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Use of a Landscape-Level Approach to Determine the Habitat Requirements of the Yellow-Crowned Night-Heron, Nycticorax violaceus, in the Lower Chesapeake Bay

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USE OF A LANDSCAPE-LEVEL APPROACH TO DETERMINE

THE HABITAT REQUIREMENTS OF THE

YELLOW-CROWNED NIGHT-HERON, *Nycticorax violaceus*,

IN THE LOWER CHESAPEAKE BAY
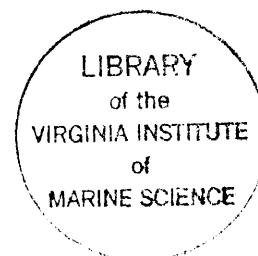
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A Thesis

Presented to

The Faculty of the School of Marine Science

The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

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by

Ellen L. Bentley

1994

This thesis is submitted in partial fulfillment of

the requirements for the degree of

Master of Arts
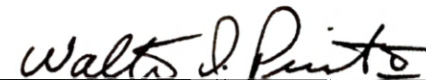
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ABSTRACT

A landscape level approach was employed to determine the habitat requirements of breeding Yellow-crowned Night-heron, *Nycticorax violaceus*. Yellow-crowns utilize wetlands for foraging and uplands for nesting. The objective of this study was to quantify the influence of within-patch and landscape-level variables on foraging and nest site selection patterns. The study site was a thirty-five mile section of the Lafayette River in the lower Chesapeake Bay. The landscape was quantified using NAPP 1:40,000 color infrared photography and ERDAS, a GIS software program. Visual surveys were conducted to locate nest sites in upland areas and marshes were observed by boat to estimate Yellow-crown use. A discriminant function analysis was utilized to distinguish nest site characteristics and a multiple regression analysis was employed to determine variables influential on bird use. Univariate regressions and ANOVA were also employed. The results suggest that Yellow-crowned Night-herons rely on mixed forest patches of loblolly pine and several deciduous tree for nesting. Foraging areas are located close to nesting sites. The marshes used preferentially had long shorelines and minimal internal area. The preferred combination of suitable nesting and foraging habitat for breeding Yellow-crown Night-herons in tidal portions of the Chesapeake Bay is described and the results demonstrate the importance of analyzing an entire ecosystem when developing a management plan.

USE OF A LANDSCAPE-LEVEL APPROACH TO DETERMINE

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INTRODUCTION

Traditionally, habitat studies have considered habitat patches to be discrete, homogeneous entities located within an ecologically, neutral landscape. Selection of foraging or nesting areas was attributed solely to characteristics of the individual patch. Variations in the surrounding landscape were not examined for their effects on use of the patch. Recently, the limitations of this approach for studies focusing on habitat selection and resource use have been identified (Turner 1990; Milne et al. 1989; O'Neill et al. 1988). It has become increasingly clear that the distribution of various organisms often cannot be understood from the processes occurring within separate habitat patches (Hansson 1992).

This realization has led ecologists to place a greater emphasis on the landscape which surrounds and encompasses habitat patches. This has resulted in the incorporation of landscape-level variables into the design of ecological studies. Landscape ecology addresses the relationship among landscape elements or patches within an overall mosaic and how such landscape structure influences a wide variety of ecological patterns and processes (Wiens and Milne 1989). Landscape-level studies focus on the effect of differences in the landscape mosaic to the flow of energy, resources, and organisms.

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A landscape-level approach is particularly important when a species requires two different resources at the same stage in the life cycle. A species may forage in one habitat type and nest in another. The resources are non-substitutable and travel between the resource patches is necessary if the species is to fulfill its needs. When this occurs at the landscape level it is defined as landscape complementation (Dunning et al. 1992). Landscapes that provide required habitat patches in close proximity may be preferentially selected and may support larger populations. A study by Petit (1989) demonstrated landscape complementation in the distribution of wintering woodland birds. Birds were shown to utilize one habitat type for roosting and a second for foraging. Only foraging patches that were in close proximity to roosting sites were utilized. Isolated habitat patches, although suitable were not selected.

Examining the processes of landscape complementation is of particular interest when addressing questions regarding wetland systems. Wetlands support a variety of vertebrate and invertebrate taxa. Many of these species require resources from both upland and wetland environments. The proximity of numerous types of wetland ecosystems to an equally diverse and numerous set of upland types provides an ideal environment for studying examples of landscape complementation.

Traditionally, studies of wetland habitats have been limited to the marshes within an aquatic system. These studies have formed the basis for

the assessment of wetland value. These values focus on and are limited to the view of a marsh as a discrete unit, rather than as a component of the landscape. This has resulted in a limited understanding of the importance of wetlands at the landscape level.

The value of a wetland as a component of a landscape has not been included in traditional wetland assessment models. However, several species rely on a specific arrangement of upland and wetland habitats. This has significance from a management standpoint because if a marsh scores low on standard wetland value criteria, it is at greater risk of being filled or altered. Therefore, the importance of wetlands as foraging sites for upland species should be included when assigning value to a wetland.

Although coastal and estuarine wetlands comprise only a small percentage of total land mass in the eastern United States, they support disproportionately high densities of birds with considerable species richness (Bildstein 1991). Coastal wetlands support a variety of species, but waterfowl, wading birds, shorebirds, gulls, and terns are the dominant residents.

Numbers and species diversity peak during migration and breeding periods. Marshes supply essential foraging habitat to migratory birds that must rest and replenish energy reserves during their long flights. Local avian populations increase considerably during the breeding season when wading birds congregate at traditional coastal-colony nesting sites (Bildstein 1991).

This congregation of wading birds, such as herons, makes them conspicuous and integral parts of wetland ecosystems in all but subpolar regions. They are dependent on aquatic resources not only for breeding success, but in most cases also in the off-season and during periods of dispersal and migration (Hancock and Elliot 1978). The dependence of herons on wetlands was well demonstrated when Jenni (1969) found that extensive wetlands are vital to the maintenance of the native heron population of central Florida. The positive correlation between wetland abundance and heron population numbers has been made by several researchers (Custer and Osborn 1978; Kushlan 1981; Jenni 1969; Gibbs et al. 1987).

In addition to their dependence on wetlands, herons often rely on woody vegetation for nesting. Therefore herons, unlike other wetland foragers, require both upland and wetland habitats during the breeding season. Several studies have been done to describe heron nest site characteristics along the Atlantic Coast (Jenni 1969; Custer and Osborn 1977; McCrimmon 1978; Beaver et al. 1980; Gibbs et al. 1987; Watts 1989), but few have attempted to determine if there were specific landscape patterns driving site selection.

The dependence of many herons on wetlands for foraging and uplands for nesting make them excellent species for investigating the relative influence of patch and landscape-level variables on site selection. Focusing

on a population of Yellow-crowned Night-herons in Virginia, the objectives of this study are to:

1) Determine the relative importance of within-marsh characteristics on patterns of marsh use by Yellow-crowned Night-herons.

2) Determine the relative influence of upland habitats on marsh use by Yellow-crowned Night-heron.

3) Determine the relative influence of upland habitats on the distribution of breeding Yellow-crowned Night-herons.

4) Determine the relative importance of marsh types and abundance on the distribution of breeding Yellow-crowned Night-herons.

YELLOW-CROWNED NIGHT-HERON NATURAL HISTORY

Distribution

The Yellow-crowned Night-heron, *Nycticorax violaceus,* is a member of the Family Ardeidae of the Order Ciconiiformes. The Yellow-crown has five distinct subspecies all of which occur in the New World. These subspecies are found in tropical to lower temperate zones and occasionally in arid areas on islands. They have been identified from the southern United States south through Central America and into northern South America. They are also found on certain islands in the Caribbean and in the South Pacific. The subspecies, *violaceus*, is found in the central and eastern United States south through Central America to Honduras. The subspecies, *violaceus*, is the subject of this study.

Ninety percent of the known populations of Yellow-crowned Night-herons in Virginia are found in the tidal areas of the lower Chesapeake Bay and its tributaries (Watts pers. comm.). This area is also known locally as lower Tidewater and includes several rivers and minor tributaries.

Foraging Ecology

The Yellow-crowned Night-heron utilizes a variety of wetland types for foraging including marshes, swamps, lakes, lagoons, and mangroves (AOU 1983). Yellow-crowns are primarily associated with coastal regions and

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islands, however, certain populations exploit freshwater wetlands (Hancock and Kushlan 1984).

Despite its name, the Yellow-crown forages actively throughout most of the day (Burleigh 1958; Herklots 1961; ffrench 1973; Kushlan 1978). Foraging generally takes place during low tide and therefore is constrained by tidal fluctuations in coastal regions (Hancock and Kushlan 1984; Watts 1988).

During low tide, Yellow-crowns may wade through exposed muddy basins and patches of intertidal vegetation, and occasionally forage in the surf on sandy beaches (Watts 1988). Riegner (1982), observed adult Yellow-crowns foraging in tide channels, tide-pool depressions, *Spartina* grass, and on mudflats. Laubhan et al. (1991) found that seasonally flooded emergent wetlands are important foraging sites for Yellow-crowns in Missouri.

The Yellow-crowned Night-heron was found to be the most sedentary forager of the seven heron species studied by Rodgers (1983), spending 80% of its time utilizing non-locomotory foraging behavior. Laubhan et al. (1991) determined that in the presence of adults, immature birds tended to forage less efficiently than when foraging alone.

The Yellow-crown is unique among the ardeids in that it specializes on crustacean prey (Bent 1926, Price 1946, Palmer 1962, Hancock and Elliott 1978; ffrench 1973; Harris 1974; Riegner 1982; Watts 1988). The species and genera of prey varies with geographic distribution. For example, crayfish,

Procambarus clarkii, are known to support Yellow-crowns feeding in freshwater wetlands of northeastern Louisiana (Niethammer and Kaiser 1983), land crabs, *Gecarcinus lateralis*, are taken in Bermuda (Wingate 1982), while fiddler crabs, *Uca spp.*, are the primary prey of Yellow-crowns in the lower Chesapeake Bay (Watts 1988).

Along the east coast of the U.S there are three species of fiddler crabs (*Uca minax*, *U. pugilator*, *U. pugnax*) that inhabit tidal marshes. Their distribution is determined by the substrate and salinity as food source is not considered a limiting factor (Teal 1958). Fiddler crab burrows are commonly reported in densities of 56-120 burrows/.25m^2 in *Spartina alterniflora* saltmarsh habitats (Bertness 1985). An associated study done during this project showed high burrow number variability within marshes with no significant difference between marsh types.

Nesting Ecology

Yellow-crowns nest as single pairs or in small colonies of 2 to 15 pairs (Parnell and Soots 1979; Watts 1989). It has been suggested by Wischusen (1979) that the low density of nests may reduce intraspecific nesting interference and may attract fewer ground predators.

Nest site selection is probably influenced regionally by both aerial and mammalian predation pressures. Nests are commonly found on the lower limb of the tree canopy on the outer half of the limb (Watts 1989; Laubhan and Reid 1991). The placement of the nests in the lower portion of the

canopy may provide a visual barrier to aerial predators. Aerial predation by crows (*Corvus brachyrhynchos* and *Corvus ossifragus*) is a significant factor for Yellow-crowns in Tidewater Virginia (Darden 1962; Watts 1989).

Pairs are also known to nest in separate trees. Locating nests in separate trees as well as on the end of branches may be a response to mammalian predation. Raccoons and opossums were responsible for 18.5% of all clutch losses and 38.0% of all young losses reported in residential areas in Tidewater Virginia (Darden, unpubl. data in Watts 1989). Yellow-crowned Night-herons in different geographic areas utilize different species of trees and shrubs for nesting. Nesting vegetation includes salt myrtle, *Baccharis halimifolia*, (Bagley and Grau 1979), hardwoods (Sutton 1967; Price 1946; Wischusen 1979; Laubhan and Reid 1991), and loblolly pine, *Pinus tadea* (Darden 1962, Watts 1989).

In a previous study done in the Tidewater Region of Virginia, it was shown that ninety-five percent of all Yellow-crown nests were found in 40- to 60-year-old loblolly pines *Pinus tadea*, while only four percent were found in hardwoods (Watts 1989). This almost complete use of pines for nesting has not been documented by workers outside the Chesapeake Bay region.

STUDY SITE

The study site is a thirty-five mile shoreline section of the Lafayette River in Norfolk, Virginia (Figure 1). The Lafayette is a major tributary of the Elizabeth River and is influenced by a microtidal regime. The main channel and the majority of the North and South Branches were included in this study. The upper portions of both branches were excluded because they were inaccessible at low tide.

Marshes

The marshes found along the Lafayette River are referred to by the number and type assigned to them in the Tidal Marsh Inventory for the City of Norfolk (Silberhorn and Priest 1987). The method used by Silberhorn and Priest (1987) defines marsh types according to the dominant species (50% or greater coverage) present within the marsh. The method defines twelve marsh types, however, only five are found along the Lafayette River (Figure 2).

The estuary system is dominated by saltmarsh cordgrass, *Spartina alterniflora*. These marshes are found with the brackish-water mixed marshes, primarily in the lower estuary. The heads of tributaries support most of the saltbush and common reed marshes. Saltbush marshes are dominated by the shrubs marsh elder, *Iva frutescens*,

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Figure 1. A map of the Lafayette River, Norfolk, Virginia.

Lafayette River Norfolk, Virginia
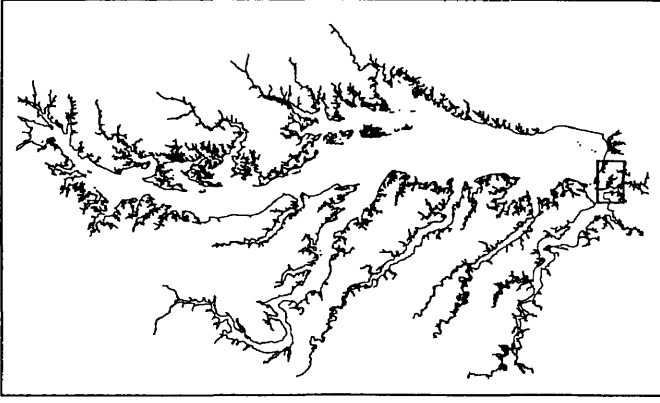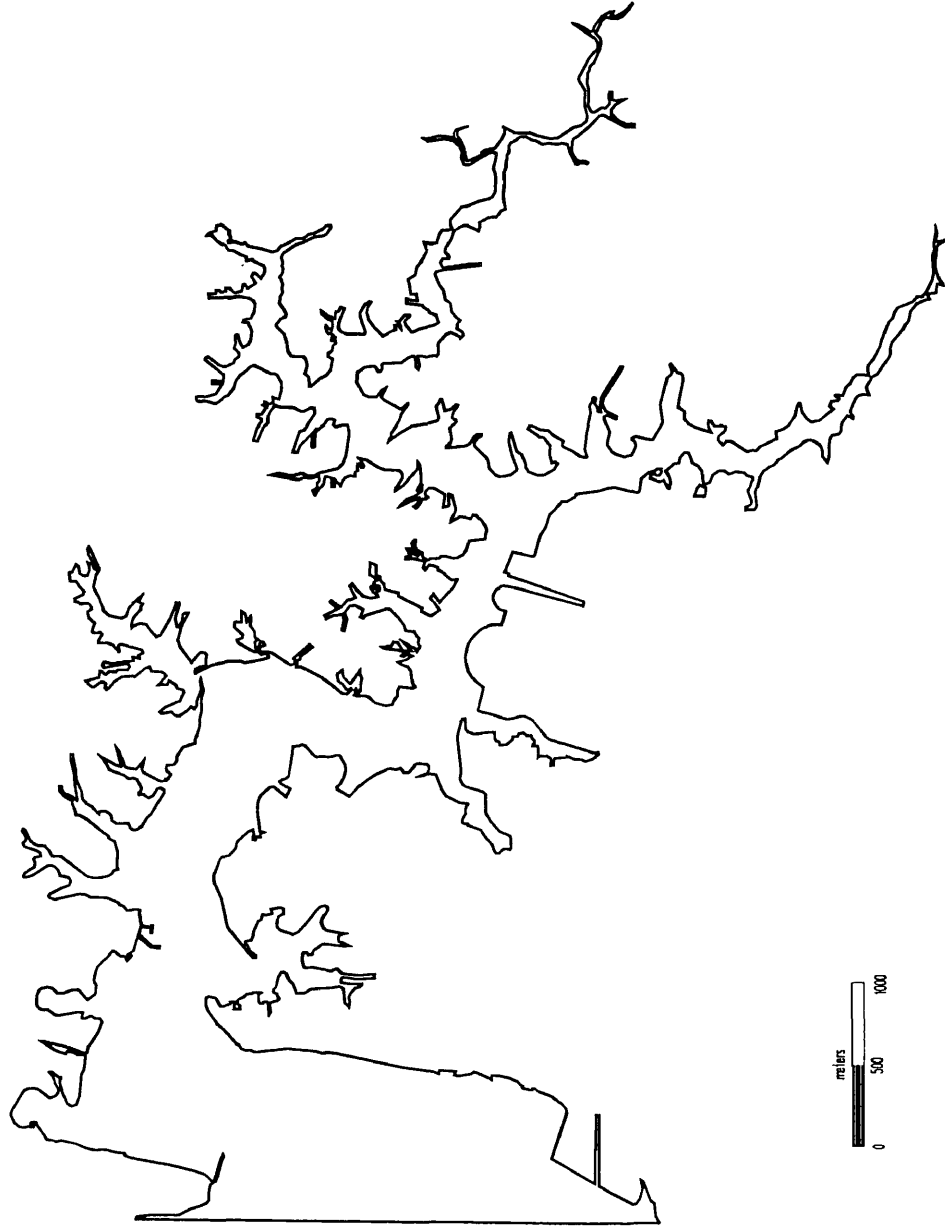
metres
0   500   1000

Figure 2. The Tidal Marshes of the Lafayette River, Norfolk Virginia.

Tidal Marshes of the Lafayette River

Spartina Marsh

Saltbush Marsh

Phragmites Marsh

Mixed-Brackish Marsh

Saltmeadow Marsh

46
47
146
71
73
105
119
126

meters

0   500   1000   1500
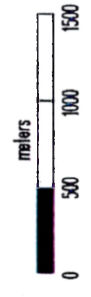
and groundsel tree, *Baccharis halimifloia*, while common reed marshes are dominated by *Phragmites australis*. The only saltmeadow marsh is made up of salt grass, *Distichlis spicata*, and saltmeadow hay, *Spartina patens*, and is located in the upper portion of the North branch.

Marshes vary in shape from long, thin fringe marshes to extensive island and cove marshes. The marshes vary in size from .25 acre to 35 acres. The presence of marshes throughout the estuary is not uniform since large portions of the river are devoid of marshes.

Uplands

The upland area surrounding the river is dominated by anthropogenic features such as housing developments and commercial industries. When present the dominate tree species are loblolly pine (*Pinus tadea*), live oak (*Quercus virginiana*), magnolia (*Magnolia grandiflora*), red maple (*Acer rubrum*), and sweet gum (*Liquidambar styraciflua*).

Industrial areas are almost entirely devoid of vegetation, but occasionally there are trees and planted grass in these areas. The housing developments vary widely in the percent cover and diversity of vegetation present. There are three basic types of tree communities that coincide with the housing developments. Type one neighborhoods typically have low housing densities (4 houses/acre), large patches (.25+ acres) of mature loblolly pine, and minimal area covered only by grass. Type two neighborhoods are dominated by deciduous trees and grassy areas, but have

similar housing densities as type one. Type three neighborhoods are defined by high housing densities (apartment complexes and condominiums), minimal open areas, and few trees.

Occupation History and Timing

Observations of Yellow-crowned Night-herons along the Lafayette River and throughout Norfolk were first documented by a resident of the area, Mrs. Darden, in 1947. Yellow-crowns nested in mature loblolly pine trees adjacent to the marsh creeks in her yard and on neighboring properties (Darden 1947). It has been suggested by Watts (pers. comm.) that the breeding population in this area has remained relatively stable at 50-60 pairs since 1946.

Yellow-crowned Night-herons return to the Lafayette River in mid-April to build nests. Clutches are generally complete in mid-May and incubation lasts approximately 37 days. Fledging lasts about 27 days and chicks are found foraging on their own in mid-July. Migration begins in late August and is over by early October.

METHODS

An analysis of foraging sites and nesting sites was undertaken for this study. Fieldwork was done to establish use patterns for foraging areas and to locate breeding sites. Variables describing the marsh and the surrounding landscape were measured to determine the effect of these variables on marsh use by Yellow-crowns. Variables describing the landscape surrounding nest sites and randomly chosen non-nest sites were used to determine the ability of these variables to separate nest and non-nest sites.

Extensive aerial photography interpretation and analysis was done to quantify landscape variables. This analysis was done using a Geographic Information System and ERDAS software.

Both univariate and multivariate statistical tests were used in the analysis. A SAS statistical package was selected for the analyses.

Field Methods

<u>Marsh Surveys</u>

Marsh sites were selected based on two criteria. First, they were included in the Tidal Marsh Inventory for the City of Norfolk (Silberhorn and Priest 1987). This was done so that accurate information on the vegetative composition of each marsh would be available. Second, the marsh was accessible at low tide by boat. There were 83 marshes along the Lafayette

River that satisfied both criteria.

Each marsh was surveyed a total of twelve times from May 13 through July 27. The dates and times of each survey are shown in Table 1. The surveys were done in seven hour blocks, 3 1/2 hours before and 3 1/2 hours after low tide. The starting point was alternated so that marshes were not always surveyed at the same relative point in the tidal cycle. Equal numbers of morning and evening surveys were conducted to vary the time of day that each marsh was surveyed.

Each marsh was surveyed using a 14 foot jon boat, to locate total number of Yellow-crowns foraging on the site. The boat was either driven slowly or rowed along the shoreline of each marsh while an observer counted foraging Yellow-crowns. The observer stood up in the boat to view the interior of extensive marshes.

When observed and counted each Yellow-crown was assigned to a category of adult, juvenile or immature based on its plumage. Adults displayed a mature plumage with all markings present. Juvenile plumage is described as devoid of immature markings, but not containing all adult markings. Immature birds showed a standard immature plumage of white base with brown flecking. The number of adult, juvenile, and immature birds foraging in each marsh was counted. The counts from each visit were

Table 1. Dates, times, and starting points of marsh surveys.

Date	Time	Starting Point
May 13	10:15-5:15	Norfolk Yacht and Country Club
May 18	1:25-8:25	Norfolk Yacht and Country Club
May 26	7:20-2:20	Lafayette Park
June 2	1:20-8:20	Lafayette Park
June 10	8:30-3:30	Lafayette Park
June 17	1:45-8:45	Norfolk Yacht and Country Club
June 24	6:45-1:45	Norfolk Yacht and Country Club
June 30	12:20-7:20	Lafayette Park
July 8	7:30-2:30	Norfolk Yacht and Country Club
July 14	12:20-7:20	Norfolk Yacht and Country Club
July 24	7:00-2:00	Lafayette Park
July 27	10:00-5:00	Lafayette Park

summed and used as an indicator of bird use.

<u>Location of Breeding Pairs</u>

Thirty nest sites with a total of 65 nests were located during walking and driving tours of the neighborhoods and woodlands surrounding the river (Figure 3). Some nest sites used in this study were located by researchers from the Center for Conservation Biology of the College of William and Mary. The location of the all nests were noted on field maps. Nests that were within 400ft of each other and were in an area of continuous canopy cover were considered to be part of the same nest site.

For comparison with nest sites, forty non-nest sites were randomly selected in upland areas throughout the estuary. For a description of the procedure used to establish non-nest sites see Appendix I. The locations of both nest and non-nest sites are shown in Figure 4.

Variable Measurements

The within-marsh and landscape-level variables for the foraging study and the landscape-level variables for the nest site study are shown in Table 3. The measurements for most within-marsh variables were taken directly from the Tidal Marsh Inventory for the City of Norfolk and are printed in italic. The within-marsh variables shoreline length, marsh/upland length, and total edge are shown in bold print. The landscape-level nest variables distance to marsh and distance to water are also shown in bold. The variables in bold print were measured from aerial photography that had

Figure 3. Locations and sizes of nest sites, Summer 1992.

Location and Size of Nest Sites

1-2 Nests ●

3-4 Nests ●

5-6 Nests ●

7 Nests ●

meters

0   500   1000   1500

Figure 4. Locations of nest sites and Random non-nest sites.

Nest and Non-Nest Sites

R10

R40

N1
N2
N3

N4

N5

R32

R29

R39
N6
N7
R35 N9
N8
R21
N10
R5
N11
N12
N10

R12

N19

N20
R13
R11

N18
R34

R1
N22 R6
R30
R23
N21

R9
R18 R15
R38

R4
R2
R7
N17
N14
N15
N16
N13

Lafayette River

N24
N25
R8 R31
N23
N26

R14
R19

R37 R16
R24
R27
R28
R33 R36

N30 N28 N27
N29
R20

R25
R22
R26

R3

R# - Random Non-Nest Sites

N# - Nest Sites

meters
0   500   1000
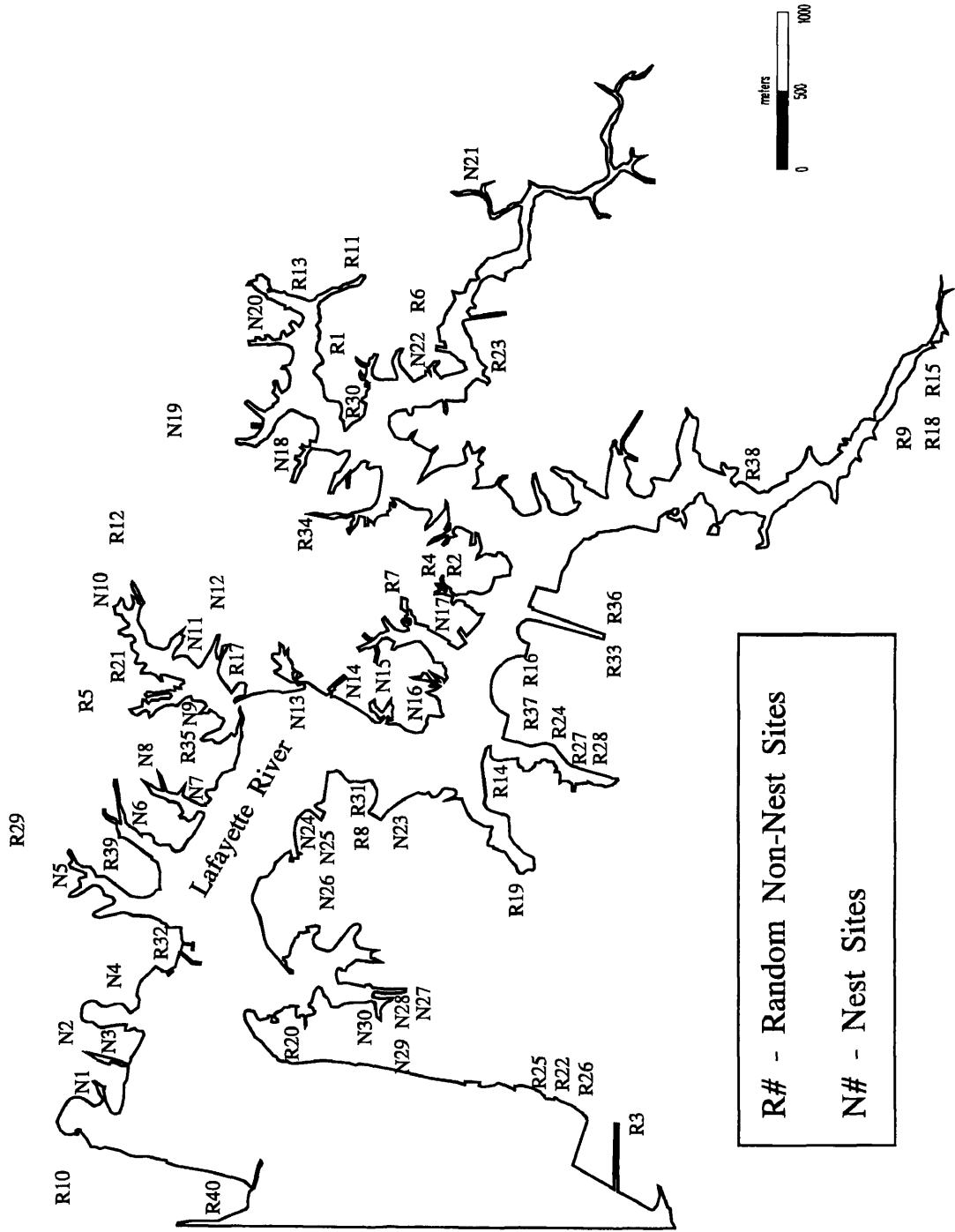
Table 3. Within-marsh and landscape-level variables.

Within-Marsh	Marsh Landscape	Nest Landscape
		Distance to Marsh
		Distance to Shoreline
Size	Number of Nests	Number of Nests
% S. alterniflora	% Marsh by Type	% Marsh by Type
% J. roemerianus	% Water	% Water
% Saltmeadow spp.	% Open Space	% Open Space
% Saltbush spp.	% Deciduous Tree	% Deciduous Tree
% P. australis	% Loblolly Pine	% Loblolly Pine
% High Marsh	% Tree Cover	% Tree Cover
Shoreline Length		
Marsh/Upland Length		
Total Edge		
Shape *		

been processed using ERDAS software (see Appendix II). The within-marsh variable shape, is the ratio of shoreline length to size.

All landscape variables were measured from processed photography using ERDAS software. The percentage of each landscape variable was quantified within three concentric regions surrounding a marsh or nest site (Figure 5). Distances were based on the size and structure of the river and observed flight patterns. Region 1 extends out 122 meters from the edge of the site. Region 2 is located between 122 and 244 meters of the site edge and regions 3 is located between 244 and approximately 488 meters of the site edge. The sum of each variable in regions 1 and 2, and in regions 1, 2, and 3 were included to determine if the accumulation of a variable with increasing distance from the site edge would influence Yellow-crown use (Figure 5).

For a description and list of all the variables for the marsh use analysis and the nest site analysis see Table 4 and Table 5, respectively.

Image Processing and Computer Analysis

The values for the landscape variables were taken from 1990 National Aerial Photography Program (NAPP) color infrared photography enlarged from a scale of 1:40,000 to a scale of 1:9600. A flow chart of the sequence of steps used to process the image is shown in Figure 6. See Appendix III for a detailed account of the ERDAS methodology.

Figure 5. Regions used in landscape analysis.
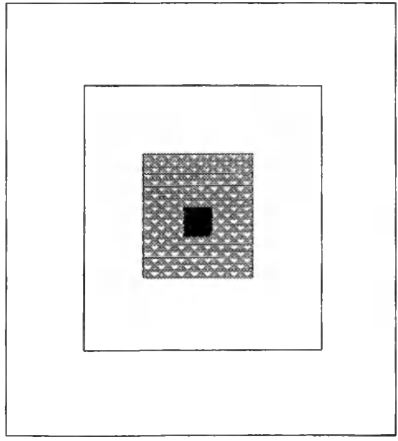
Region 1   Region 2   Region 3
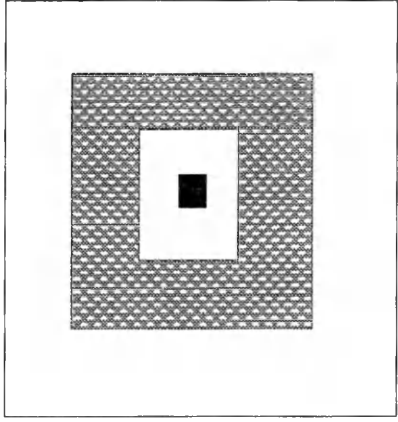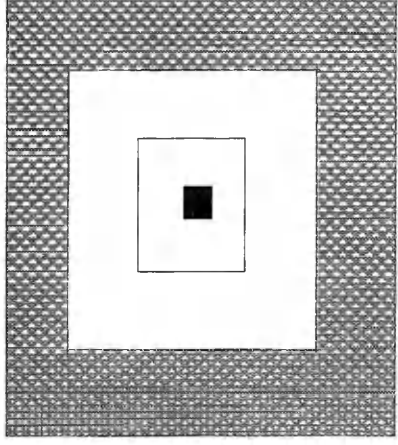
Regions 1 + 2   Regions 1 + 2 + 3

■ Site

▨ Area of Analysis
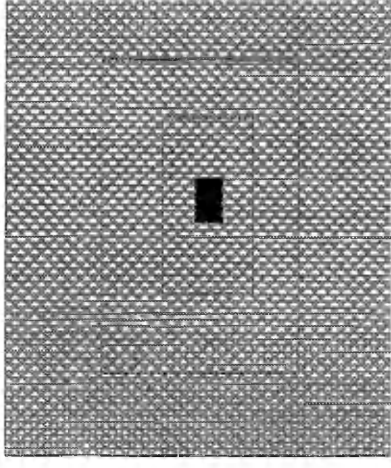
Table 3. Measured variables for foraging study.

<u>**Variable**</u>   <u>**Explanation**</u>

Within-Marsh Variables:

size	size in square meters
watmar	length of water/marsh margin in meters
marup	length of upland/marsh margin in meters
totedg	length of total edge of marsh (watmar + marup)
shape	estimate of shoreline length to size
sa	% *Spartina alterniflora* in marsh
jr	% *Juncus roemerianus* in marsh
md	% *Distichlis spicata,Spartina patens* in marsh
sb	% *Baccharis halimifolia,Iva frutescens* in marsh
sc	% *Spartina cynosuroides* in marsh
pa	% *Phragmites australis* in marsh
himarsh	% jr,md,sb,sc, and pa in marsh

Landscape-level Variables:
  Cumulative Variables:

nst1	# of nests in region 1
nst2	# of nests in regions 1 and 2
nst3	# of nests in regions 1, 2, and 3
sprat1	% *Spartina* marsh in region 1
sprat2	% *Spartina* marsh in regions 1 and 2
sprat3	% *Spartina* marsh in regions 1, 2, and 3
mbrat1	% mixed-brackish marsh in region 1
mbrat2	% mixed-brackish marsh in regions 1 and 2
mbrat3	% mixed-brackish marsh in regions 1, 2, and 3
sltrat1	% saltbush marsh in region 1
sltrat2	% saltbush marsh in regions 1 and 2
sltrat3	% saltbush marsh in regions 1, 2, and 3
phrrat1	% *Phragmites* marsh in region 1
phrrat2	% *Phragmites* marsh in regions 1 and 2
phrrat3	% *Phragmites* marsh in regions 1, 2, and 3
smhrat1	% saltmeadow marsh in region 1
smhrat2	% saltmeadow marsh in regions 1 and 2
smhrat3	% saltmeadow marsh in regions 1, 2, and 3
hmrat1	% high marsh in region 1
hmrat2	% high marsh in region 1 and 2
hmrat3	% high marsh in region 1, 2, and 3

Table 3. continued.

<u>**Variable**</u>   <u>**Explanation**</u>

Variable	Explanation
watrat1	% water in region 1
watrat2	% water in regions 1 and 2
watrat3	% water in regions 1, 2, and 3
opnrat1	% open space in region 1
opnrat2	% open space in regions 1 and 2
opnrat3	% open space in regions 1, 2, and 3
decrat1	% deciduous trees in region 1
decrat2	% deciduous trees in regions 1 and 2
decrat3	% deciduous trees in regions 1, 2, and 3
lobrat1	% loblolly pine in region 1
lobrat2	% loblolly pine in regions 1 and 2
lobrat3	% loblolly pine in regions 1, 2, and 3
forat1	decrat1 + lobrat1
forat2	decrat2 + lobrat2
forat3	decrat3 + lobrat3

Landscape-level Variables:

Single Region Variables:

Variable	Explanation
nss2	# of nests in region 2
nss3	# of nests in region 3
sps2	% *Spartina* marsh in region 2
sps3	% *Spartina* marsh in region 3
mbs2	% mixed-brackish marsh in region 2
mbs3	% mixed-brackish marsh in region 3
sls2	% saltbush marsh in region 2
sls3	% saltbush marsh in region 3
phs2	% *Phragmites* marsh in region 2
phs3	% *Phragmites* marsh in region 3
sms2	% saltmeadow marsh in region 2
sms3	% saltmeadow marsh in region 3
hms2	% high marsh in region 2
hms3	% high marsh in region 3
was2	% water in region 2
was3	% water in region 3
ops2	% open space in region 2
ops3	% open space in region 3
des2	% deciduous trees in region 2
des3	% deciduous trees in region 3
los2	% loblolly pine in region 2
los3	% loblolly pine in region 3
fos2	des2 + los2
fos3	des3 + los3

Table 4. Measured variables for nest site study.

Variable   Explanation
Landscape-level Variables:

dismar	distance to the nearest marsh in meters
diswat	distance to the nearest water in meters

Cumulative Variables:

nst1	# of nests in region 1
nst2	# of nests in regions 1 and 2
nst3	# of nests in regions 1, 2, and 3
sprat1	% *Spartina* marsh in region 1
sprat2	% *Spartina* marsh in regions 1 and 2
sprat3	% *Spartina* marsh in regions 1, 2, and 3
mbrat1	% mixed-brackish marsh in region 1
mbrat2	% mixed-brackish marsh in regions 1 and 2
mbrat3	% mixed-brackish marsh in regions 1, 2, and 3
sltrat1	% saltbush marsh in region 1
sltrat2	% saltbush marsh in regions 1 and 2
sltrat3	% saltbush marsh in regions 1, 2, and 3
phrrat1	% *Phragmites* marsh in region 1
phrrat2	% *Phragmites* marsh in regions 1 and 2
phrrat3	% *Phragmites* marsh in regions 1, 2, and 3
smhrat1	% saltmeadow marsh in region 1
smhrat2	% saltmeadow marsh in regions 1 and 2
smhrat3	% saltmeadow marsh in regions 1, 2, and 3
tmarsh1	% total marsh in region 1
tmarsh2	% total marsh in regions 1 and 2
tmarsh3	% total marsh in regions 1, 2, and 3
watrat1	% water in region 1
watrat2	% water in regions 1 and 2
watrat3	% water in regions 1, 2, and 3
opnrat1	% open space in region 1
opnrat2	% open space in regions 1 and 2
opnrat3	% open space in regions 1, 2, and 3
decrat1	% deciduous trees in region 1
decrat2	% deciduous trees in regions 1 and 2
decrat3	% deciduous trees in regions 1, 2, and 3
lobrat1	% loblolly pine in region 1
lobrat2	% loblolly pine in regions 1 and 2
lobrat3	% loblolly pine in regions 1, 2, and 3
forat1	decrat1 + lobrat1
forat2	decrat2 + lobrat2
forat3	decrat3 + lobrat3

Table 4. continued.

<u>**Variable**</u>   <u>**Explanation**</u>

Landscape Variables:
  Single Region Variables:

sps2	% *Spartina* marsh in region 2
sps3	% *Spartina* marsh in region 3
mbs2	% mixed-brackish marsh in region 2
mbs3	% mixed-brackish marsh in region 3
sls2	% saltbush marsh in region 2
sls3	% saltbush marsh in region 3
phs2	% *Phragmites* marsh in region 2
phs3	% *Phragmites* marsh in region 3
sms2	% saltmeadow marsh in region 2
sms3	% saltmeadow marsh in region 3
tsmar2	% total marsh in region 2
tsmar3	% total marsh in region 3
was2	% water in region 2
was3	% water in region 3
ops2	% open space in region 2
ops3	% open space in region 3
des2	% deciduous trees in region 2
des3	% deciduous trees in region 3
los2	% loblolly pine in region 2
los3	% loblolly pine in region 3
fos2	des2 + los2
fos3	des3 + los3
nss2	# of nests in region 2
nss3	# of nests in region 3

Figure 6. Flow chart of ERDAS methodology.

Aerial Photograph
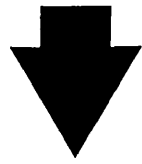
$\Downarrow$ Scan Photographs

Image File Created

$\Downarrow$ Rectify

Georeference

Georeferenced Image File
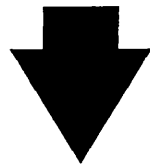
$\Downarrow$ Classification

Maxclas Isodata

Classified Image

$\Downarrow$ Stitch Images

Study Site Image

$\Downarrow$
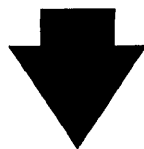
**Extract Information
Search/Summary**

Due to the size of the study area the photos were scanned five separate times. This created five distinct image files. Each image file was georeferenced to assign map coordinates and rectified to conform them to map projections.

An unsupervised classification method was employed for assigning class values to the landscape. After the image was classified each picture element, or pixel, was assigned to one of eleven classes. The classes include loblolly, deciduous, water, spartina, phragmites, mixed-brackish, saltbush, saltmeadow, roads, and man-made structures. Each class was color modified so that classification errors could be identified. Errors in classification were corrected manually.

Once classification was complete the five image files were stitched together so that information extraction could begin. Separate image files were created for each of the 83 marsh sites and 70 nest/non-nest sites. Percentages of each landscape variable within a region were calculated by dividing the number of pixels for each class by the total number of pixels in each region.

Statistical Analysis

The goal of this study is to determine which intrinsic and/or landscape factors effect habitat use by Yellow-crowned Night-Herons. To accomplish this, two multivariate designs were devised. One design explores the use of marshes and their surrounding landscape using a multiple regression analysis. The second design examines nest site landscape characteristics using a discriminant function analysis. In both designs, a univariate statistical approach precedes the multivariate test.

Univariate Statistical Approaches

<u>Foraging Study</u>

All measured variables (Table 3) were tested for normality by calculating the Shapiro-Wilk statistic and by plotting them against a normal curve. Variables that were not normal were transformed by taking the log (x), log(x + 1), or the sqrt(x) and were reevaluated for normality. If the transformed variable did not conform to normality it was removed from further analysis.

Each remaining variable was regressed against the transformed value of bird use. Bird use was transformed because heteroscedasticity was identified. The log(x + 1) was used to transform bird use.

Nest Site Study

All measured variables (Table 4) were tested for normality by

calculating the Shapiro-Wilk statistic and by plotting them against a normal

curve. Variables that were not normal were transformed using sqrt(x) and

log(x + 1) to attempt to establish normality. Each normal variable was

entered into a One-Way ANOVA by group, nest sites and non-nest sites.

The Wilcoxon 2-Sample Test, a non-parametric test, was used to test

variables that did not meet the parametric assumption of normality. This

was done to determine if there was a significant difference between the two

groups for a given variable.

Multivariate Statistical Approaches

Multiple Regression Analysis of Marsh Use

Variables that did not have significant F statistics in the univariate

regressions were not selected for use in the multiple regression analysis. In

addition, the variables pertaining to the % high marsh by region were not

included in the multiple regression because of limited sample sizes. A

correlation matrix consisting of the significant variables was created to test

for independence. Variables that exhibited independence were entered into

a stepwise multiple regression analysis. The percentage of loblolly pine in

regions 1 and 2 were included in the analysis despite their degree of

correlation because of the ecological significance of loblolly pines to nesting

Yellow-crowns as noted by Watts (1989). These variables were regressed

against the dependent variable bird use. A backward elimination stepwise multiple regression procedure was utilized for the analysis (SAS 1985).

Discriminant Function Analysis of Nest Sites

A correlation matrix was created for all normally distributed variables that were significantly different between groups. Variables that were highly correlated with other variables were removed from the analysis to avoid redundancy and to reduce the dimensionality of the analysis.

A backward elimination stepwise discriminant function procedure was utilized to determine which variables would contribute significant discriminating power to the analysis. A discriminant function procedure was run on the variables identified by the stepwise procedure. Since the data did not show homogeneity of within covariance matrices, the within covariance matrices were used to develop the quadratic discriminant function.

RESULTS

Foraging Results

Seasonality

A total of 930 Yellow-crowned Night-herons were observed over the course of the entire survey. Of this a total of 757 adult, 70 juvenile, and 103 immature birds were observed. The number of Yellow-crowned Night-Herons seen on each survey day is shown in Figure 7. Juvenile birds were observed foraging with adults 72 % of the time. Immature birds were seen foraging with adults 75 % of the time. However, immature birds were never observed foraging in the same marsh with juvenile birds. Birds of all life stages were seen foraging alone. In no case were Yellow-crowns foraging in close proximity to other Yellow-crowns or to other species. Yellow-crowns were generally seen foraging at least 5 meters from another bird.

There was an increase in the total number of birds seen per survey over time. Figure 7 also shows a breakdown of the total number of adult, juvenile, and immature birds for each survey. The highest total number of birds were seen on July 8 and the lowest total number of birds was seen on May 26. The number of adult birds range from 48 to 75, juvenile birds range from 0 to 14, and immature birds from 0 to 35. Adults were observed during the entire survey period. Juveniles were not observed until

34

Figure 7. Total number of Yellow-crowns foraging for each survey.

Number of Birds per Survey

Legend:
- Immatures
- Juveniles
- Adults

Y-axis: Number of Birds (0, 20, 40, 60, 80, 100, 120)

X-axis: Survey Dates — may13, may18, may26, jun2, jun10, jun17, jun24, jun30, jul8, jul14, jul24, jul27
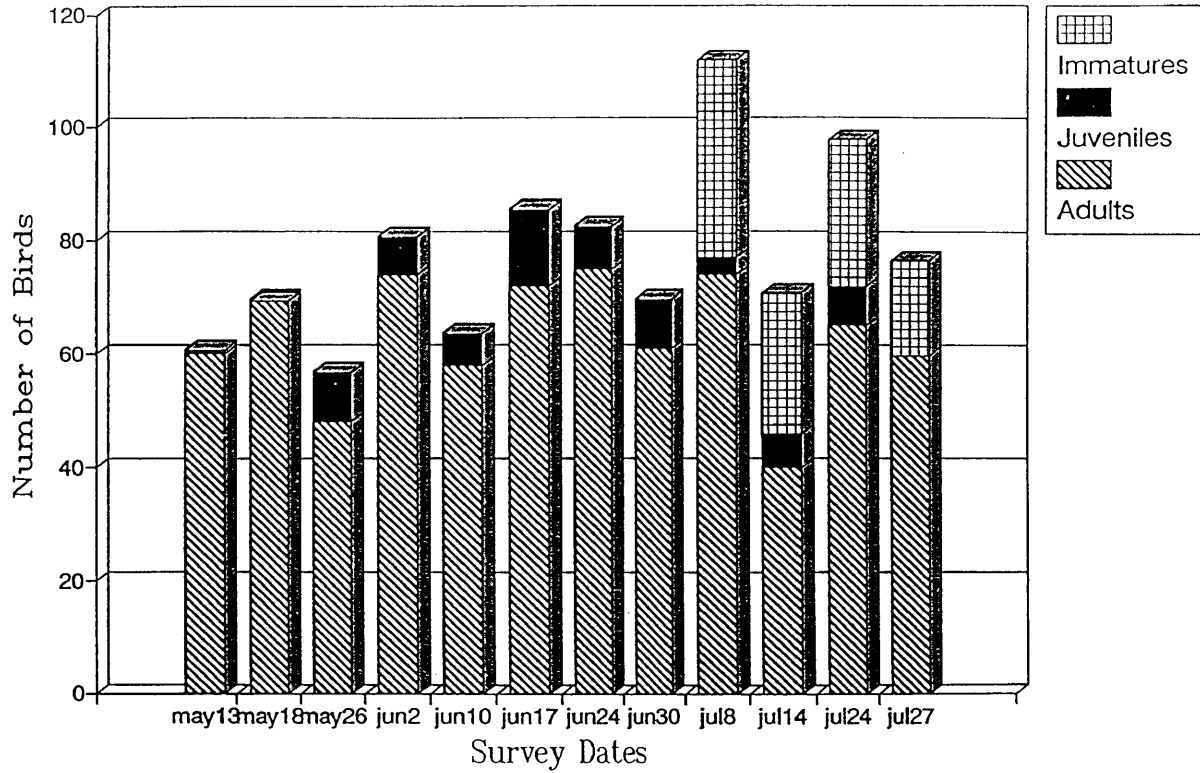
May 26 and immatures were not seen foraging until July 8.

The percentage of marshes used during each survey is shown in Figure 8. The percentage of marshes used range from 36% to 58%. There is an increase in the percentage of marshes used over time. During the first six surveys the average percent use was 44%. The average percent use increased to 52% during the last six surveys. This is a significant increase between the number of marshes used during the first six surveys and the number of marshes used in the last six surveys. There were only four marshes (47, 66, 93, and 146) that were used by Yellow-crowns during every survey.

Marsh Use

All birds were seen foraging within approximately 3 meters of the marsh edge, either in the interior of the marsh or on the mudflat. The sum of all weekly counts range from 0 to 66 Yellow-crowns per marsh. The three marshes with the highest total number of birds were marshes 146, 73, and 47 with total bird counts of 66, 59, and 48, respectively (Figure 2). The marshes in which no birds were seen are 105, 119, and 126.

The total number of adults range from 0 to 55 with the highest number of adults seen at marshes 146, 73, and 47. The total number of juveniles range from 0 to 9 with the highest number of juveniles seen at marshes 73 and 46. The total number of immatures range from 0 to 9. The marshes with the highest total counts of immatures are marshes 71, 73, and

Figure 8. Percentage of marshes used for each survey.

Percentage of Marshes
Used per Survey
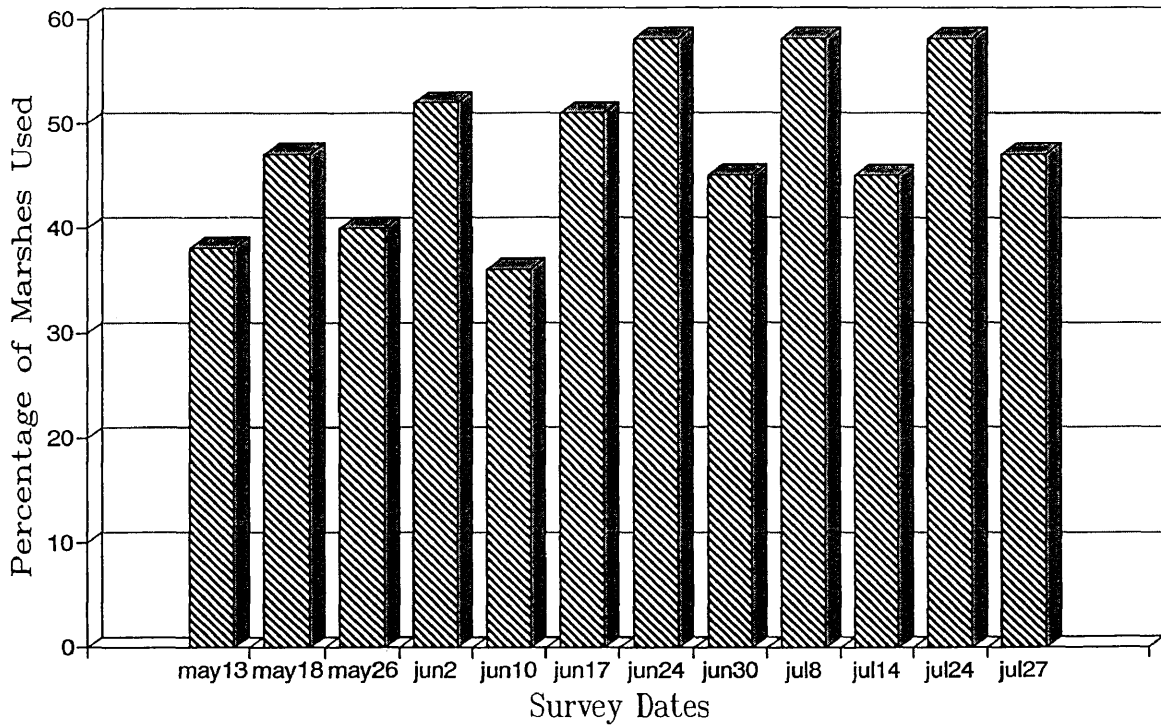
146 with counts of 9, 7, and 8 respectively.

Univariate Results

The results of all univariate analyses are shown in Appendix IV.

Regression equations for variables that were significant at a $p < .05$ alpha

level are shown in Appendix V. Regression plots, regression equations, and

r^2 values for the regression of bird use on the separate variables shoreline

length and total edge; shape; high marsh 1 and high marsh 2; high marsh

1 + 2 and high marsh 1-3; nest 1 + 2 and nest 1-3 are shown in Figures 9-

13, respectively.

There is a positive slope for the regressions of bird use on shoreline

length, total edge, nest 1 + 2, and nest 1-3. There is a negative slope for

the regressions of bird use on all high marsh variables.

Multiple Regression Analysis

The multiple regression analysis was conducted to assess the

influence of several independent variables on marsh use by Yellow-crowned

Night-herons. Based on the results of the univariate tests, seven

independent variables were selected to use in the multiple regression. The

variables selected are shoreline length, shape, % saltbush within the marsh,

number of nests in regions 1 and 2, number of nests in regions 1-3,

% loblolly pine in region 1, and % loblolly pine in region 2.

Figure 9.   Regression plots of log(x + 1) transformed values of bird use

on shoreline length and total edge.

Y = -0.074 + 0.408X
r^2 = 0.21, p < 0.001

Log [(# of Birds) + 1]

Log [(Marsh Shoreline in meters) + 1]

Y = -0.16 + 0.40X
r^2 = 0.16, p ≤ 0.001

Log [(# of Birds) + 1]

Log [(Length of Marsh Edge in meters) + 1]
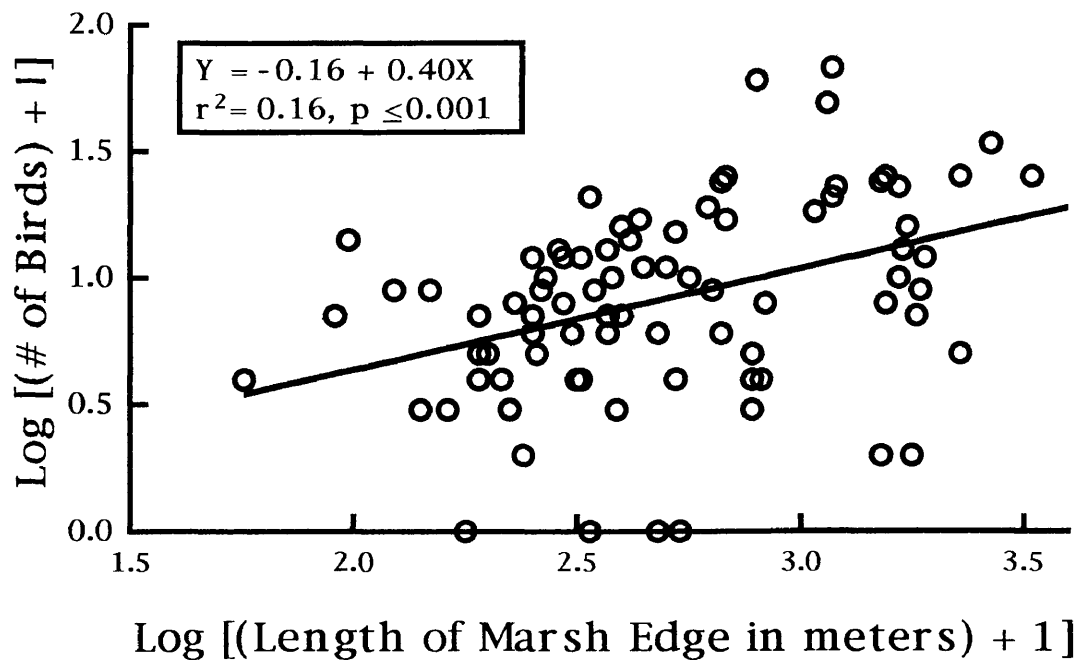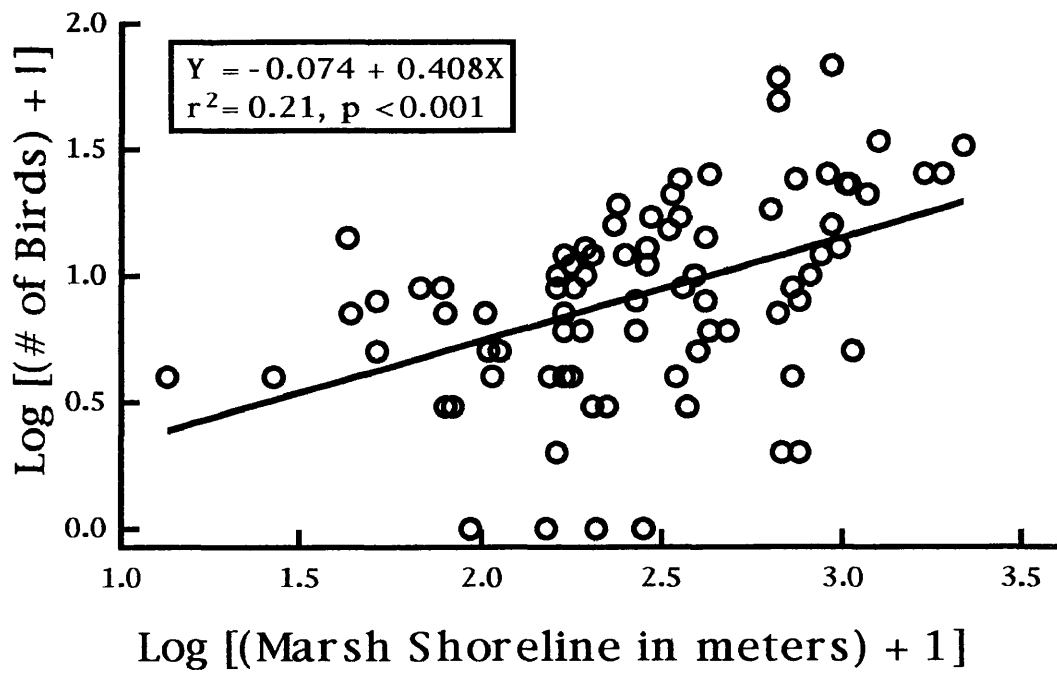
Figure 10. Regression plot of log(x + 1) transformed values of bird use

on shape.

Y = 0.05 + 0.24X
$r^2 = 0.11$, p < 0.01
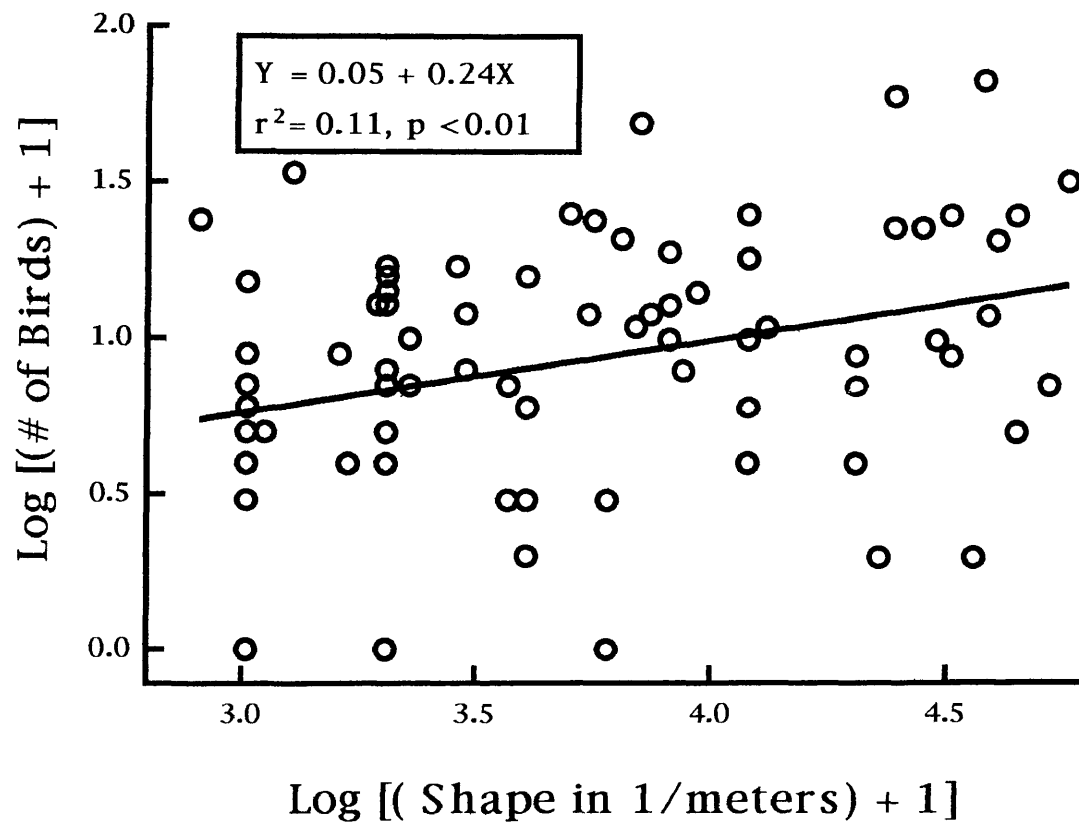
Figure 11. Regression plots of the log(x + 1) transformed value of bird use

on the log(x) transformed value of high marsh 1 and high

marsh 2.

Y = 0.97 - 0.43X
r^2 = 0.26, p < 0.05

Log [(# of Birds) + 1]

Log [% High Marsh in Region 1]

Y = 0.91 - 0.34X
r^2 = 0.40, p ≤ 0.001

Log [(# of Birds) + 1]

Log [% High Marsh in Region 2]
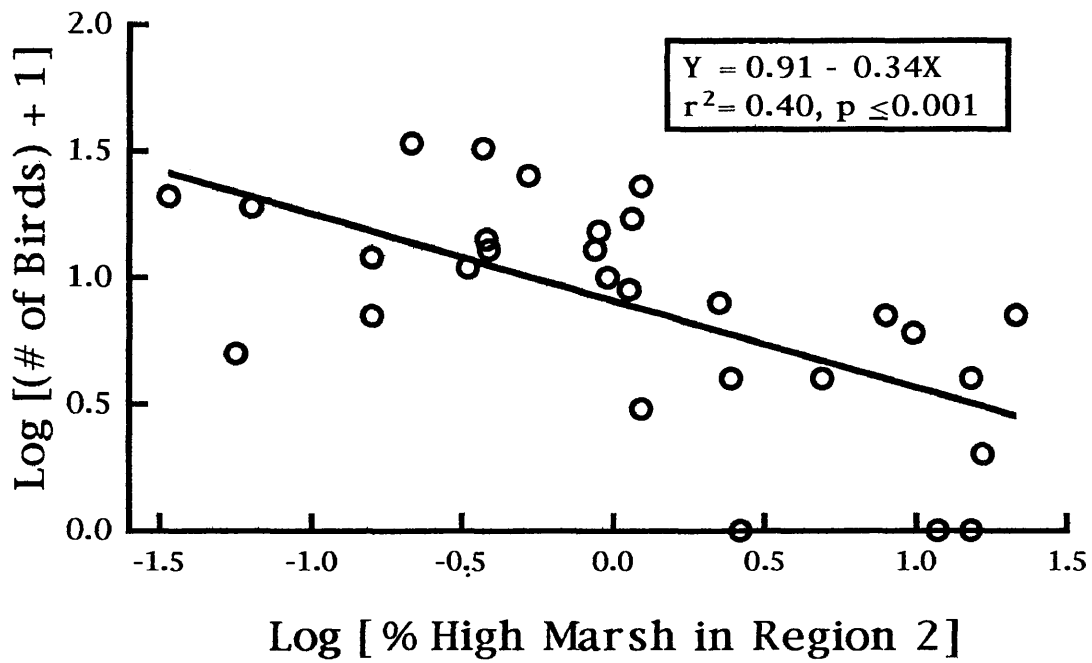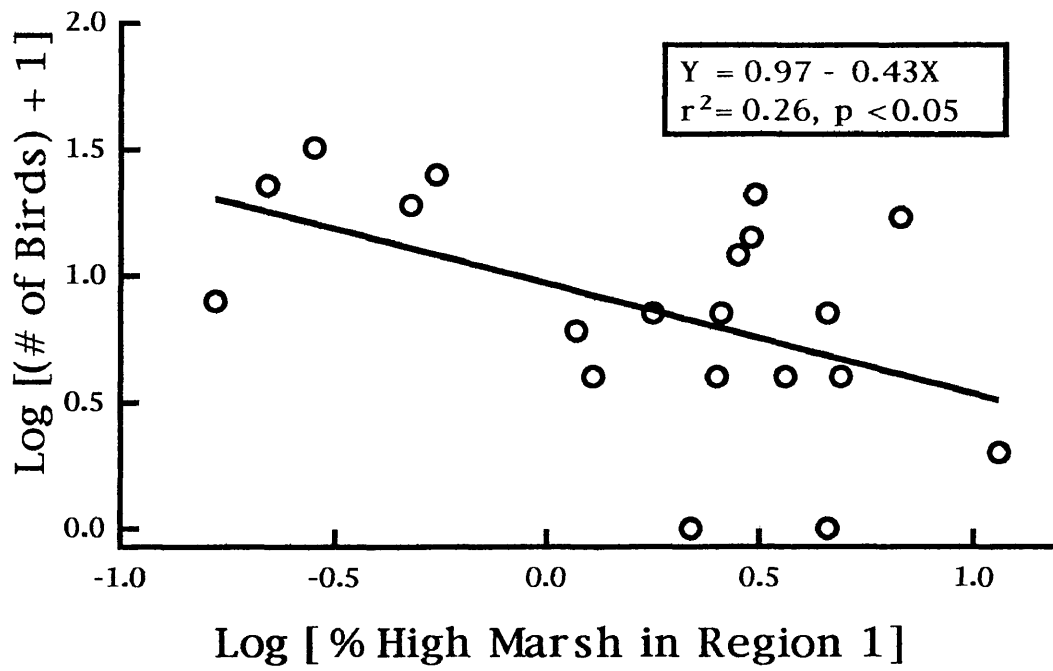
Figure 12. Regression plots of the log(x + 1) transformed value of bird use

and the log(x) transformed value of bird use on high marsh

1 + 2 and high marsh 1 + 3

Top panel:

$$Y = 0.91 - 0.39X$$
$$r^2 = 0.37, \ p < 0.001$$

Y-axis: Log [(# of Birds) + 1]

X-axis: Log [% High Marsh in Regions 1+ 2]

Bottom panel:

$$Y = 0.83 - 0.25X$$
$$r^2 = 0.14, \ p \leq 0.01$$

Y-axis: Log [(# of Birds) + 1]

X-axis: Log [% High Marsh in Regions 1- 3]
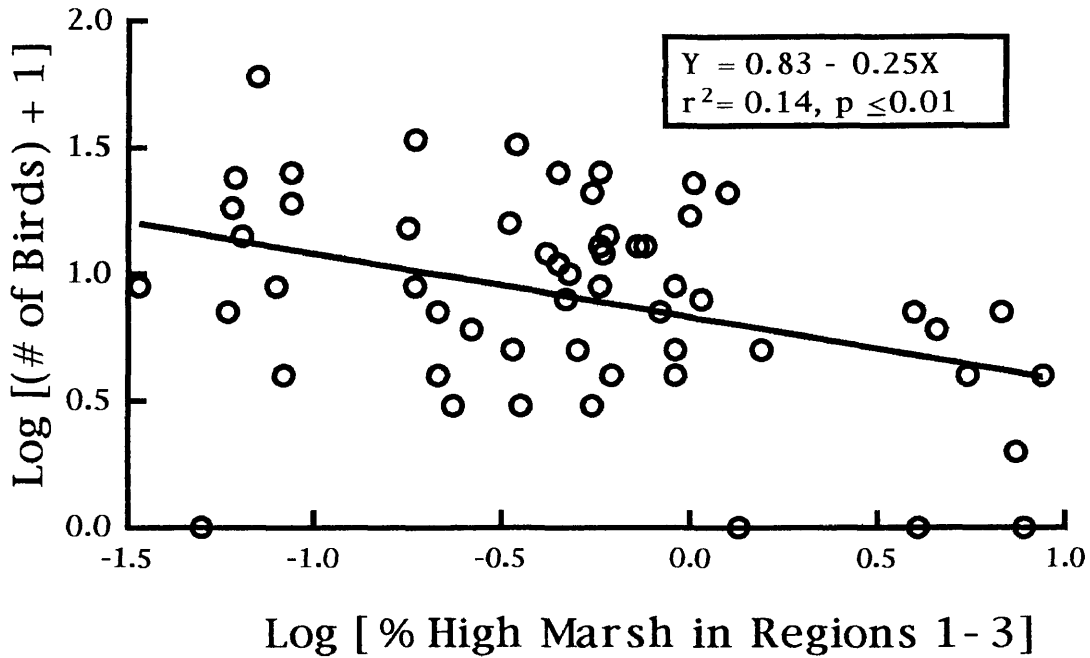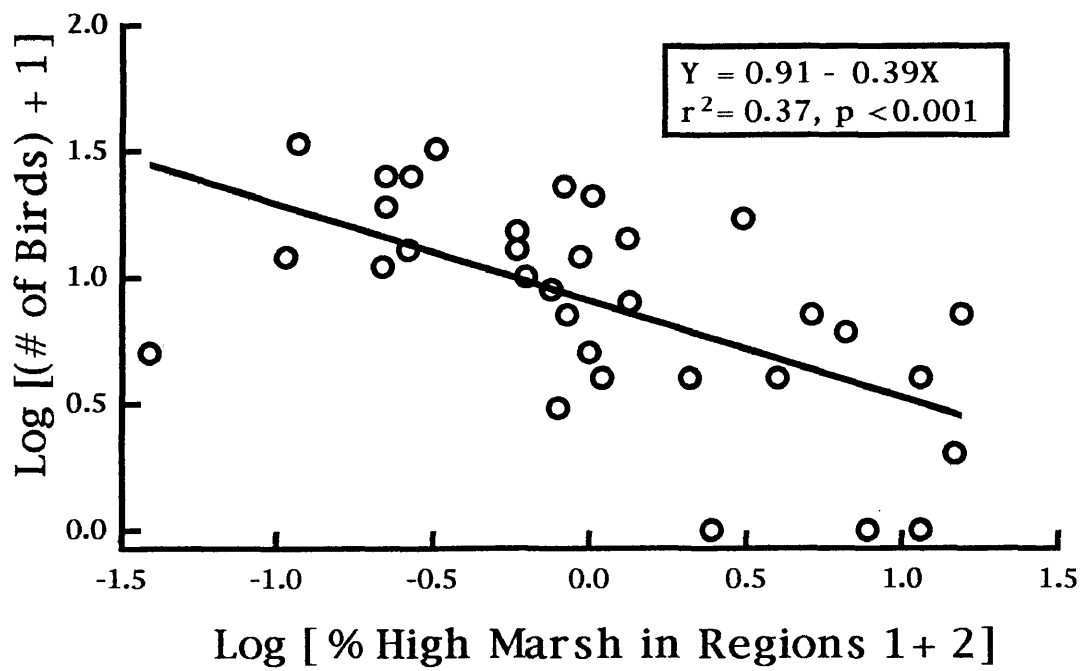
Figure 13.   Regression plots of the $\log(x + 1)$ transformed values of bird use

on nest $1 + 2$ and nest 1-3.

Top panel:

$$Y = 0.81 + 0.41X$$
$$r^2 = 0.12, \ p < 0.001$$

y-axis: Log [(# of Birds) + 1]

x-axis: Log [(# of Nests in Regions 1+2) + 1]

Bottom panel:

$$Y = 0.65 + 0.48X$$
$$r^2 = 0.24, \ p \leq 0.001$$

y-axis: Log [(# of Birds) + 1]

x-axis: Log [(# of Nests in Regions 1-3) + 1]
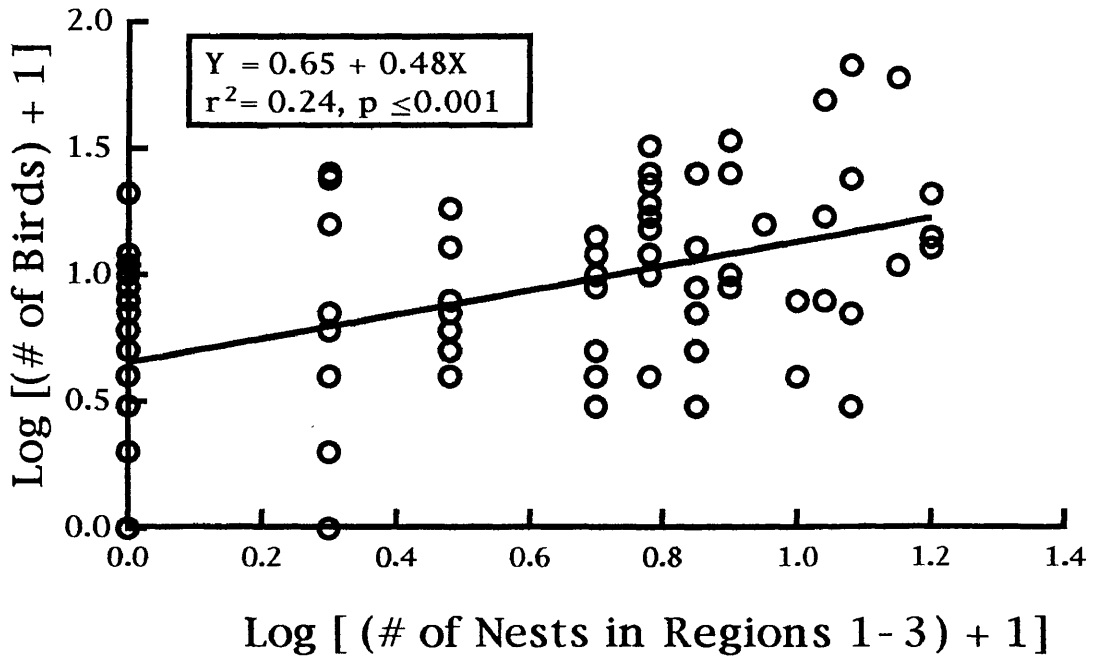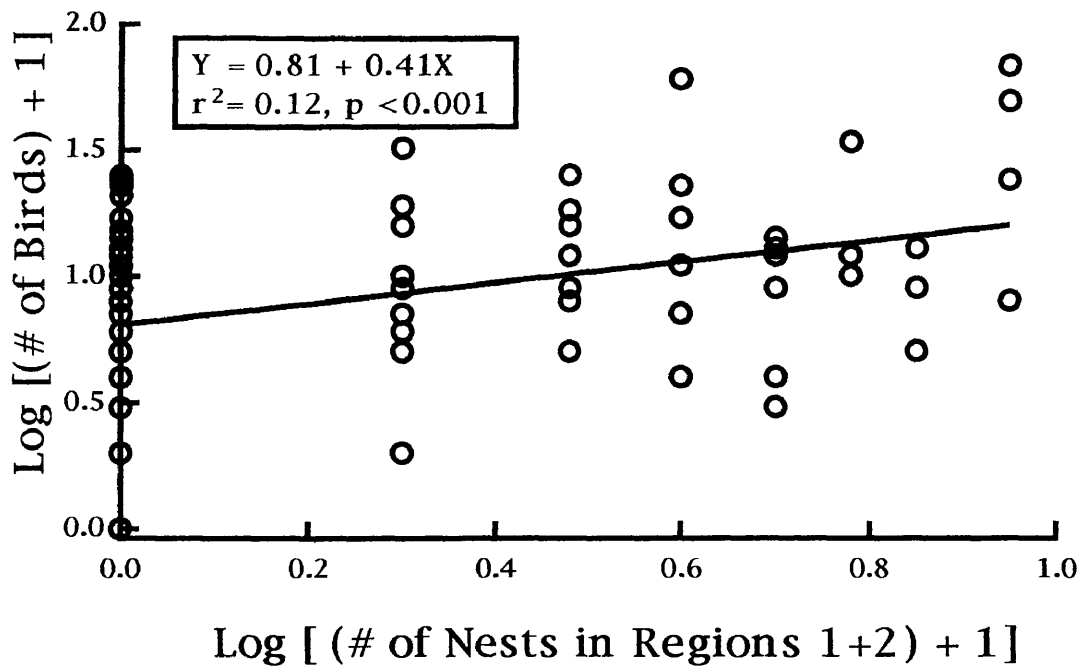
The backward elimination procedure for the multiple regression

removed the variables % saltbush within the marsh and number of nests in

regions 1 and 2. This resulted in a highly significant multiple regression;

$$F = 17.49 \quad p = .0001 \quad (r^2 = .5317)$$

The resulting equation is shown below:

bird use = -.8 + .6 (# of nests 1-3) .3 (shoreline length) + .2 (shape) +

.02 (% of loblolly in 1) - .03 (% of loblolly in 2)

(Figure 14)

Appendix VI. shows the F statistics and probabilities for the variables in the

equation.

Figure 14. Schematic representation of significant marsh

variables in relation to the marsh site.

Significant Marsh Variables

3

2

1

Shape
Shoreline
Length

# of Nests
% Loblolly Pine

# of Nests
% Loblolly Pine -

# of Nests
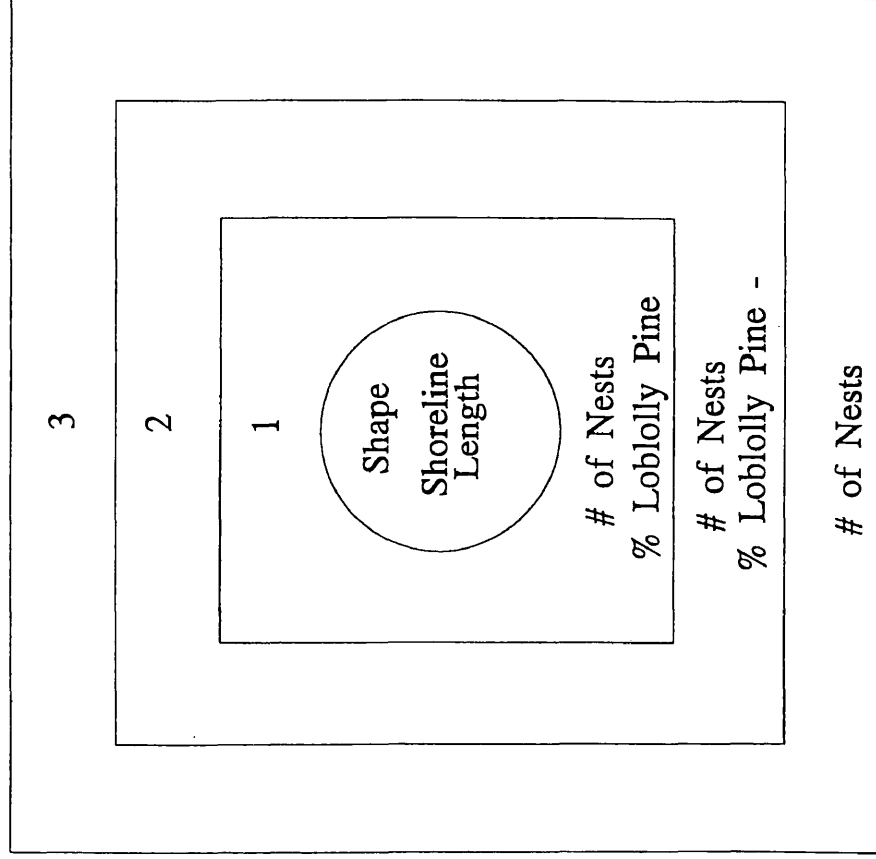
Nest Study Results

Of the 65 nests that were identified during the 1992 field season,
only one was not located in a loblolly pine tree. This nest was found on the
lower limb of a sweet gum tree. Nests were located on the end of the lower
limb of loblolly pine trees that were approximately 40-60 years old. The age
of a tree was estimated by comparison with trees of known ages.

The nest sites were on average 111 $\pm$ 11 meters from the nearest
shoreline. The distances to the nearest shoreline ranged from 61 meters to
244 meters. The location and size of each nest site and its proximity to a
marsh is shown in Figure 3. The relationship of nest sites to high use
marshes can be seen by reviewing Figure 2 and Figure 3.

<u>Univariate Results</u>

The results of all univariate analyses are shown in Appendix VII.
Figure 15 shows that the mean distance (m) to the nearest marsh is greater
for the random sites than for nest sites. The mean percentages of *Spartina*
alterniflora marsh and total marsh within regions 1 and 2 are greater for nest
sites than for random sites and is shown in Figure 16.

The mean percentage of deciduous and loblolly tree cover in all
regions is greater for nest sites than random sites. These differences are
shown in Figure 17. There is a higher mean number of nests in regions
1 + 2 and 1-3 for nest sites than for random sites as shown in Figure 18.

Figure 15. Mean distance to the nearest marsh by nest site

type.
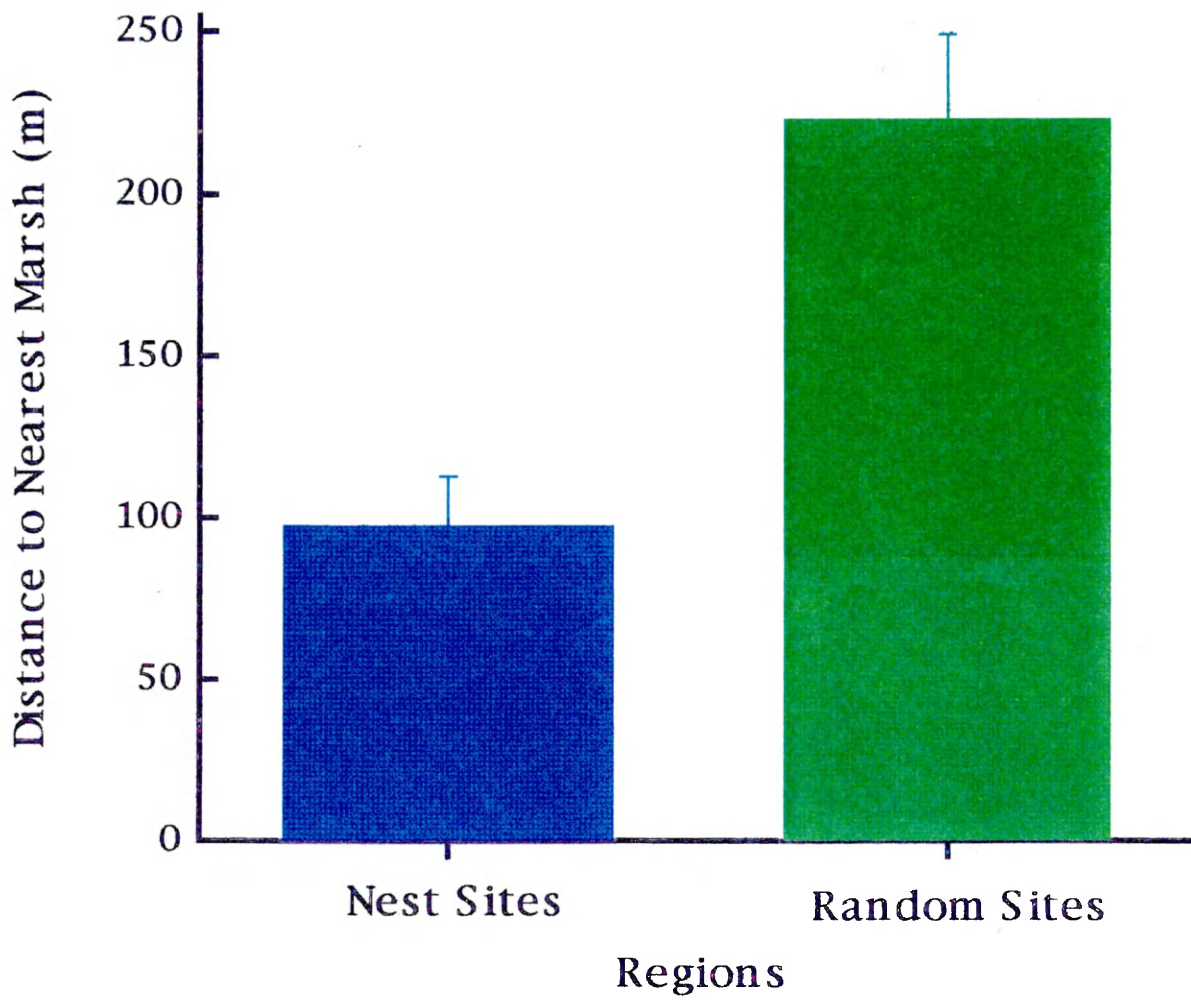
Figure 16. Mean percentage of *Spartina alterniflora* and total marsh in

several regions by nest site type.
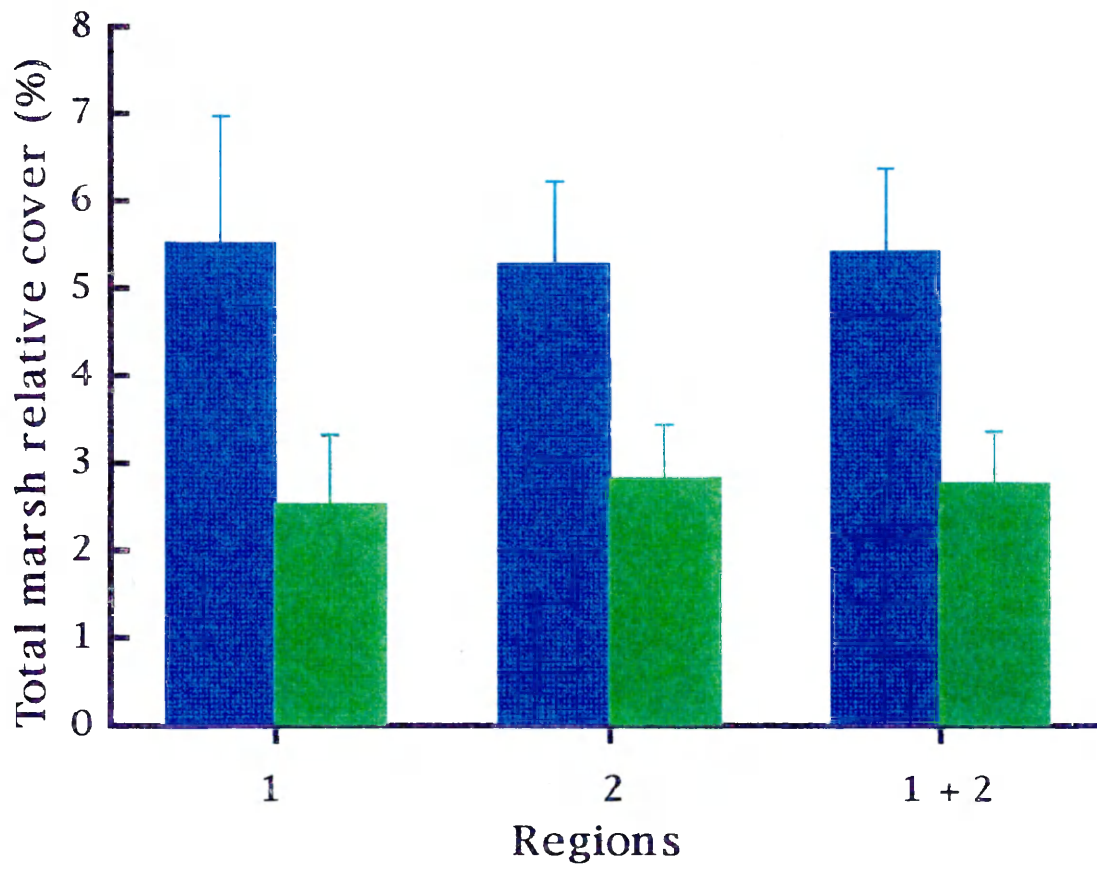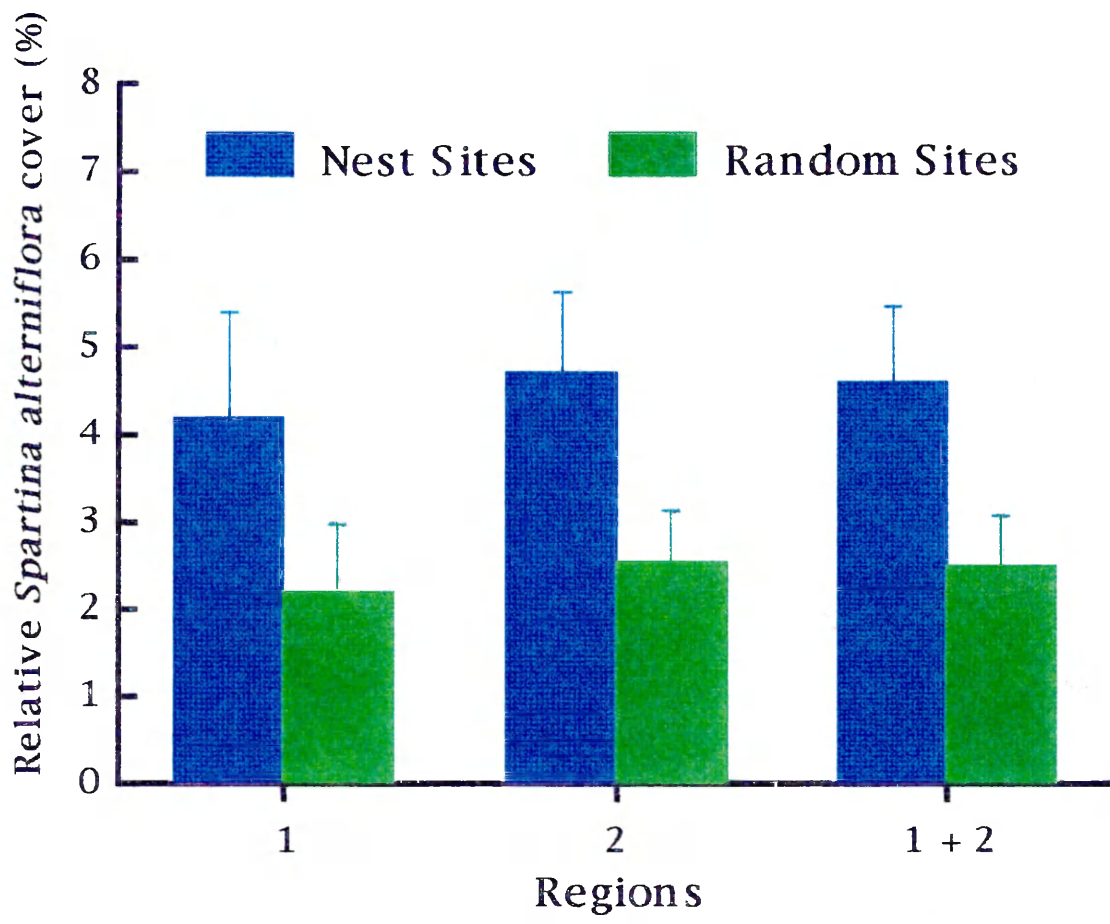
Figure 17. Mean percentage of loblolly pine and deciduous tree in several

regions by site type.
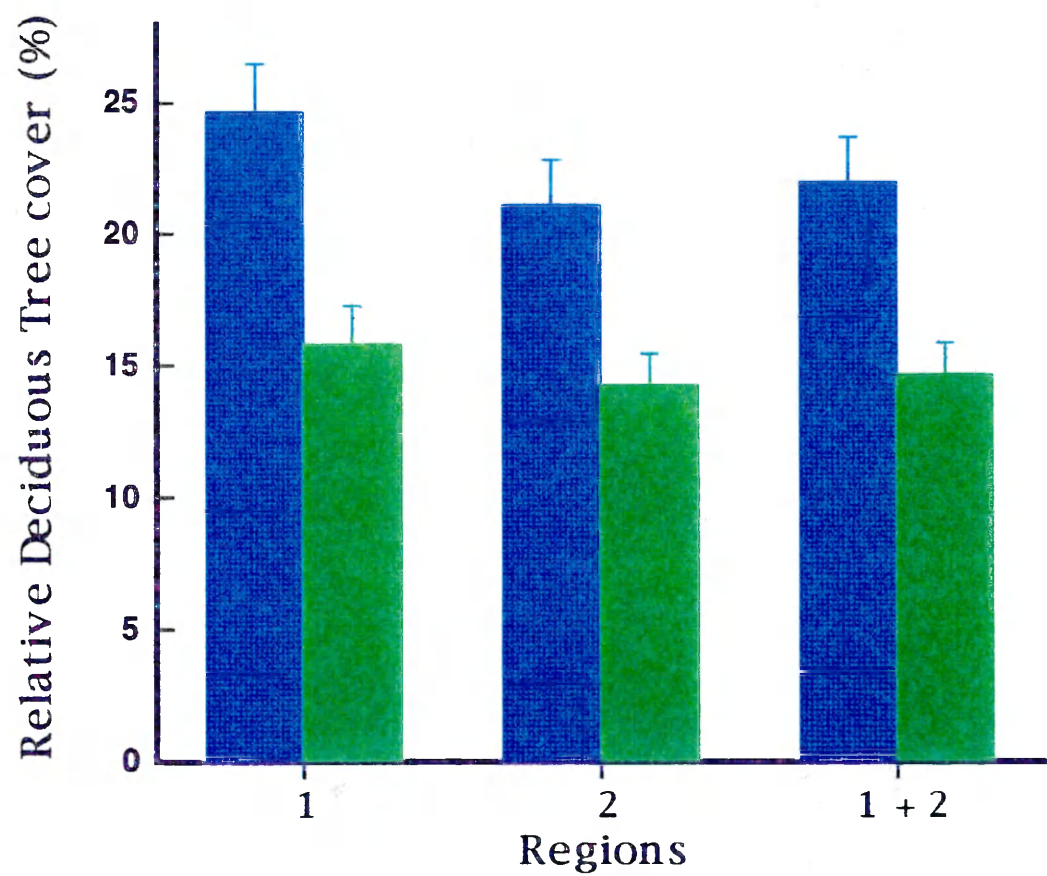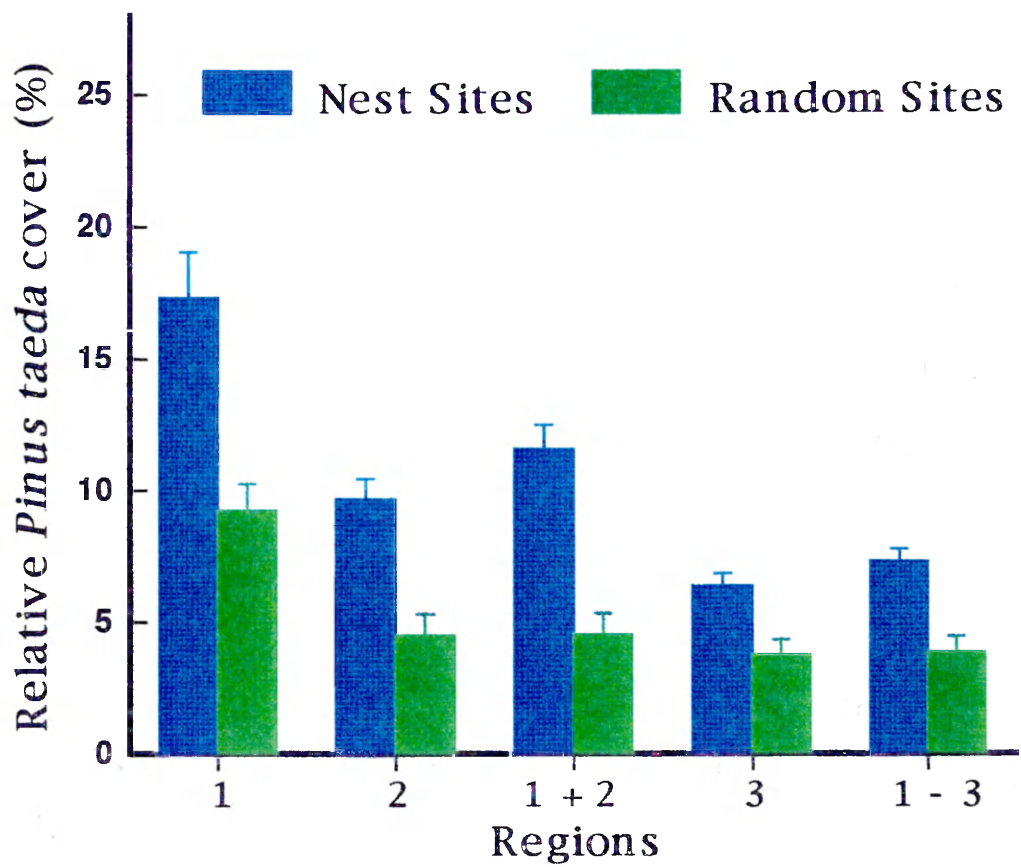
Figure 18. Mean number of nests in several regions by nest site

type.
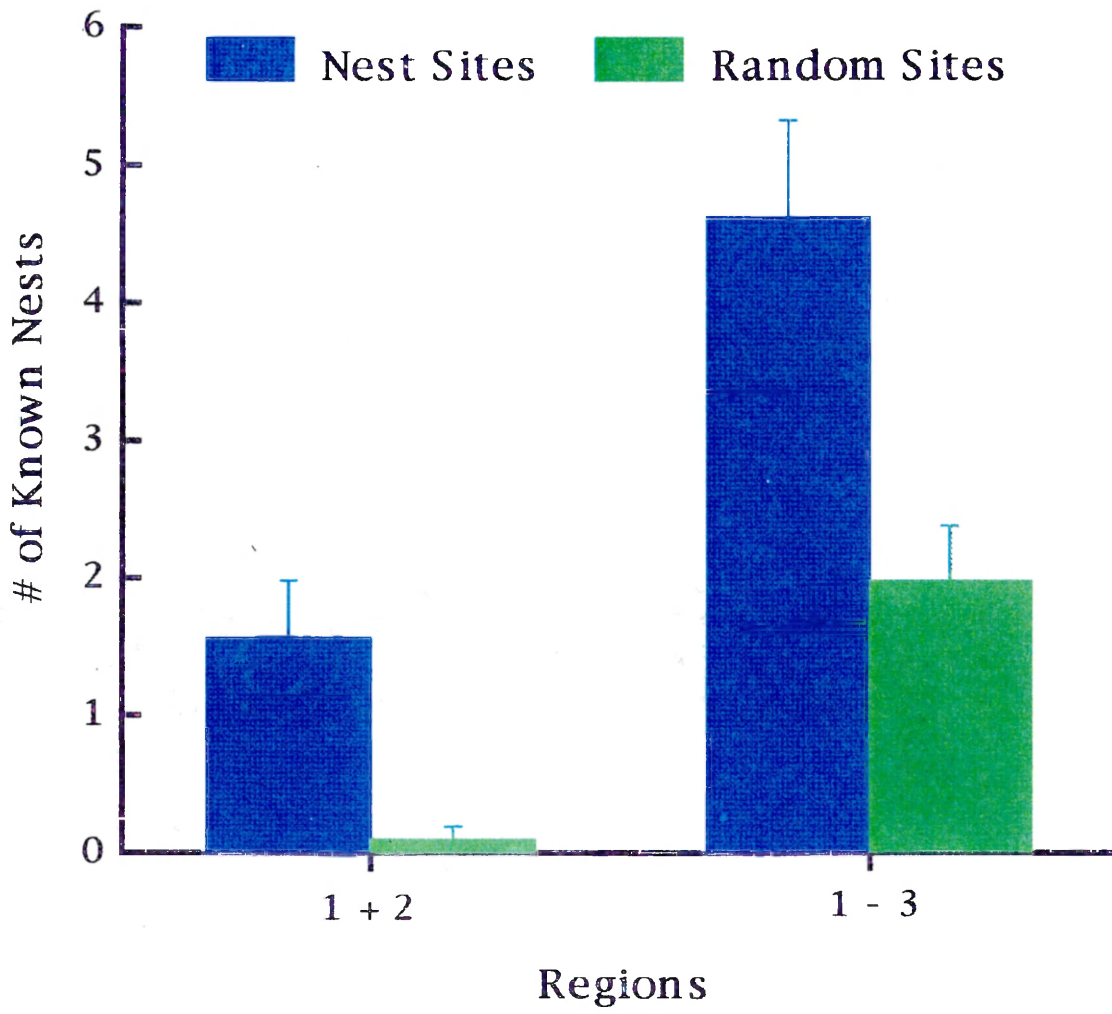
Discriminant Function Analysis

The discriminant function analysis was conducted to determine what elements of the landscape are useful in discriminating between nest and non-nest sites. Based on the results of the univariate tests, 18 variables were eligible for entry into the discriminant function analysis. However, to avoid redundancy, a correlation matrix was created with the 18 selected variables. Removal of variables highly correlated with others left 10 variables for the analysis. These variables include distance to nearest marsh; percentage *Spartina* in region 2; percentage deciduous tree in regions 1, 2, and 1-3; percentage loblolly pine in regions 1, 2 , 3, and 1-3; and the number of nests in regions 1-3.

These 10 variables were entered into a stepwise discriminant function analysis utilizing the backward elimination option. This further reduced the variable set by selecting only those variables that had good discriminating power. The remaining variables include distance to the nearest marsh, percentage deciduous tree in region 1, and the percentage loblolly pine in regions 1 and 2 (Figure 19). The F statistics and the probabilities for the selected variables are shown in Appendix VIII.

The variables selected by the stepwise procedure resulted in a highly significant discriminant function analysis;

$$F = 19.843 \quad p = .0001$$

The F statistic is computed from D^2, the Mahalanobis distance.

Figure 19. A schematic representation of the significant

nest variables in relation to the nest site.

Significant Nest Variables

3

2

1

% Loblolly Pine
% Deciduous Tree

% Loblolly Pine

Distance
to
Nearest Marsh
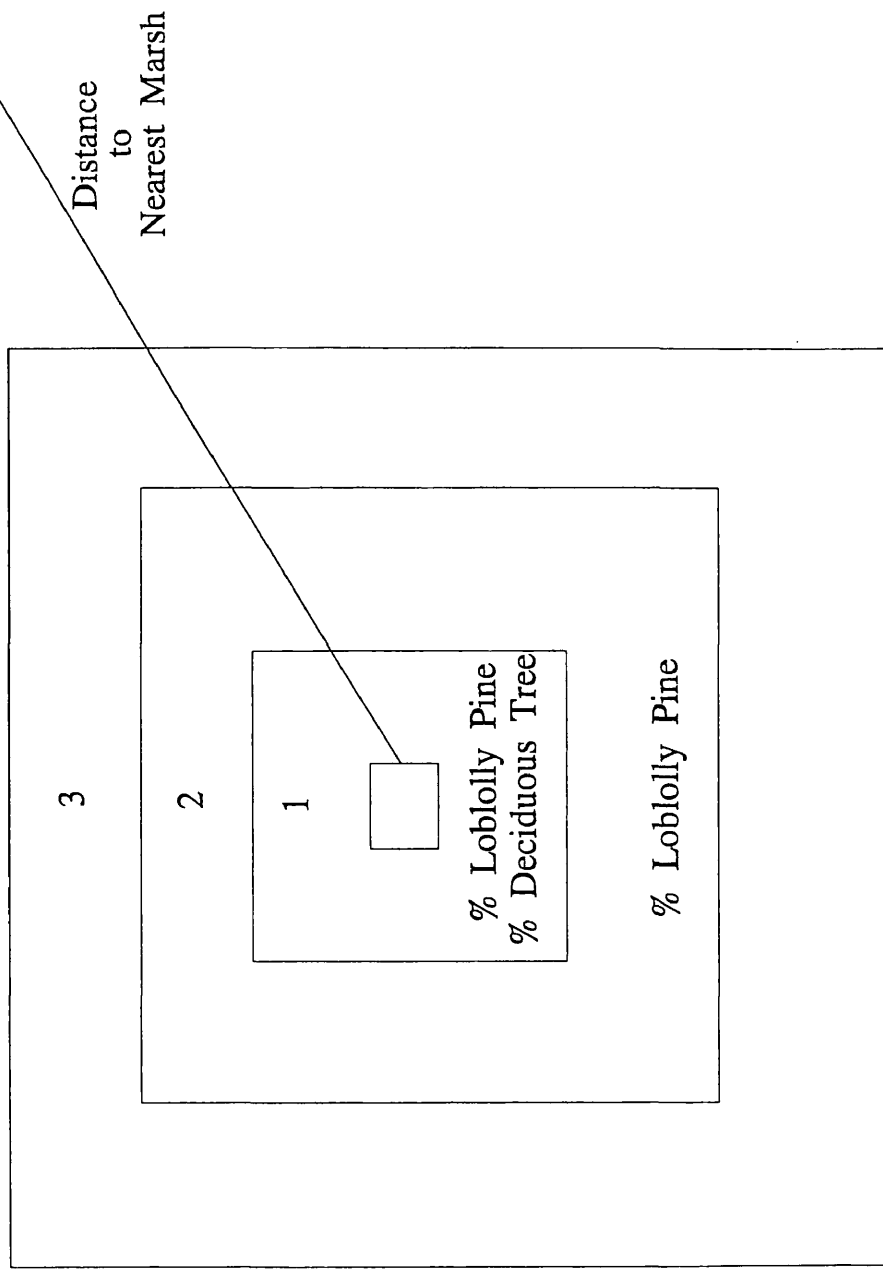
The variables identified by the stepwise procedure were entered into a discriminant function analysis. The test of homogeneity of variance between the variance-covariance matrices resulted in;

Chi-square value = 26.47   p = .0032

Therefore, the within covariance matrices were used in the discriminant function. The discriminant function had excellent reclassification results based on the quadratic equation created. There were 3 observations misclassified in class 1 (nest sites) and 4 in class 2 (non-nest sites). This results in only a 10% misclassification rate and reassurance that the equation accurately reflects the observed data.

Discussion

Seasonality and Marsh Use

Yellow-crowned Night-herons in the lower Chesapeake Bay generally lay complete clutches by mid-May and fledge young in mid-July (Watts 1989). The chronological change in the number of birds seen foraging in the marshes of this study is consistent with the change expected due to the breeding chronology of the population. Most clutches were completed from late April to mid-May and brooding began in late May and early June (Watts unpubl. data). Immature birds were first observed in the marshes during the week of July 8 when fledging began.

Young herons learn to forage effectively and to select profitable foraging sites by observing adult behavior (Kushlan 1981). Since both immature and juvenile Yellow-crowns were seen foraging with adults approximately 75% of the time I suspect that adults were used as indicators of quality foraging areas and as role models for learning foraging behavior. The presence of an immature or juvenile bird alone in a marsh would not ensure a profitable feeding site. This may explain why juvenile and immature birds were never observed foraging together in the same marsh without the presence of an adult.

Yellow-crowned Night-herons are solitary foragers, although more

than one bird may use an exposed mudflat (ffrench 1973). Their solitary foraging behavior and the observed mean distance of approximately 5 meters between foraging birds in this study is likely a reaction to prey behavior. Yellow-crowns move very slowly when foraging because fiddler crabs will return to their burrows if movement is detected. The presence of other birds in close proximity would lead to more fiddler crab disturbance and less foraging time. A greater distance between foraging birds would result in fewer incidents of prey dispersal. Erwin (1983) has shown similar results with Great Egrets and Little Blue Herons. He observed that these herons are not common in large groups and generally forage alone at a distance of 5 meters from another bird. He attributes this to the fact that both species are slow and methodical in their feeding methods and that foraging in large groups would be disruptive.

The total number of birds seen per survey increased as the survey progressed. This could be a result of adults being released from incubation duties, of adults foraging rigorously to feed growing young (Kushlan 1981), and of fledglings foraging on their own in the marshes. The two low total bird counts on July 14 and July 27 could have been due to the fact that both were mid-day surveys. Although the foraging strategy for Yellow-crowns is dependent on the tidal cycle (Hancock and Kushlan 1984; Watts 1988) and is not restricted by time of day (Kushlan 1978), air temperatures commonly range between 90-100 F degrees during the summer and could

limit feeding in the marshes and on the open mud flats.

The percentage of marshes used during each survey increased slightly during the course of the study. This could be a result of immature birds using poorer quality marshes because they have not learned to forage effectively. The choice of atypical or poor quality foraging sites by juvenile birds has been documented (Kushlan 1981). Poorer quality marshes are defined here by infrequent use by adult birds.

Immature birds could also be selecting poorer quality marshes because they may be unoccupied by other birds. This is a plausible explanation since it was demonstrated by Laubhan et al. (1991) that immature birds have higher foraging efficiency when not foraging in the presence of adults.

Finally, the increase in the percentage of marshes used over time could be due to post fledging dispersal. Dispersal of juveniles and adults occurs at the end of nesting (Kushlan 1981). Adults may stray farther from their nest sites to forage after their chicks have fledged. However, to address these alternate explanations precise identification of individual birds is necessary.

The highest use marshes were those that are in close proximity to nest sites. This is demonstrated by reviewing Figures 2 and 3. The numbers of the high use marshes were 146, 73, 71, 47, and 46. This trend holds for adult, juvenile, and immature Yellow-crown marsh use totals. These results were expected because an ideal breeding place for herons

should have an adequate supply of nesting materials and should be reasonably close to suitable feeding areas (Jenni 1969).

Univariate Regressions

<u>Marsh size and shape</u>

It has been shown that larger wetlands may attract and support more birds and species than smaller wetlands (Brown and Dinsmore 1986; Breininger and Smith 1990; Watts 1992). This study has shown that the Yellow-crowned Night-heron is not an area-dependent forager, but prefers marshes with small areas and long shorelines. Marshes that have minimal interior area and are dominated by marsh/water edge habitat are preferred. This is an expected result in light of their foraging strategy. Yellow-crowns feed on fiddler crabs that are found on the marsh/mudflat boundary during low tide.

The positive slope in the regression of marsh shoreline length on Yellow-crown use suggests that Yellow-crowns may prefer marshes with longer shorelines. Marshes with longer shorelines will also offer a more extensive, contiguous foraging area.

Total edge is the sum of shoreline length and marsh/upland length. As the total edge of a marsh increases the amount of suitable foraging edge will probably also increase. This would be favorable to foraging Yellow-crowns and is reflected in the positive slope of the regression of bird use on total edge.

Shape is the ratio of shoreline length to marsh size and the positive slope of the regression line indicates that marshes with larger values for shape support higher numbers of foraging Yellow-crowns. Therefore, Yellow-crowns select marshes with long shorelines and small areas more frequently than marshes with short shorelines and large areas. The variable shape can be explained as the amount of surface area available to Yellow-crowns for foraging.

Effects of High Marshes

Fiddler crab burrow density increases from the marsh edge to the marsh flat and then decreases with increasing elevation (Bertness and Miller 1984). High marshes provide less suitable habitat for fiddler crabs and will likely support a smaller population. Therefore, there could be less suitable foraging habitat in areas dominated by high marshes.

An increase in the percentage of high marsh in the regions surrounding a marsh will cause a decrease in Yellow-crown use in that marsh. This could reflect the fact that fiddler crabs are less available to foraging Yellow-crowns. An alternative explanation could be that high marsh vegetation, such as saltbushes and *Phragmites australis* may be more difficult for large birds like Yellow-crowns to move through.

Nest Site Proximity

As expected, an increase in the number of nests within the three regions surrounding a marsh will lead to an increase in Yellow-crown use in

that marsh. These results agree with Jenni (1969) in that they confirm the fact that successful heron breeding areas provide nest habitat and materials in close proximity to foraging areas. This is an example of habitat complementation as discussed by Dunning et al. (1992).

This also suggests that Yellow-crowns do not travel long distances (>488 meters) from the nest site to forage. The distances generally traveled by Yellow-crowns in this study is much shorter than the mean distance of 1.4 km reported by Custer and Osborn (1978). Their sample size was small (n = 2) which may account for the discrepancy.

Multiple Regression Analysis

The multiple regression included several variables discussed previously and a few new variables. The regression analysis identified five variables that were important in determining Yellow-crowned Night-heron use of marshes along the Lafayette River. The within-marsh variables shoreline length and shape were both significant in the multiple regression. The variables nest 1-3, loblolly pine 1 and 2 were significant at the landscape-level in the multiple regression.

The variable nest 1-3 was significant in the univariate regression and is also influential in the multiple regression. This supports the suggestion that a marsh is used more frequently if it is located near to nests. Therefore, a marsh located near to a nest site is valuable to breeding herons as stated by Jenni (1969). More specifically, marsh use by Yellow-crowned

Night-herons depends on the number of nests within approximately 488

meters of the marsh site. An increase in the number of nests within regions

1-3 of a marsh caused an increase in Yellow-crown foraging in that marsh.

The length of the marsh shoreline was significant in univariate

regression and is also an important positive factor in driving the multiple

regression. Fiddler crabs are the predominant prey source of the Yellow-

crowned Night-heron in the tidal regions of Virginia (Watts 1988). Fiddler

crabs leave their burrows during low tide and feed on detritus along the edge

of the marsh on the tidal flats. Yellow-crowns stalk the perimeter of

marshes to capture fiddler crabs. Therefore, longer marsh shorelines offer

greater foraging opportunities. Fewer interruptions in foraging over time

may lead to an increase in foraging efficiency. Increasing the time spent

locating and capturing prey and minimizing the time spent moving to another

section of marsh shoreline serves to improve foraging success.

The shape of a marsh, the ratio of marsh shoreline to size, also

contributes positively to marsh use in both the univariate and the

multivariate cases. The use of a marsh increases with an increase in the

value for shape. This indicates that marshes with long shorelines and small

areas are preferred for foraging. Long, thin marshes will offer more foraging

area than large marshes which border upland on the majority of their edge.

For example, marsh islands, spit, and fringe marshes will offer more foraging

opportunities to the Yellow-crown because a larger portion of the marsh

consists of water/marsh edge. As stated earlier, this finding does not support existing results that state that avifauna in general prefer larger marshes.

Marsh use by Yellow-crowns increases directly with an increase in the presence of loblolly pine within 122 meters of the marsh edge. The dependence of foraging on loblolly pines within 122 meters of the edge of the marsh indicates that marshes that are near wooded areas are preferred to marshes near treeless areas. These results are consistent with earlier descriptions of Yellow-crown Night-heron habitat as being shady, mature woods near to water (Mengel 1965; Sutton 1967; AOU 1983). Also, loblolly pines are the primary nesting habitat for Yellow-crowns in the tidal regions of Virginia (Watts 1989). The mean distance of nest sites to the shoreline in this study was 111 meters, which lies within region 1. Yellow-crowns may prefer foraging in marshes that are near to pines because they may offer shelter from high winds and direct sunlight and may provide suitable roosting and nesting areas. A shady foraging area will allow a Yellow-crown to move more freely amongst fiddler crabs with a decreased chance of detection.

Lastly, the regression analysis identifies the variable % loblolly pine in region 2 as having an inverse relationship to marsh use. Therefore, as the amount of loblolly pine in region 2 increases the use of the marsh decreases. This suggests that Yellow-crowns in this region prefer small patches of pine

to large contiguous stands. If this is true, the presence of loblolly pine patches of this size in urban areas such as the areas surrounding the Lafayette River are ideal for breeding Yellow-crowns. However, it is conceivable that this result is an artifact of the variation structure of my data.

Although the multiple regression analysis eliminated the within marsh variable, % saltbush, it is important to note that it has a negative effect on foraging by Yellow-crowned Night-herons. This is consistent with the results of the univariate analyses of % high marsh in the regions. Therefore, the presence of high marsh within a marsh or surrounding a marsh will have a negative effect on marsh use by Yellow-crowns.

Nest Sites

The location of the majority of the nests on the lower limb of 40-60 year old loblolly pine trees is consistent with the information gathered by Watts (1989). Despite the use of hardwoods and shrubs in other regions of their range, Yellow-crowns rely almost exclusively on the use of loblolly pine for nesting in the tidal reaches of Virginia. As previous studies have shown (Wischusen 1979; Watts 1989), all nests were located in separate trees.

Nest sites generally consisted of 1 to 2 nests, but several sites contained 3 to 5 nests. All nest sites located contained 7 or fewer nests. These Yellow-crown colonies are smaller than previously documented along the Lafayette River and in other regions. Darden (1962) observed a colony

of 19 pair nesting along the Crab Creek portion of the Lafayette River. The mean colony size studied in a hardwood wetland in Missouri was approximately 4 pair over a two year period (Laubhan and Reid 1991). Parnell and Soots (1979) describe the size of Yellow-crown colonies as 2 to 15 pairs.

The size of heron nesting colonies is limited by the availability of foraging habitat (Gibbs 1987). The limited availability of foraging habitat may explain the over representation of small colony sizes along the Lafayette River. For example, the lack of success of the 7 pair colony in recent years (Watts pers. comm.) could be due to the lack of foraging habitat in the area surrounding the nest site.

It is energetically favorable for nests to be located close to the nearest shoreline since it minimizes flight distance to foraging areas. A short distance to a foraging site will maximize foraging time and minimize travel time. This is particularly important to species that are tidally dependent and may have to travel farther during high tides. A significant increase in flight distances for Great Egrets, White Ibis, and Black-crowned Night-heron during high tide was shown by Custer and Osborn (1978).

The occurrence of high use marshes in the near vicinity of large nest sites is an expected result for a species that relies on two distinct habitats during the breeding season. It is important to note that immatures are most heavily utilizing the marshes that are nearest to nest sites.

Univariate Analyses

The univariate analyses identified several important differences between nest and non-nest sites. There were clear differences in the amount and type of marsh in the vicinity of the nest and non-nest sites. There was also a significant difference in the upland tree structure between site types.

<u>Marshes</u>

My results agree with previous studies that show that extensive wetlands are vital to the maintenance of native heron populations (Jenni 1969; Gibbs et al. 1987). The mean distance from a marsh to a nest site is significantly shorter than to a non-nest site. This suggests that the selection of a nest site depends on its proximity to a marsh. Also, there is a higher percentage of total marsh within regions 1 and 2 surrounding a nest site. Therefore, nests sites are both closer to marshes and are surrounded by a higher percentage of total marsh.

When high and low marsh types were analyzed separately, I found that there was a significantly higher percentage of *Spartina* marshes within regions 1 and 2 surrounding nest sites. This implies that in addition to the significance of marshes in general, *Spartina* marshes are of particular importance to nesting Yellow-crowns. This is an anticipated result because *Spartina* marshes support high prey densities with fiddler crabs burrow densities ranging from 56-120 burrows/.25m^2 (Bertness 1985). It has also

been shown that substratum hardness and root mat density increases with elevation (Bertness and Miller 1984). High marshes might not supply a suitable burrowing environment for *Uca* spp. which would limit population densities. The resulting prey densities in high marshes might be insufficient to attract or support foraging Yellow-crowns.

<u>Uplands</u>

Yellow-crown Night-heron habitat has been described as swampland that is "gloomy and forbidding with little but the great trees, the muddy water, and the fallen tree trunks" (Nice 1929). Although this is not always the case, Yellow-crowns typically breed in tall trees in shady, wooded situations near water (AOU 1983). My results complement these descriptions of breeding areas, but describe a previously unexamined portion of their range. Therefore, I have described a dependency on a unique forest structure and composition. There is a significantly greater percentage of both deciduous and loblolly pine tree cover surrounding nest sites than non-nest sites.

Discriminant Function Analysis

Distance to the nearest marsh was selected in the analysis as having significant discriminating power. The distance of the randomly chosen non-nest sites were restricted to within 305m of the shoreline. This was done so that they would be located as near to the river as the nest sites. However, they were not restricted by distance to the nearest marsh. Since

there is an extensive amount of shoreline modification along the Lafayette

River, proximity to the river does not guarantee nearness to a marsh.

However, a shorter distance from nest site to marsh site is favored by

Yellow-crowns. This is understood in terms of limiting the amount of energy

spent moving to and from foraging sites.

The analysis identified deciduous and loblolly pine tree cover in close

proximity to the nest as having good discriminatory power. Watts (1989)

has shown that the primary nesting tree for the Yellow-crowned Night-heron

in the lower Chesapeake Bay is loblolly pine. He suggests that this provides

a selective advantage by reducing clutch predation. Based on observations

of adults standing over and wing shading young birds, he feels that loblollies

provide inadequate shade. A dense mix of both loblolly and deciduous trees

immediately surrounding a nest tree would address both the issues of shade

and visual protection. Early in the breeding season the loblollies would help

reduce clutch predation during egg laying and incubation. By the time of

hatching, leaf out would have occurred and the deciduous trees could

provide adequate shading for the chicks. I suggest that mixed forest

situations are preferentially selected by Yellow-crowned Night-herons.

Conclusions

My results suggest that breeding Yellow-crowned Night-herons are preferentially utilizing wooded areas which are in close proximity to marshes. The immediate nest site is characterized by the predominance of small patches of loblolly pine mixed with various deciduous trees. The mean distance of these wooded patches to the nearest marsh is 111 meters.

The landscape within approximately 500 meters of the nest site is distinguished from unused areas by the presence of low marsh. The marshes used most consistently have long shorelines, minimal interior area, and are dominated by low marsh vegetation. Therefore spit, fringe, and island marshes are important to foraging Yellow-crowns.

These results agree with previous work done on heron ecology by reinforcing the fact that herons rely on the juxtaposition of suitable nesting and foraging habitat during the breeding season. My results also agree with other work that has been done regarding nest site preferences in the lower Chesapeake Bay. However, I have shown that foraging Yellow-crown Night-herons do not depend on large marshes to forage like other marsh reliant species.

Management Implications

To a very large extent the problems of conserving the herons of the world are indistinguishable from the problems of wetlands conservation (Hancock and Elliot 1978). The Yellow-crowned Night-heron is no exception. Approximately one-half of the bay's wetlands have been lost since the colonial era and losses are still accruing (Horton and Eichbaum 1991). Filling of wetlands, seawalling, and the marine contamination associated with intense residential development has decimated fiddler crab habitat and threatens existing Yellow-crown foraging habitat (Watts 1991). In addition, the fragmentation of remaining wetlands is occurring because of the addition of boat ramps and private docks. Fragmentation of marshes will have a negative impact on the foraging activities of Yellow-crowned Night-herons because, as demonstrated in this project, they prefer marshes with long, continuous shorelines.

The negative effects of wetland loss on heron nesting and roosting are aggravated by the widespread destruction of tree cover (Hancock and Elliot 1978). The Chesapeake Bay has lost forty percent of its forests and losses due to waterfront development and logging continue (Horton and Eichbaum 1991). This study has shown that in addition to utilizing individual loblolly pine trees for nesting, a high percentage of loblolly pine

and deciduous tree cover is an important factor for nest site selection. Continued deforestation of upland habitat will have a negative impact on local Yellow-crowned Night-heron populations.

The methodology outlined in this study represents one approach to analyzing the landscape. The result is a demonstration of the importance of analyzing an entire ecosystem when developing a management plan. Multiple resources in the landscape are identified and analyzed by focusing on processes occurring within them.

Specifically, this study has shown that a close association of suitable upland and wetland habitats are necessary in order for the Yellow-crown Night-heron to continue to breed successfully in the tidal portions of the Chesapeake Bay. To ensure that the necessary components of the upland and wetland environments are preserved in correct spatial arrangement a landscape-level approach to wetland and upland management is essential.

Recommendations for Future Research

In order to improve the understanding of the breeding chronology, habitat requirements, and population status of the Yellow-crowned Night-heron additional studies should be undertaken. A comparative study of several breeding regions should be done in separate drainages to test the hypotheses developed in this study.

For each region more intensive fieldwork should be undertaken. The nests should be located as eggs are being laid and monitored during the course of the study. This will give a more accurate assessment of breeding success. Birds from each nest should be color banded to insure precise identification. Marshes should be monitored at least two times per week to get a more accurate assessment of use. Flight lines and flight distances from the nest to foraging areas should be studied to develop a better understanding of foraging range. These studies will add to the information known regarding the population status and distribution of the Yellow-crowned Night-heron.

Appendix I. Method for randomly choosing non-nest sites.

To establish non-nest sites an outline of the Lafayette River was isolated from a file containing an outline of the Chesapeake Bay using ARC-INFO and the CREATE command. A grid was created using the ARC-INFO GENERATE command. The grid was superimposed over the outline and the image was printed out. Each cell of the grid was 122 meters on a side. The location of the nest sites were marked on the printed map and grid. Suitable cells were determined based on these criteria:

1) They must be at least one cell away from a nest site cell to avoid overlapping with nest site landscape.

2) They must be within 2 1/2 cells from the shoreline.

3) They cannot occur in the river portion of the landscape.

The random sites were chosen within 2 1/2 cells or 305 meters from the shoreline because the mean distance (110.7 meters) plus three standard deviations (3x62.3 meters) of the nest sites to the shoreline was chosen as an outerlimit. The mean distance to the nearest shoreline was determined from measurements taken from the nest positions on the aerial photograph.

The number of suitable cells were counted and a random number generating program was guided to select forty random numbers using MINITAB. The forty cells selected were used as non-nests sites in the analysis.

Appendix II. Use of ERDAS to measure distances.

The length of the water/marsh and the marsh/upland margins and the distances to nearest marsh and shoreline were measured from the computerized image using the ERDAS operation SMEASURE. SMEASURE allows linear measurements to be taken from the displayed image. Since the image was georeferenced the units (meters) were taken from the display memory.

Appendix III. GIS methodology

The photography was scanned five separate times to encompass the entire study area using a Howtek ScanmasterIII and was interpreted using a Geographic Information System and ERDAS software. Extensive image processing was necessary before information could be extracted from the scanned image.

The scanned images are image or data files that consist only of numbers. The representation of the data files form images when they are displayed on a screen or are printed out. Each number in the image file is a data file value also known as a picture element or a pixel.

The image data or pixels are organized in a grid. Each pixel is located by an x and y coordinate system. Data that is organized in this way is called raster data and is located in *.TIF files.

In order to manipulate this information using ERDAS it must be transformed into an ERDAS formate. This is done by creating a *.LAN file from the *.TIF file using the ERDAS command RDTIFF. All image files were transformed from *.TIF files to *.LAN files in this way. However due to inconsistencies in the photograph one scanned image was highlighted by increasing the color and intensity of the red band before it was saved as a *.TIF file.

The *.LAN files were then georeferenced and rectified. Georeferencing is the process of assigning map coordinates to image data. The image files were georeferenced using the commands GCP and COORDN. GCP allows you to assign map coordinates to specific pixels. The ground control points used were in UTM units and were taken from the most recent topographic maps available using a UTM ruler. COORDN transforms the locations of the ground control points, gcps, so they are true in their relationship to each other and then gives you an RMS error. The RMS error is the distance between the input location of a gcp, and the retransformed location for the same gcp. Thirteen to fifteen gcps were entered for each image and all RMS values were less than 4.

Rectification projects the data onto a plane and conforms it to a map projection. This was done using the NRECTIFY command. After all images were georeferenced and rectified the command BSTATS was used to build a file of statistical information about the data in the image files. BSTATS was

repeated after every subsequent procedure to update the statistical files for each image file.

The files were then prepared for classification. Extensive preliminary analysis was done to determine the most appropriate type of classification scheme to use. Multispectral classification is the process of sorting pixels into a specific number of individual classes based on their data file values. The unsupervised classification method was chosen for this project since the urban landscape is extremely complex. The complexity of the landscape is expressed by landscape variables having numerous spectral subtleties.

The ISODATA command was used to form clusters based on the spectral characteristics of the data. ISODATA forms clusters based on how the image data is plotted in spectral space. Each pixel is assigned to a cluster whose mean is the closest to the mean of the pixel. The statistics are done using the values assigned to red, blue, and green color bands of a pixel. The maximum number of clusters to be considered was set at 100 because it provided the most accurate and useful information.

After using ISODATA the pixels were assigned to a class using MAXCLAS. The MAXCLAS command assigned each pixel to one of 100 classes according to a decision rule. The maximum likelihood decision rule was chosen because it is the most accurate of the classifiers. Files created by ISODATA and MAXCLAS are *.GIS files.

The classes created by MAXCLAS were examined using COLORMOD

and recoded into eleven classes. The RECODE command is the only command used to recode classes in this study. The classes include loblolly, deciduous, water, spartina, phragmites, mixed-brackish, saltbush, saltmeadow hay, roads, and man-made structures. Each image was then thoroughly checked for misclassification of pixels against the aerial photograph. Misclassification errors were extensive due to the complexity of the urban landscape and the inability of the software to determine the difference between rooftops, shade, and water. Errors were corrected using the GISEDIT command. Extensive field work and photo interpretation allowed me to classify the images properly and to correct classification errors.

The five separate classified images were then connected together using the STITCH command. At this point the study area was complete and information extraction could begin. The object was to collect information on the number of pixels in each class within specified distances from the edge of the marsh and the edge of the nest sites (ie. use sites). The distances chosen were 122, 244, and approximately 488 meters from the edge of the use sites.

In order to get this information a specific procedure was developed and followed. First the marsh or nest site being analyzed was recoded to an unused class so that its value would not be calculated in the analysis. Then a box 4 inches on a side (1in = 800ft) was digitized on the screen with the

marsh or nest site at the center using DIGSCRN. CUTTER was then used to make this area its own *.GIS file. SEARCH was employed on the area 203 pixels or 244 meters from the edge of the use site. Each pixel is 1.2 meters on a side. Then pixels 1-102 were recoded to class 1 and pixels 103-203 were classified into class 2. The rest of the image was left in class 204. The pixels in class 1 correspond to region 1, class 2 to region 2, and class 204 to region 3. SUMMARY was then used to obtain the number of pixels of each type within each class. The total number of pixels within each area was also given.

This information was then loaded into a SAS program for analysis. Percentages of each landscape variable within a region were calculated by dividing the number of pixels for each class by the total number of pixels in each region. Percentages were used to allow direct comparison of a variable between areas of different sizes. The sum of each variable percentage in regions 1 and 2, and in regions 1, 2, and 3 were included to determine if the accumulation of a variable with increasing distance from the site edge would influence Yellow-crown use.

Appendix IV. The tests of normality, transformations used, and results of univariate regressions.

Variable	Shapiro-Wilk Statistic	Transform[a]	F Statistic	P
Size	.90	L	1.5	ns
Watmar	.98	L	21.7	< 0.001
Marup	.93	S	2.7	ns
Totedg	.97	L	15.4	< 0.001
Shape	.90	L	9.9	< 0.01
Sa	.89		1.2	ns
Jr				
Md				
Sb	.95	S	4.2	< 0.05
Sc				
Pa	_			
Himarsh	.95	S	1.2	ns
Nst1				
Nst2	.76	L	11.3	< 0.001
Nst3	.86	L	25.5	< 0.001
Sprat1	.92	L	.14	ns
Sprat2	.96	L	.03	ns
Sprat3	.97	L	2.05	ns
Mbrat1				

Appendix IV.   ----continued-----

Mbrat2

Mbrat3

Sltrat1

Sltrat2

Sltrat3

Phrrat1

Phrrat2

Phrrat3

Smhrat1

Smhrat2

Smhrat3

Hmrat1	.93	P	6.09	< 0.05
Hmrat2	.97	P	17.67	< 0.001
Hmrat3	.95	P	9.07	< 0.01
Watrat1	.96		.18	ns
Watrat2	.94		.02	ns
Watrat3	.93		.09	ns
Opnrat1	.97		.002	ns
Opnrat2	.94		.002	ns
Opnrat3	.97		.59	ns
Decrat1	.96		.00	ns

Appendix IV. ----continued----

Decrat2	.97			.00	ns
Decrat3	.99			.5	ns
Lobrat1	.91			4.6	< 0.05
Lobrat2	.93			5.5	< 0.05
Lobrat3	.89			5.4	< 0.05
Forat1	.94			1.5	ns
Forat2	.96			1.7	ns
Forat3	.97			1.1	ns
Nss2					
Nss3					
Sps2	.97		S	.16	ns
Sps3	.97		S	1.5	ns
Mbs2					
Mbs3					
Sls2					
Sls3					
Phs2					
Phs3					
Sms2					
Sms3					
Hms2	.96		P	17.64	< 0.001

Appendix IV. ----continued----

Hms3	.89	L	8.00	< 0.01
Was2	.90		.00	ns
Was3	.92		.08	ns
Ops2	.94		.00	ns
Ops3	.97		1.05	ns
Des2	.97		.00	ns
Des3	.98		.73	ns
Los2	.93		5.17	< 0.05
Los3	.91		2.98	ns
Fos2	.96		1.46	ns
Fos3	.96	-	.16	ns

[a] - The transformations done were :

$$L = \log(x + 1) \qquad S = \text{sqrt}(x) \qquad P = \log(x)$$

Appendix V. Equations for marsh variables with univariate regressions significant at the .05 alpha level that were not shown in Figures 9-13.

Variable	Equation	r^2
Sb	$Y = 1.12 - .049X$	.05
Hms3	$Y = 1.12 - .21X$	.09
Lobrat1	$Y = .81 + .015X$	.05
Lobrat2	$Y = .77 + .02X$	.06
Lobrat3	$Y = .74 + .03X$	.06
Los2	$Y = .77 + .02X$	.05

Appendix VI. Statistics for variables in the multiple regression equation.

Variables	F Statistic	Prob > F
Intercept	11.65	.001
Nest 1-3	36.87	.0001
Shoreline Length	12.43	.0007
Loblolly 1	5.1	.0268
Shape	5.02	.0279
Loblolly 2	4.76	.0322

Appendix VII. Descriptive Statistics on untransformed variables and univariate test results.

Variable	Nest (N = 30) X ± SE	Random (N = 40) X ± SE	F Stat[a]	P
Dismar	97.5 ± 15.4	222.9 ± 26.3	16.6	< 0.001
Diswat	89.7 ± 11.5	103.2 ± 10.4	1.84	ns
Sprat1	4.2 ± 1.2	2.2 ± .77	6.45[a]	< 0.05
Sprat2	4.6 ± .87	2.5 ± .57	8.96	< 0.01
Sprat3	3.3 ± .48	2.9 ± .47	1.31	ns
Mbrat1	.14 ± .08	.33 ± .23	.08[a]	ns
Mbrat2	.16 ± .1	.20 ± .11	.03[a]	ns
Mbrat3	.18 ± .08	.2 ± .08	.36[a]	ns
Sltrat1	.06 ± .06	0.0 ± 0	1.33[a]	ns
Sltrat2	.14 ± .08	.06 ± .03	.01[a]	ns
Sltrat3	.17 ± .13	.38 ± .19	1.76[a]	ns
Phrrat1	1.14 ± 1.2	0.0 ± 0	1.33[a]	ns
Phrrat2	.52 ± .5	.04 ± .04	.11[a]	ns
Phrrat3	.16 ± .14	.05 ± .03	.26[a]	ns
Smhrat1	0.0 ± 0	0.0 ± 0	0.00[a]	ns
Smhrat2	0.0 ± 0	0.0 ± 0	0.00[a]	ns
Smhrat3	0.0 ± 0	0.0 ± 0	1.33[a]	ns
Tmarsh1	5.53 ± 1.44	2.54 ± .79	7.97[a]	< 0.01
Tmarsh2	5.42 ± .95	2.77 ± .59	8.82[a]	< 0.01

Appendix VII. -----continued-----

Tmarsh3	3.77 ± .57	3.5 ± .56	.11	ns
Watrat1	15.2 ± 3.2	10.9 ± 2.3	1.02	ns
Watrat2	22.21 ± 3.2	17.5 ± 2.6	1.13	ns
Watrat3	31.3 ± 2.9	24.5 ± 2.9	3.46	ns
Opnrat1	21.8 ± 1.3	27.1 ± 2.1	3.08	ns
Opnrat2	21.7 ± 1.2	25.0 ± 1.6	2.33	ns
Opnrat3	20.1 ± 1.0	22.0 ± 1.4	1.06	ns
Decrat1	24.68 ± 1.8	15.89 ± 1.4	15.62	< 0.001
Decrat2	21.98 ± 1.7	14.68 ± 1.2	13.54	< 0.001
Decrat3	16.34 ± .9	13.77 ± .8	4.78	< 0.05
Lobrat1	17.36 ± 1.7	9.27 ± 1.0	56.97	< 0.001
Lobrat2	11.59 ± .9	4.55 ± .8	37.43	< 0.001
Lobrat3	7.33 ± .45	3.89 ± .56	22.58	< 0.001
Fortot1	42.03 ± 2.3	20.58 ± 2.0	49.74	< 0.001
Fortot2	33.57 ± 1.9	19.23 ± 1.7	31.62	< 0.001
Fortot3	23.67 ± 1.0	17.67 ± 1.0	17.24	< 0.001
Nst1	0.00 ± 0	0.0 ± 0	0.0	ns
Nst2	1.57 ± .41	0.1 ± .09	17.26[a]	< 0.001
Nst3	4.63 ± .70	1.98 ± .40	10.19	< 0.01
Nss2	See Nst2			
Nss3	3.1 ± .6	1.9 ± .4	2.36[a]	ns

Appendix VII.   -----continued----

Sps2	4.72 ± .91	2.55 ± .58	8.23	< 0.01
Sps3	2.9 ± .47	2.9 ± .47	.10	ns
Mbs2	.17 ± .12	.15 ± .07	.35[a]	ns
Mbs3	.18 ± .08	.19 ± .1	.18[a]	ns
Sls2	.17 ± .1	.08 ± .04	.008[a]	ns
Sls3	.18 ± .14	.46 ± .22	2.97[a]	ns
Phs2	.23 ± .22	.06 ± .05	.11[a]	ns
Phs3	.07 ± .05	.05 ± .03	.29[a]	ns
Sms2	0.0 ± 0	0.0 ± 0	0.0[a]	ns
Sms3	0.0 ± 0	0.0 ± 0	1.33[a]	ns
Tsmar2	5.29 ± .94	2.84 ± .60	8.40[a]	< 0.01
Tsmar3	3.39 ± .57	3.66 ± .59	.11	ns
Was2	24.5 ± 3.6	19.7 ± 2.8	1.27	ns
Was3	33.3 ± 3.1	26.1 ± 3.2	2.51	ns
Ops2	21.7 ± 1.3	24.3 ± 1.6	1.45	ns
Ops3	19.7 ± 1.1	21.4 ± 1.5	.73	ns
Des2	21.13 ± 1.7	14.28 ± 1.2	11.64	< 0.01
Des3	15.1 ± .8	13.6 ± .8	1.61	ns
Los2	9.70 ± .76	4.53 ± .79	26.52	< 0.001
Los3	6.39 ± .47	3.77 ± .55	15.69	< 0.001
Fos2	30.84 ± 1.9	18.80 ± 1.7	22.27	< 0.001
Fos3	21.49 ± 1.0	17.39 ± 1.0	7.93	< 0.01

[a] : Wilcoxon 2-Sample Test gives Chi-Square Approximation Statistic.

Appendix VIII. Statistics for the variables selected in the Stepwise Discriminant Function Analysis.

Variable	Partial R^2	F Statistic	P
Slobrat1	.2430	20.87	< 0.001
Pdismar	.1130	8.28	< 0.01
Decrat1	.0959	6.90	< 0.05
Los2	.064	4.44	< 0.05

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