a geographic location for analysis. Having a record of each nesting tree allows for a geographic location to be associated with each tree, correlated with nest counts, and analyzed spatially.

Methods and Procedure

Data Collection

Beginning in March of 1999, fieldwork began for recording GPS locations of each nesting tree in the rookery. Since nesting counts for this heronry have been taken for many years, a numbering system for identifying nesting trees had previously been established. Two numbering systems are currently in place. Each observed nesting tree within the colony has been given an identification number by either Saint Mary's University, the United States Fish and Wildlife Service or both. Saint Mary's University initiated the tagging system using rectangular metal tags nailed to the tree. When the FWS began monitoring the area, they created a new numbering system using small round metal tags. Trees with Saint Mary's tags have in most cases, been given a FWS tag as well. As part of the fieldwork for this study, GPS points were recorded for all tagged trees found as well as those trees newly occupied by nesting pairs that had not yet been recorded. Trees in the colony that had nests in them and no ID tag were given sequential numbers following the last known tagged tree IDs. Approximately 448 trees within the study area have been recorded with either tags and/or GPS points, 310 of the 448 tree locations were recorded with a GPS unit. Some trees were not found due to lost tags and inability to find tags on fallen trees. In cases where a tree has both a Saint Mary's tag and a Fish and Wildlife tag, both have been recorded and correlated with a single GPS point. On occasions where a tree had multiple trunks, and separate id tags given for each trunk, one GPS point was taken and assigned to each ID number separately. When fallen nesting trees were located, a GPS point was still taken to allow for a location to be assigned to past nesting counts despite the loss of the tree for future nesting. A Trimble Geo-Explorer Model 1 was used for recording each tree position in the rookery. GPS points were differentially corrected using Trimble Pathfinder Office 1.1 and have an expected accuracy of 2-5 meters.

The study area is essentially an island during times of high water levels and could only be accessed by boat during the duration of this project's field research. A Mad River folding canoe was used to reach the rookery and to collect data because of its lightweight and ability to be carried and maneuvered by one person. The FWS hand drawn map (Figure 2) was used as a guide to locate trees in the colony, however, it proved to be inaccurate and was missing many trees that had been tagged, but were never recorded on the map.

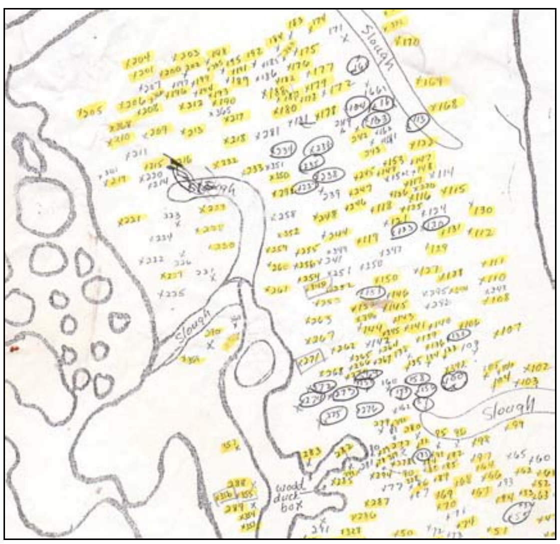

Figure 2. FWS Hand Drawn Map

Once a tree with a tag was located, the Trimble unit was used to record its position. Tree tag number, GPS file name, tree species, and the number of nests per tree were recorded (table 2). Tree species were primarily silver maple

Table 2. Example of data recorded

FWS Tag #	Old SMU tag # (if present)	GPS file #	Number of nests	Tree Species

(*Acer saccharinum*) and swamp white oak (*Quercus bicolor*). The GPS unit required in this study requires the signal connection to at least four satellites to give an accurate reading. On a clear day, recording a tree's position took approximately a minute, however, on cloudy or overcast days, it took an hour or more. The original study goals were to collect all GPS points and nest counts before birds started to lay eggs. However, flooding of the heronry created many obstacles that affected data collection and resulted in a longer data collection period than anticipated.

Data Compilation

All GPS points were correlated to their associated tree identification number. Excel files were created for all past nesting counts for each year and were then correlated with the GPS point location files in ESRI's ArcView Software. A master point shape file was created displaying all of the recorded trees in the heronry (Figures 3 & 4). When the tree GPS point layer was combined with the vegetation layer, it can be observed that most of the nesting territory lies in wooded terrestrial and shallow water areas. The heronry also is surrounded by sloughs and river channels contributing to the island effect and frequent flooding of the nesting site, making the area difficult to access. Each nesting year's data were queried to create new point shape files for each individual year.

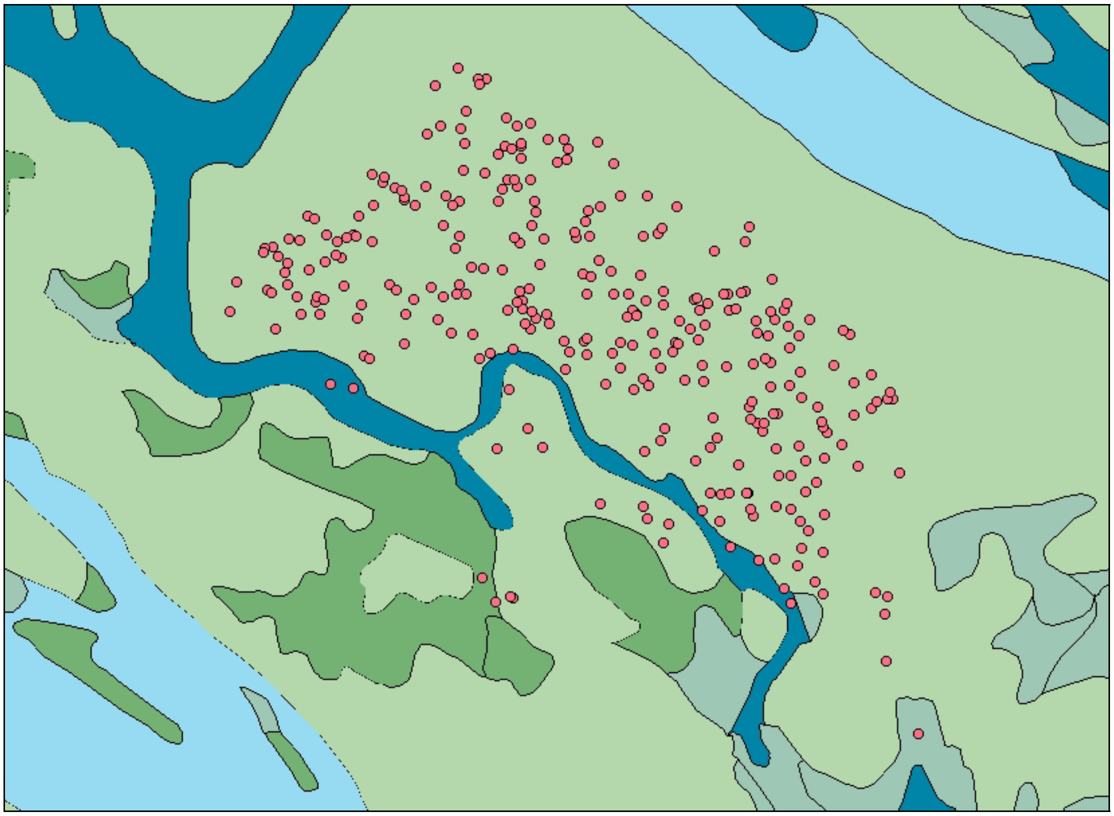

Figure 3. Newly created map of nesting tree

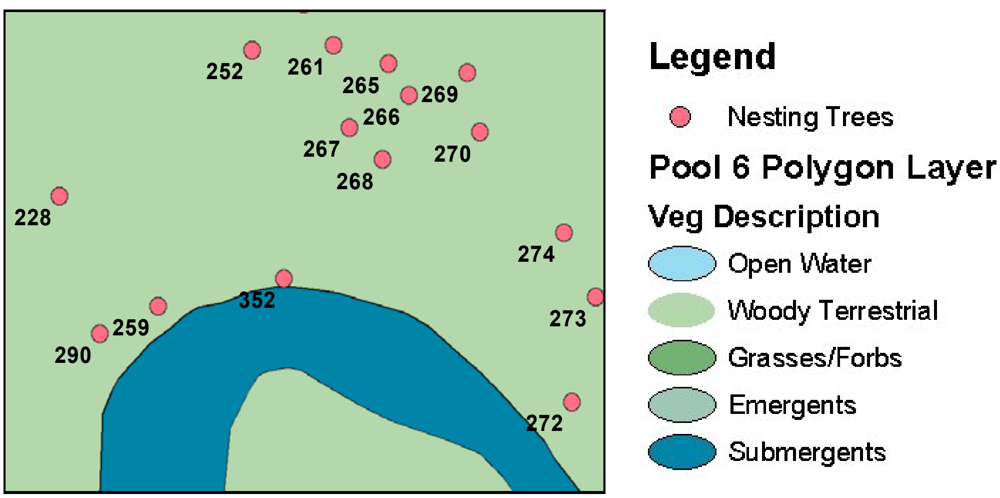

Figure 4. Nesting trees labeled with tag ID numbers.

Creating annual nesting tree inventories and maps allowed for comparison from year to year with in the heronry. Temporal changes within the heron colony can also be visualized. These shape files were later converted to coverages for density analysis in ESRI™ Spatial Analyst. GIS Software used to combine, create, and analyze maps inclded; ESRI™ ArcView 3.2, ArcInfo Workstation, ArcGis 8.2 and 8.3 including the extensions, Spatial Analyst and Geostatistical Analyst.

Results

With an accurate map of nesting trees in the heronry, nesting data can be correlated to a position within the colony and thus analyzed spatially. All nesting counts for trees with GPS positional points were sorted by year. Nesting numbers for the years of 1980-1983 remained consistent in numbers with an average of 283 nests and 81 trees per year. During the years of 1993-1996, the population tripled and showed an increase in overall numbers by 1996. Severe storms, tornadoes, straight-line winds in excess of 90 mph, heavy rains and hail swept across southeastern Minnesota during the spring and summer of 1998, resulting in the loss of thousands of trees (NOAA 2003). Many nesting trees and nests were lost and resulted in a drastic decline in population numbers recorded during and after 1998. 1999 showed an increase in population to approximately half of the pre-storm level (figure 5). Since 1999, the nest count has stabilized at approximately 400 nests per year or about half of its density prior to the storms in 1998 but more than twice the nest densities noted in the 1980s (figure 6 & table 3). Nest counts before 1980 as well as those for the year 2000 and beyond were obtained from the FWS but earth coordinates were not obtained for these years and hence data before 1980 and for 2000 and beyond are not further analyzed in this paper.

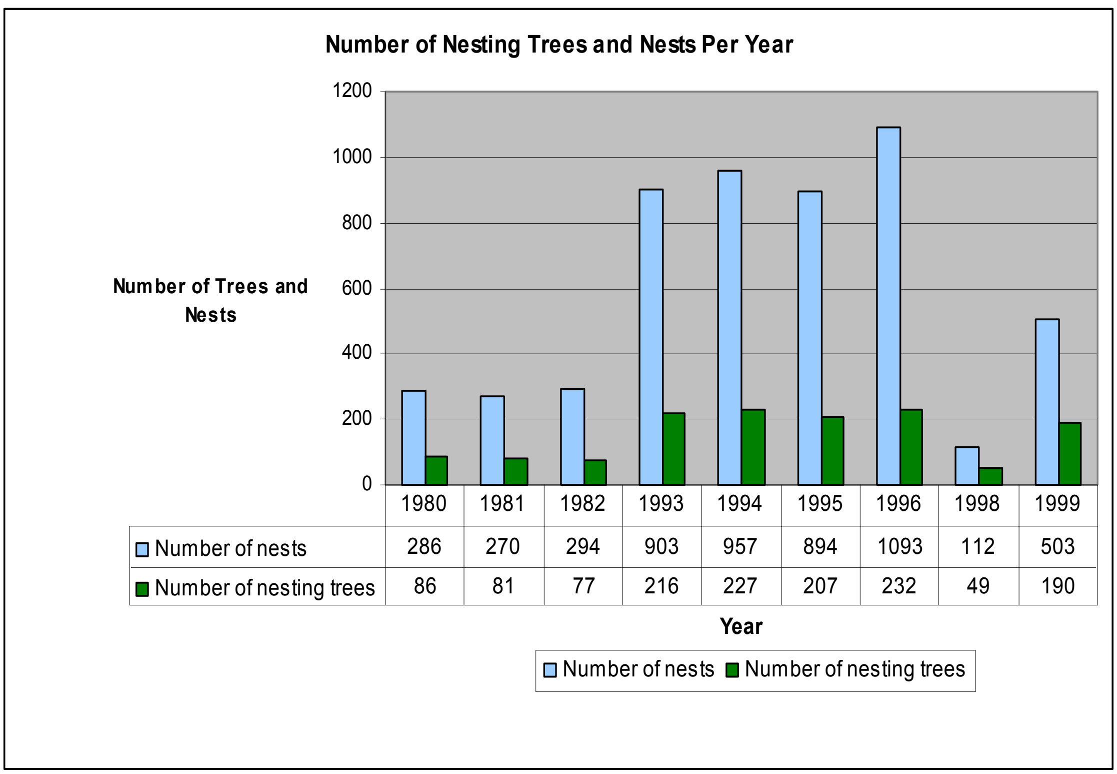

Figure 5. Totals for numbers of nests and nesting trees per year. *Storms in 1998 took down many nests and nesting trees resulting in low counts for that year.

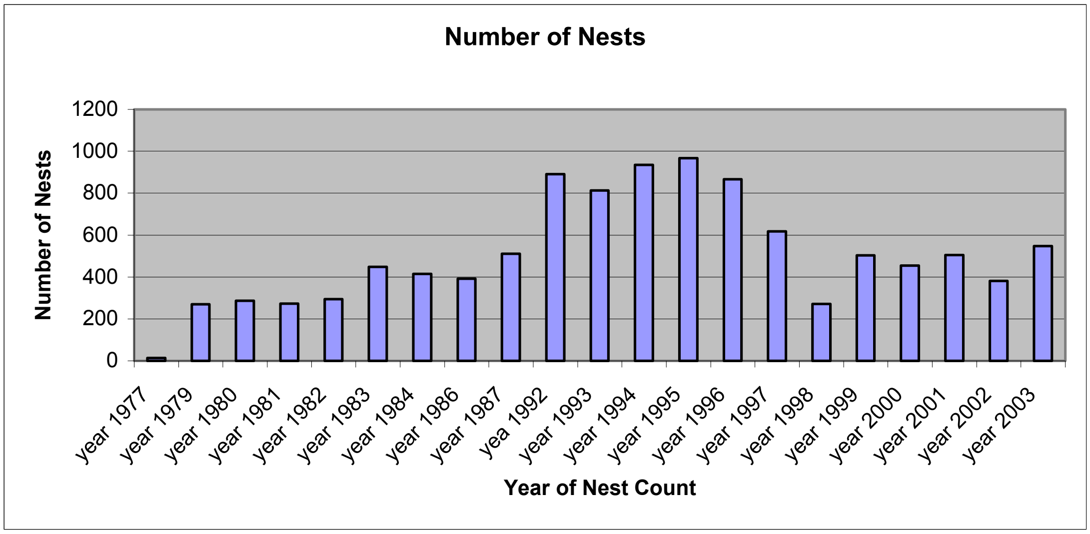

Figure 6 . Population graph for all years of data collected for the Merte's Slough Heronry.

Table 3. Population numbers collected by Saint Mary's University and UFW for the years data was.

	Fish and Wildlife Nest Data	**SMU Nest Data**	**Ave. of two years**
Year	Number of Nests	Number of Nests	Ave. number of nests
1977	13		
1978			
1979	270		
1980	287	286	286.5
1981	277	270	273.5
1982		294	
1983	449		
1984	415		
1985			
1986	392		
1987	511		
1988			
1989			
1990			
1991			
1992	891		
1993	723	903	813
1994	912	957	934.5
1995	1040	894	967
1996	639	1093	866
1997	618		
1998	430	112	271
1999		503	
2000	455		
2001	505		
2002	381		
2003	547		

Point files for each year's nesting tree locations were created to view the spatial overview of the heronry and how it has changed over the years. Four years are shown here for comparison (Figure 7). The Mertes Slough heronry is primarily expanding outward to the West and South West. The northeastern edge of the heronry remains static over time, suggesting a possible environmental boundary the birds may be sensitive to. There is also a railroad track to the north east of the heronry; this may be an explanation of the lack of expansion in that direction.

Locations of high nesting density were identified using ArcMap ArcInfo, and Spatial Analyst. A density map was made for each year to show nesting "hot spots" (Figure 8). Areas with dark centers represent the highest concentrations of nests. While identifying nesting hot spots, it was observed that areas of the highest nesting density remained consistent through out the years of 1993 through 1999. To display the consistency of density concentration locations over the years, contours of each year's density maps were created with Spatial Analyst, and

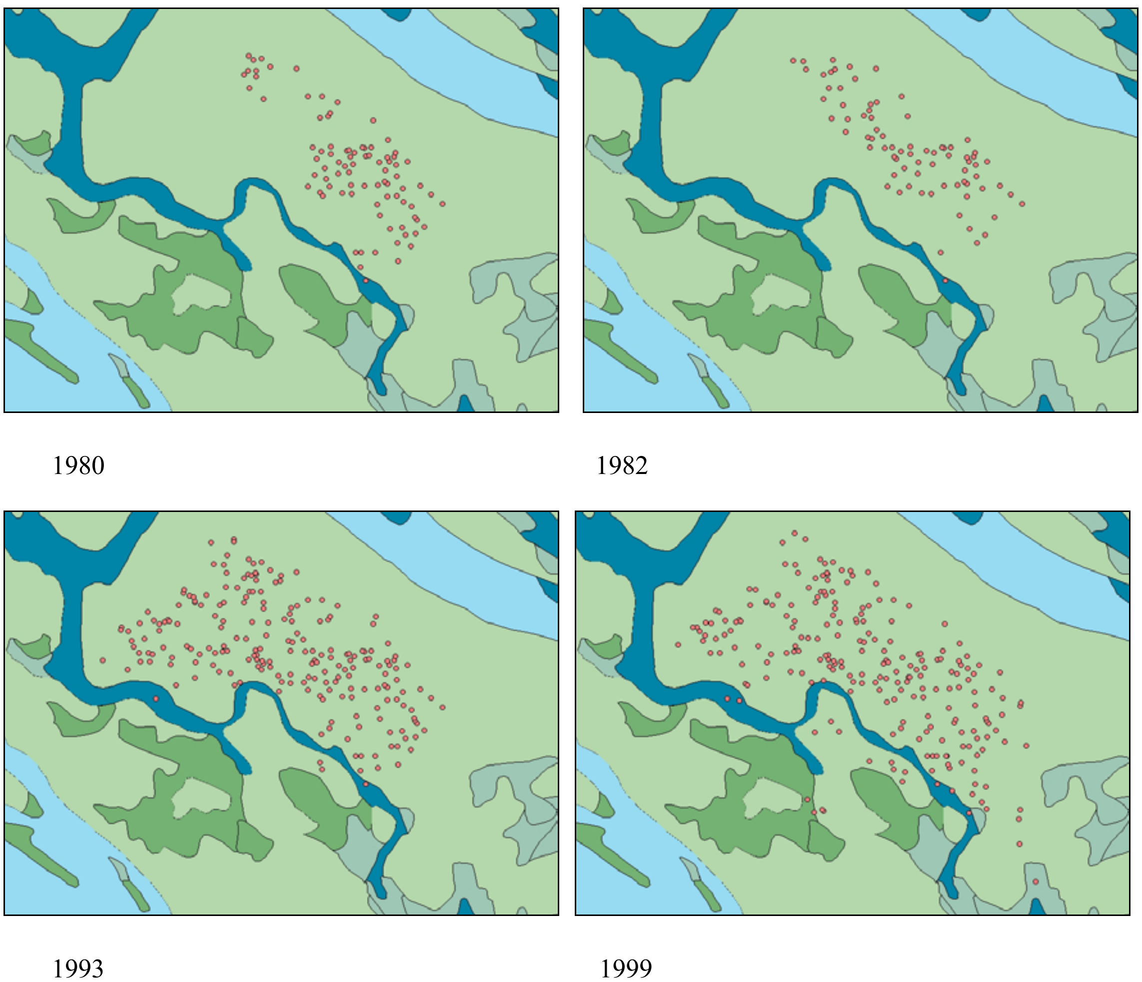

Figure 7. Point layer of nesting tree GPS locations for Mertes Slough Rookery for the years of 1980, 1982, 1993, and 1999.

layered to show the resulting overlapping image (Figure 9). The density map for 1993 and the density contours for 1996, and 1999 are shown overlapped for comparison. The arrows point out consistency of areas with high nesting density. Consistency in nesting site selection year after year may be evidence that herons and egrets are re-using existing nests, or that there may be optimal nesting conditions located in those sites such as; good nesting tree structure, optimal protection, or preferred tree species. What attracts the birds to nest in these sites is unknown however, by being able to visualize the density patterns, the conditions that exist in those locations can be investigated in future studies. Identifying the characteristics of these preferred areas may contribute to the protection and preservation of this rookery and others like it.

Due to concern about heron and egrets' sensitivity to disturbance, investigating the impact of increased canoe traffic through the slough was a main objective of this study. It was suspected that the birds are moving their nests away from the canoe path in response to boaters. Using GIS, the canoe path corridor was selected from the GIS vegetation coverage. Spatial buffers were created from this canoe route to create zones in incremental distances, moving away from the canoe path, from which nesting measurements could be made.

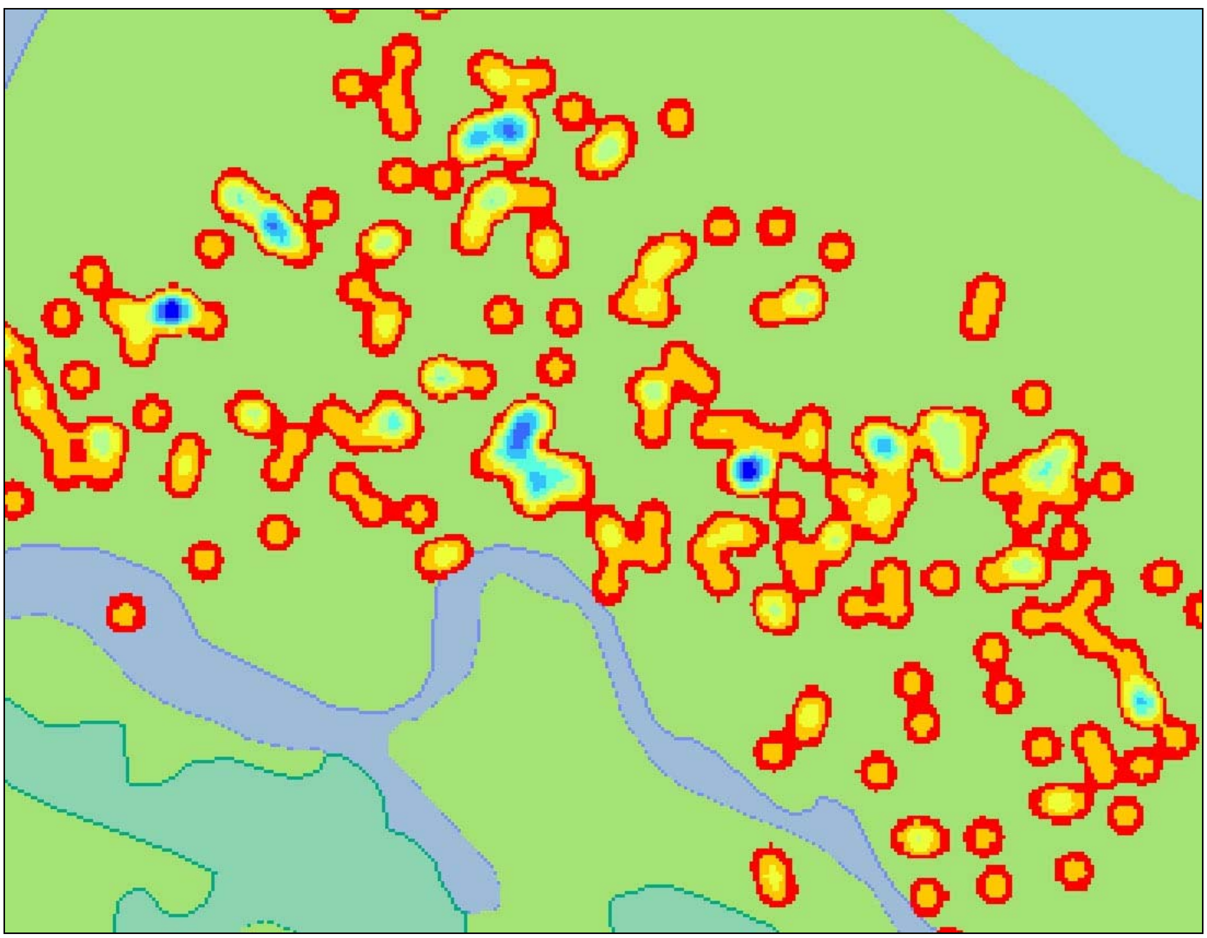

Figure 8. Density Map showing hotspots for the 1993 Nesting Count.
Areas with dark centers show highest nesting density.

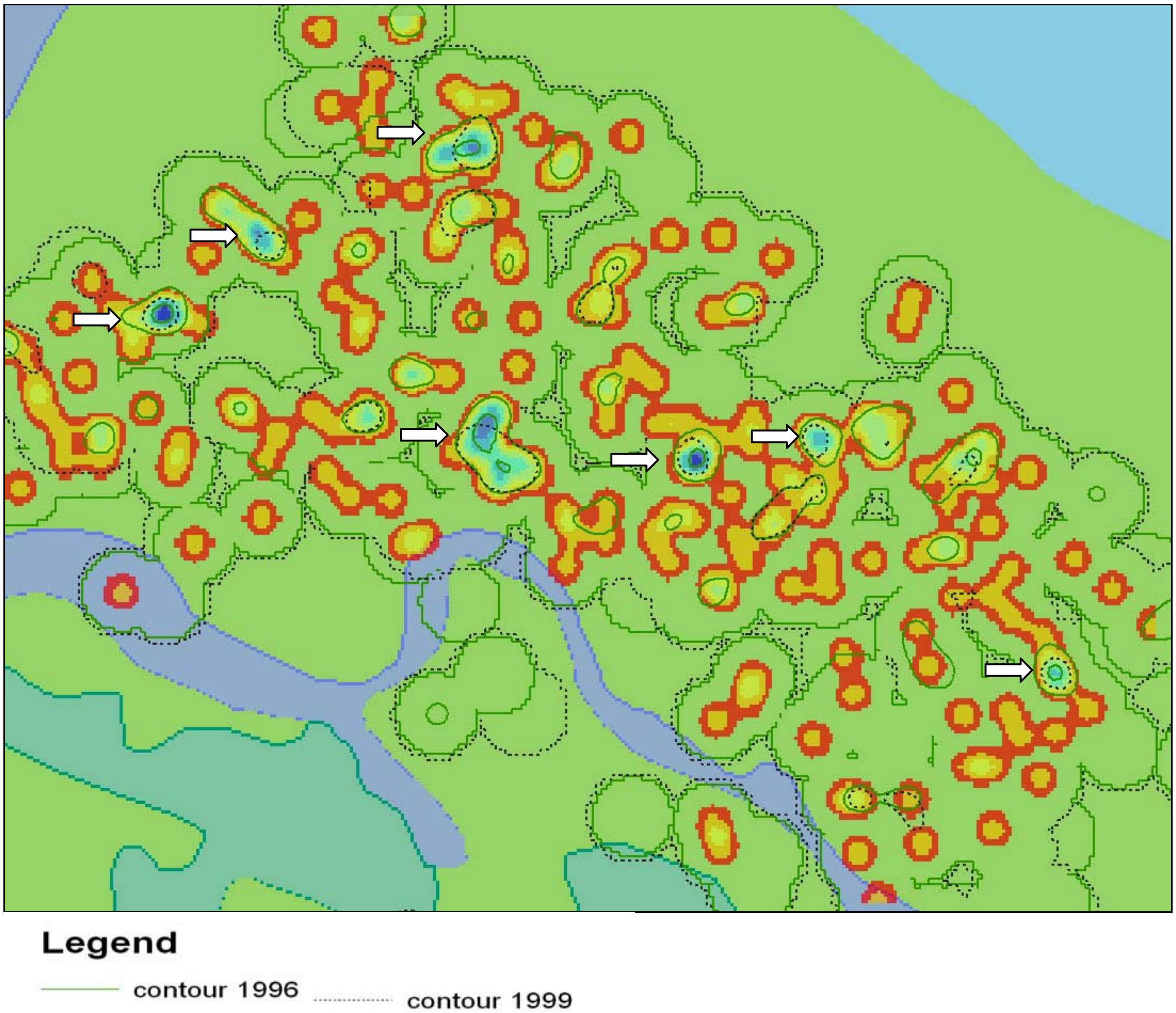

Figure 9. Density contours for the years of 1996 and 1999 are layered on top of 1993 nesting density map to display consistency over time in areas of large nest numbers

By using spatial buffers created in ArcInfo, the numbers of nesting trees and the number of nests at specified distances were identified and enumerated along with their spatial relationship to the canoe path. Isolating the selected nesting trees and nest numbers per year and per buffer zone, allowed for observation of nesting patterns in relation to the canoe corridor. To accomplish this, spatial buffers in increments of ten meters radiating outwards from the canoe path were created. The first buffer zone created included the canoe path and ten meters beyond. Four additional ten-meter buffer zones were then created from this original buffer zone (Figure 10). The number of nesting trees and the number of nests were identified within each buffer zone per year to determine if nest patterns over time indicate possible response to disturbance. Since there was such a large gap of missing nesting data for the years between 1982, and 1993, only the years 1993-1999 were used in this analysis.

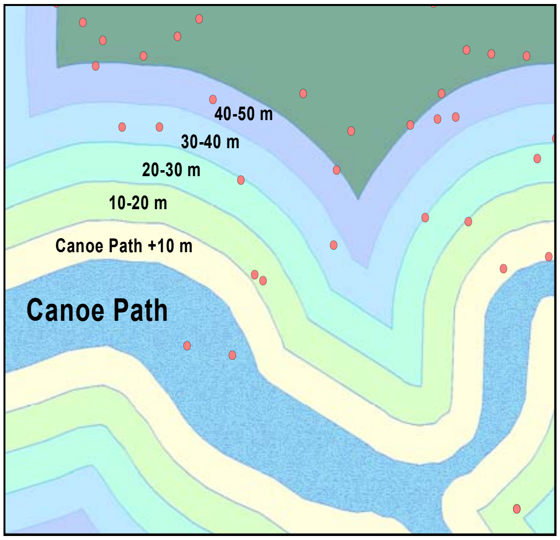

Figure (10). Spatial Buffers of Canoe Path and Nesting Tree Point Locations for the year 1999. Buffers zones are created at ten-meter intervals.

Descriptive Statistics

Zone Summary

Descriptive statistics indicated that the typical number of nests per year, per buffer zone for all years in the sample was about 30, and the typical number of nesting trees per year was about 12. Both variables showed considerable variation, as indicated by their standard deviations (table 4). In the sample, nests and nesting trees were more numerous in zones that were further from the canoe path. The number of nests peaked at 30-40 meters from the path, however, and the number of nesting trees peaked at about 20-30 meters (Figures 11-12). Both charts show an increase in nesting tree and nest numbers as their distance is farther from the canoe path. However, nesting trees and numbers of nests decline in the 40-50m range.

Descriptives by Year

The number of nests and of nesting trees fluctuated from year to year, and any clear trend was difficult to identify descriptively. Both variables decreased sharply in 1998, the year of multiple damaging storms, and increased the following year (Table 5).

Descriptives by Year and Zone

When divided by year and zone, the number of nests and nesting trees clustered in greater numbers at some distance from the canoe path, but declined at or before the 40-50 meter zone. Compared to number of nesting trees, the number of nests tended to peak at a greater distance from the canoe path. Thus, blue herons' nests were concentrated in fewer trees at greater distances from the path. The number of

Table 4. Descriptive Statistics per buffer zone for all years in sample. Ranges show min. and max. nest and nesting tree numbers.

	Path+ 10m	10-20m	20-30m	30-40m	40-50m
Nest Numbers					
Mean	13.17	32.67	40.67	47.5	24.5
Std.Dev.	6.765	13.171	17.455	22.088	12.865
Range of nest numbers	5-22	10-46	10-60	11-71	1-35
Nesting tree numbers					
Mean	7.5	12	16.17	14.5	11.17
Std.dev	2.881	3.633	5.845	5.128	5.269
Range of nesting tree numbers	4-11	6-16	6-23	5-19	1-16

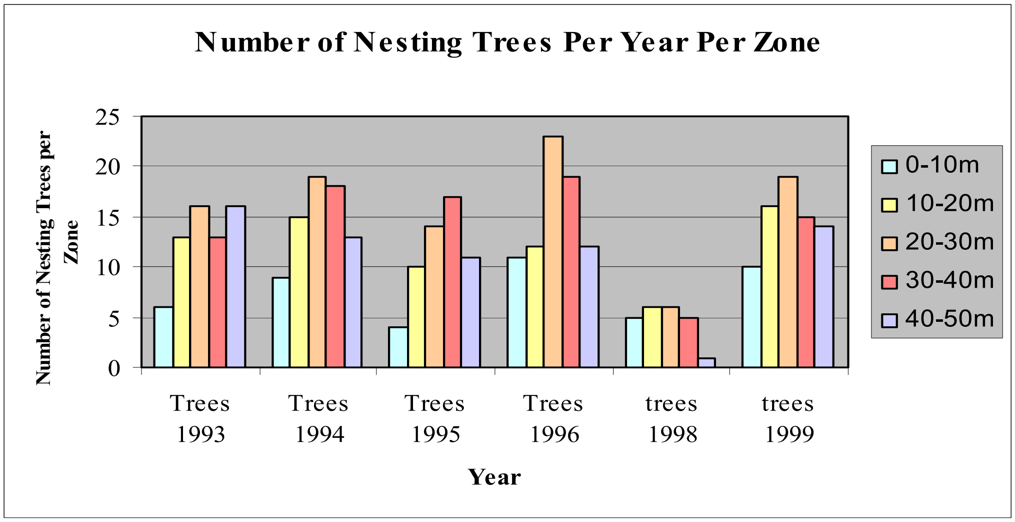

Figure 11. Display of Nesting Tree Counts per Buffer Zone.

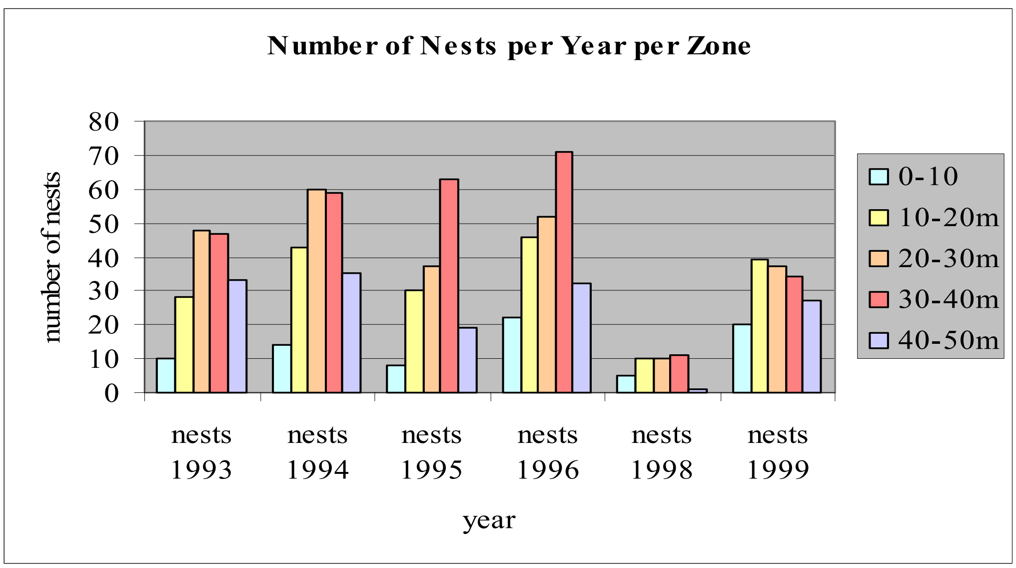

Figure 12. Display of Nest Counts per Buffer Zone

Table 5. Descriptive Statistics for Nests and Nesting Trees per Year Within Buffer Zones

	1993	1994	1995	1996	1998	1999
Nests						
Mean	33.2	42.2	31.4	44.6	7.4	31.4
Std.Dev.	15.611	19.018	20.816	18.863	4.278	7.829
Nesting Trees						
Mean	12.8	14.8	11.2	15.4	4.6	14.8
Std.Dev.	4.087	4.025	4.868	5.32	2.075	3.271

Table 6. Number of Nests and Nesting Trees per Year, per Zone

Nests	0-10	10-20m	20-30m	30-40m	40-50m	area outside of zones
year 1993	10	28	48	47	33	737
year 1994	14	43	60	59	35	746
year 1995	8	30	37	63	19	737
year 1996	22	46	52	71	32	870
year 1998	5	10	10	11	1	75
year 1999	20	39	37	34	27	346

Nesting Trees	0-10m	10-20m	20-30m	30-40m	40-50m	area outside of zones
year 1993	6	13	16	13	16	152
year 1994	9	15	19	18	13	153
year 1995	4	10	14	17	11	151
year 1996	11	12	23	19	12	155
year 1998	5	6	6	5	1	26
year 1999	10	16	19	15	14	116

nests outside of the zones is included with the zone nesting counts for trend comparison of the entire rookery (table 6).

Descriptive Statistics by Storm

Highly damaging storms in the summer of 1998 uprooted or damaged at least 23 tagged nesting trees within the heronry. Many known nesting trees were not found while collecting the trees' GPS points. These trees may have fallen during the storms and lost tags, or were submerged underwater at the time of the study. The loss of the 23 trees recorded as fallen, make up for the loss of an average of 61 nests per year. High winds may also have contributed to the loss of nests within the heronry. The number of nests and of nesting trees within buffer zones showed notable declines during the years of 1998 and 1999. Compared with means, standard deviations were larger after the storm. The increased variation reflected low initial numbers and a subsequent rebound in both nests and nesting trees. (Table 7).

Table 7. Descriptive Statistics of Nests and Nesting Trees with Storm Variable.

Nests	Before Storm	After Storm
Mean	37.85	19.4
Std.Dev.	18.088	13.978

Nesting trees	Before Storm	After Storm
Mean	13.55	9.7
Std.Dev.	4.559	5.964

Multivariate Analysis

Correlation and regression analysis were conducted between the variables, total nests, total nesting trees, year, buffer zone and storm to determine if predictive relationships existed between the variables. First, a correlation analysis was performed and it was found that highly significant correlation values existed between the total nests and total nesting trees, and between the total number of nests and storm (Table 8). From this, it can be concluded that there are highly significant predictive relationships between the number of trees and the total number of nests in the buffer zones. There is also a highly significant relationship between the number of nests in the buffer zone and before and after the 1998 summer storm event in the heronry. Minimal correlation relationships exist between total nests and buffer zones as do the number of trees and buffer zone. Following this, regression analyses were performed to determine the relationships amongst these variables. There was no significant regression relationship between the total number of nests and buffer zone. The best regression relationship existed between the number of nests and the number of nesting trees in the buffer zones. This produced an equation ($p < .001$) and $R^2 = .788$:

No. Nests = -6.921 + 3.148(No. Nesting Trees)

Addition of the storm variable added minimal additional explanation to the number of nests present in the buffer areas. Here R^2 was .817 and the regression equation was:

No. Nests = 5.47 + 2.921(No. Nesting Trees) – 7.203(Storm)

Discussion

Using Geographic Information Systems Technology, combined with fieldwork and statistics, spatial and behavioral nesting patterns were identified in the Mertes Slough Heron and Egret colony. Since 1977, the number of nests has increased from 13 nests, to a high population count of 1093 in 1996. Severe storms in 1998 resulted in the loss of many trees and nests, causing a dramatic dip in nest counts for 1998 (112) and 1999 (503). However, the years following the storm (1999-2003) have shown a positive rebound and are showing gradual growth.

Table 8. Correlation matrix between buffer zone (zone), year, total number of nests (nests), nesting trees (trees) and storm.

	Zone	Year	Nests	Trees	Storm
Zone	----	.000	.287	.267	.000
Year			-.319	-.202	.892**
Nests	----		----	.887**	-.471**
Trees	----		----	----	-.348

**Significant at the 0.01% error level

Overall, the heronry is expanding in size both temporally and in nest numbers and areas of high nesting density have remained consistent. Buffer zone analysis found when each year's data was analyzed independently, nests and nesting trees increased in number as they moved away from the canoe path for the first four zones, 0-40 meters. Nesting numbers declined at or before the 40-50 meter buffer zone. Compared to the number of nesting trees per buffer zone, the number of nests per zone tended to peak at a greater distance from the canoe path. The pattern of nest selection preferences in each zone can be clearly seen when the GPS points of nesting trees are displayed within the buffer zones, and in Excel charts as well. However, looking at the population trends per zone, over time, are not as easily detected visually. Despite seeing a clear trend in nest selection sites farther from the canoe path for each *individual* year in the buffer zones, over all as time progresses, nests in the entire heronry were found to be migrating in the direction of the canoe corridor. Since the birds are shifting their nesting territory towards the canoe path, there may be preferential environmental factors attracting them, or canoe traffic may be subsiding in recent years. Despite this trend of movement towards the canoe path over time, the birds are still showing sensitivity to nesting too close to the canoe corridor, as we see in the decrease of nest numbers per buffer zone closer to the canoe path. Levels of heron disturbance responses vary with the type of intrusion. Many studies have been conducted on the negative effects of human disturbance on reproductive success. Harassment may result in increased mortality of young while disturbances frighten adults from their nests. Eggs may get too hot or too cold, young may be prematurely frightened from their nests, nutrition intake is reduced due to regurgitation when frightened, and adults may abandon nests altogether (Vos, *et al.* 1985). When studying boat intrusions, Vos *et al.* observed that 92% of the birds in their study showed minimal response to boats passing by their nesting territory, while 8% temporarily left their nests. Boat intrusions that did invoke herons to leave their nests, were caused by canoes or slow moving boats close to nesting trees. Vos *et al*. observed that great blue herons reacted most to human disturbances early in the breeding season and were less easily disturbed once eggs were laid. However, their study also suggested that in some cases, the birds might have habituated to non-threatening intrusions. While making observations and collecting GPS points for this study, behaviors of the birds were similar to those findings of Vos *et al*. Early in the season, birds often left their nests and made vocal calls in response to the canoe passing underneath. As the season continued, the birds either habituated to the canoe's presence or were less responsive due to incubating duties. Taking data while in the canoe took longer than on foot so disturbance may have been greater simply due to the longer time it took to collect data, thus the more time a human was in the birds' territory. Collecting data on foot was often quicker, but the forest floor was littered with dead sticks, which made more noise. The noise of breaking sticks seemed to disturb the birds the most. Reactions from the birds included vocal responses, alighting from their nests, defecation and regurgitation.

Due to increasing visitors to the heronry, discoveries about the heron and egrets' nesting preferences in relation to the canoe path may help wildlife managers with decisions about how to manage the heronry's use and how to educate visitors entering the heronry. Wildlife enthusiasts exploring the colony by canoe may choose to do so during non-critical breeding and nesting times if they have knowledge that it disrupts the wildlife.

The data collected and compiled for this study open up seemingly endless possibilities for analysis. Point layer creation, density maps, and heron population data tables will be useful for future students and biologists to help monitor the heron and egret population's health, as well as that of the surrounding habitats. All data from this study will also assist the FWS in their goal to map and create GIS databases for all rookeries in the Upper Mississippi River National Wildlife and Fish Refuge.

Summary

Geogaphic Information Systems (GIS) were used to examine the nesting behaviors of great blue herons (*Ardea herodias*) and great egrets (*Ardea alba*) in the Mertes Slough area of Pool 6, Upper Mississippi River National Wildlife and Fish Refuge. Heron and egret nesting trees and nests were located by canoe and locations were recorded by the use of global positioning system (GPS) technologies. GPS coordinates were then correlated to past nesting studies by tree identification numbers, resulting in a timeline of spatial patterns for the rookery that could be analyzed to identify trends. Due to the concern for this heronry's status and the observation of increased canoe traffic, special attention was given to the explorations of nesting patterns in relation to a recreational canoe path that traverses through the heronry. This study's findings suggest that the heronry is expanding over time and in the direction of the canoe path, however, herons and egrets show preference for nesting sites in areas 20-30, and 30-40m from the canoe path.

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