An Analysis of Human Recreational Impacts on the Reproductive Success of American Oystercatchers (*Haematopus palliatus*):

Cape Lookout National Seashore, North Carolina.

by

Julie S. Novick

Date:

Approved:

Dr. Lynn A. Maguire, Advisor

Dr. Norman L. Christensen, Dean

Master's Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University
1996

Abstract

Increased human usage of coastal regions is often detrimental to the reproductive success of breeding shorebirds. The American oystercatcher, *Haematopus palliatus*, is a shorebird that requires large expanses of relatively undeveloped sandy coastline and is sensitive to human disturbance. These birds can be found within Cape Lookout National Seashore, which encompasses the southern islands of the Outer Banks of North Carolina. The Resource Management Division of Cape Lookout National Seashore is concerned about the effects of human use, especially vehicular use, on the reproductive success of the oystercatcher. I monitored oystercatcher nesting and human activity levels on South Core Banks, an island within Cape Lookout National Seashore. Effects of high levels of human usage were assessed. The probability of nesting success was estimated with respect to different levels and types of human activity. The most influential factor affecting reproductive success was vehicular use on the beach front, especially on weekends, which are characterized by high human usage. Management suggestions to reduce the effects of vehicular usage include educational programs, pamphlets and outdoor placards, stricter enforcement of existing regulations, and new regulations of vehicle usage during the breeding season.

Table of Contents

Page Number

Abstract i

Table of Contents ii

List of Figures iv

1.0 Introduction 1

1.1 Cape Lookout National Seashore 2

1.2 Research Needs 4

1.3 Oystercatcher Natural History 5

2.0 Methods 7

2.1 Summary of Methods 7

2.2 Study Area 8

2.3 Human Census 9

2.4 Oystercatcher Monitoring 10

2.5 Statistical Analysis 11

3.0 Results 12

3.1 Human Activity - Spatial Distribution 12

3.2 Human Activity - Temporal Distribution 14

3.3 Oystercatcher Reproductive Success 16

3.4 Relationship Between Temporal Use and Reproductive Success . . 19

3.5 Relationship Between Spatial Use and Reproductive Success 19

3.6 Logistic Regression Results 20

4.0 Discussion 21

4.1 Interpretation of Analysis 21

4.2 Sink and Source Population Dynamics 24

4.3 Extrapolation for Other Species 24

4.4 Errors and Weaknesses 25

4.5 Management Options 25

Page Number

5.0 Conclusions 28

6.0 Acknowledgments 28

7.0 Literature Cited 30

Appendices

Appendix A (Human Activity Census Form) 33

Appendix B (Oystercatcher Monitoring Form) 34

Appendix C (South Core Banks Map) 35

Appendix D (Summary of Oystercatcher Activity) 36

List of Figures

Page Number

Figure 1. South Core Banks, Cape Lookout National Seashore. 2

Figure 2. Cross section of South Core Banks 8

Figure 3. Distribution of total human activity on South Core Banks for the 1995 nesting season 13

Figure 4. Distribution of total human activity on South Core Banks for the 1995 nesting season 13

Figure 5. Type and location of human activity 14

Figure 6. Distribution of human activity from 0800 to 1800 15

Figure 7. Distribution of human activity with respect to the day of the week . 15

Figure 8. Distribution of nests in the study area 16

Figure 9. Nesting chronology of the American oystercatcher during the 1995 breeding season on South Core Banks 17

1.0 Introduction

Increasing human activity in the coastal environment for recreation and development often leads to detrimental effects for coastal wildlife species (Watson and Kerley 1995). This trend is true for North Carolina's coastline, including Cape Lookout National Seashore (CLNS). Increased activity can lead to the removal, or disturbance, of essential feeding and breeding habitats for coastally breeding bird species, such as the American oystercatcher, *Haematopus palliatus* . Humans expose this species to increased disturbance and intrusion during feeding and at key points during its breeding seasons. The American oystercatcher, a large yet wary shorebird, seems to be very vulnerable to these negative impacts of human activities along the coast. Although the oystercatcher is currently expanding its range due to the elimination of hunting pressure by the Migratory Bird Act, it now may be suffering from loss of habitat and human disturbance (Rappole 1981).

The historical range of the oystercatcher, within the United States, was along the Gulf coast states and the Atlantic coast states, from Florida to Maine (Post and Raynor 1964). Due to extreme hunting pressure, its range was reduced to the southeastern states and the Gulf coast states. Presently, this species is expanding its range and can be found breeding as far north as New York (Zarudsky 1985). Within North Carolina, this species nests in all coastal regions.

CLNS is part of the Outer Banks system of barrier islands on North Carolina's coast (Figure 1). Oystercatchers use CLNS for wintering and breeding grounds. The resource management division at the CLNS is concerned about the effects of human activity within the national seashore on the reproductive success of the oystercatcher. They are particularly concerned about the effects of off-road vehicle usage since this constitutes one of the main recreational activities of the national seashore.

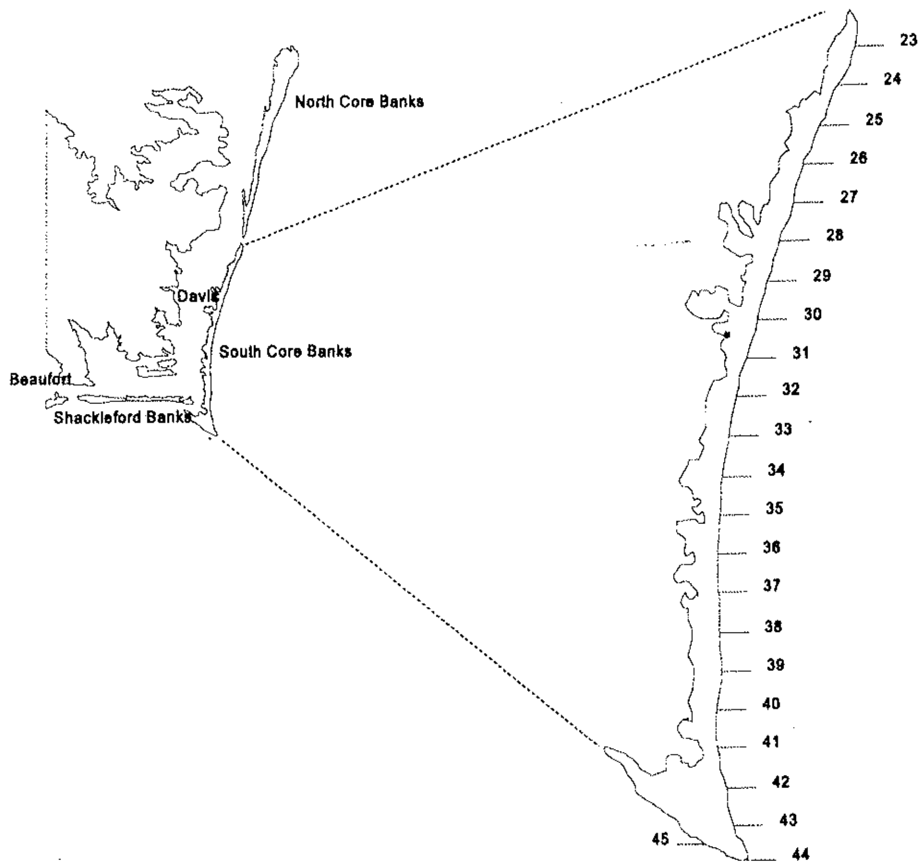


Figure 1. South Core Banks, Cape Lookout National Seashore. The pedestrian ferry dock for the visitor center and the lighthouse is located at mile 41. The vehicle ferry dock for the fish camp is located at mile 30.

1.1 Cape Lookout National Seashore

CLNS is a relatively young member of the National Park System. Two of the three barrier islands that make up CLNS were bought by the North Carolina state government and turned over to the federal government and the third was acquired directly by the federal government. National Seashore status was granted in 1976. It currently consists of three undeveloped barrier islands, representing 57 miles of shoreline, which are located off the coast of North Carolina from Ocracoke Inlet to Beaufort Inlet. The National Park Service administers these lands, as part of a National Seashore. Written into the enabling legislation, in 1966, is the foremost goal of this National Seashore, to preserve an area possessing outstanding natural and recreational values for public use and enjoyment (PL 89 - 366, sec. 4). CLNS has also been designated as an International Biosphere Research Area.

The three barrier islands that comprise this National Seashore are North Core Banks, South Core Banks and Shackleford Banks. These islands are divided by Barden's Inlet and New Drum Inlet. The islands are accessible only by public ferry or private boats. None of the islands have paved roads but North and South Core banks have a primitive back road system. Foot traffic and overnight camping are allowed on all three islands. Vehicle traffic and rental of a limited number of fishing cabins are permitted on North and South Core Banks (EIS 1976). Vehicle use is regulated by a permit system. There is no limit to number of permits issued. Regulations a vehicle user must follow include only using the islands during the months specified on the permit and adhering to "no-drive" zones. These zones include the dune system, posting shorebird breeding areas and posted sea turtle nesting areas. Other structures on North and South Core Banks include leased cabins, an uninhabited historical village, an abandoned coast guard station that serves as an educational center and a United States Coast Guard automated lighthouse (GMP 1982).

The island chosen for this study was South Core Banks. This island is approximately 25 miles in length and extends southward from New Drum Inlet to the Cape Lookout Bight area. This island has a northeast to southwest orientation. The ocean side of the island consists of sandy beaches and a low profile dune system. This coastline is a dynamic system affected by the ocean currents and the prevailing wind patterns. The sound side, or western shore, of this island is a more stable ecosystem which consists of grasslands and salt marshes.

Federally listed endangered and threatened species that use the island have been monitored and documented by the national seashore. These species include several species of nesting sea turtles, bird species such as the piping plover, *Charadrus melodus*, and plant species such as sea beach amaranth, *Amaranthus pumilus*. These species receive legal protection via the Endangered Species Act. Although many other unlisted species are vulnerable to the same threats as the endangered and threatened species, their populations have not been monitored or protected (Burger 1986, Jeffery 1987, Buick and Paton 1989, Hockin *et. al* 1992). Research is needed to identify possible adverse impacts to these species. An example of such a species is the American Oystercatcher.

1.2 Research Needs

The American oystercatcher has been identified by CLNS as a species that needs further research to estimate effects of human recreational activity (Jeff Cordes, Biological Technician, CLNS, personnel communication). This species requires breeding areas with large expanses of relatively undisturbed sandy shores and tidal flats. This requirement is often at odds with the recreational users of the national seashore, especially off-road vehicle users. The main recreational activity on South Core Banks is surf fishing. This is usually accompanied by high usage of off-road vehicles.

This study was conducted in order to acquire data necessary to quantify human activity, particularly vehicular activity, and to estimate the reproductive success of the American oystercatcher. With this information, an analysis was done to identify any correlation between human activity and reproductive success. Using these results, management options were suggested.

1.3 Oystercatcher Natural History

Oystercatchers are territorial and usually solitary birds, but they can be seen in scattered pairs or small flocks, especially in winter (Ehrlich *et al.* 1988). Oystercatchers feed in the tidal zones, muddy or sandy flats and salt marshes (Ehrlich *et al.* 1988). They feed mainly on large visible prey (Nol 1989), including mollusks, worms, echinoderms and crustaceans (Richards 1988). The oystercatcher is considered a resident bird in North Carolina, although the species will form groups in the winter and move away from its breeding grounds (Peterson 1980).

The oystercatcher nests only in coastal regions (Peterson 1980). It establishes breeding territories in early spring. In mid-spring, the oystercatcher lays 2-3 spotted, buff-colored eggs in a scrape, or depression, in the sand. The incubation period lasts approximately 3-4 weeks and the young stay with the adults for approximately four weeks or, oftentimes, much longer (Ehrlich *et al.* 1988). This extended period enables the young to observe the adult birds and learn how to search for and capture prey, an essential skill for hatchling survival. Other essential skills for survival include being able to run from predators or squat in the sand, camouflaging themselves from predators. The latter often exposes the hatchlings to more danger if they squat in the pathway of an oncoming vehicle.

The lifespan of an oystercatcher is not well documented. The longevity record for a wild oystercatcher is 14 years (R.B. Clapp *et al.* 1982). Oystercatchers are believed to begin breeding at three to six years of age. After their first breeding, adult oystercatchers can be expected to live an average of ten years (Newton 1989). Mortality rates are highest for chicks, both during their fledgling stage and their first winter (Kersten and Brenninkmeijer 1995). It is thought that adult oystercatchers are subject to the same mortality rate every year during adulthood. Adult oystercatchers usually succumb to disease, predators, weather and poor food supply, rather than old age (Kersten and Brenninkmeijer 1995).

Oystercatchers select a breeding territory and defend it throughout the breeding season. A breeding, or nesting, territory is selected mainly for its accessibility to the salt marshes and the ocean (Ens *et al.* 1992). The birds depend on both resources for food. The easier the access is to plentiful food resources, the better equipped the parents are to raise young successfully (Nol 1989). Other factors used for picking a territory may include proximity to other oystercatchers, quality of the beach and dune ecosystems, and human disturbance.

Timing of the breeding season seems to coincide mainly with food availability. It has been noted that the earliest and first clutches of the oystercatcher may be more successful (Ens *et al.* 1992). This may be attributed to a variety of reasons including food availability, predator populations, weather and human activity levels. A good territory appears to be one that allows the parents to spend more time watching over the eggs and the brood instead of flying to feeding areas and defending against predators (Nol 1989).

2.0 Methods

2.1 Summary of Methods

The oystercatcher population on South Core Banks was monitored from April 15 through July 15, most of the breeding season. Data collection included estimated dates of laying, hatching, fledging and mortality of the oystercatcher. Size of clutch, number of chicks and location of the nest were also recorded. Some behavior was recorded and used to help to determine the condition of the eggs and the chicks and to understand the needs of the oystercatcher better.

Human activity was documented by recording type and location of human usage on South Core Banks. These surveys were conducted six days a week at varying times. This cycle provided a summary of human activity throughout the week and for most daylight hours.

An exploratory analysis of the raw data was done to look for any obvious trends in oystercatcher breeding biology and distribution of human activity. A timing analysis was done to elucidate the effects of days with high levels of human use on rates of egg and hatchling mortality. Logistic regression methods were used to explore influential factors affecting fledging success.

2.2 Study Area

The study area is located on South Core Banks (Figure 1), from the northern tip of the island, approximately mile 22.5, to the southern tip of the island, approximately mile 46. The areas surveyed were divided into the following habitats: the beach, the beach/dune boundary, the dunes and the backroad (Figure 2). The total area of this study includes a stretch of island approximately 23.5 miles long and usually less than 0.25 mile wide.

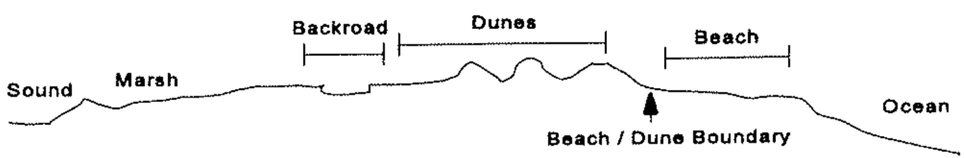


Figure 3. Cross section of South Core Banks. This shows the division of each mile section into beach, beach/dune boundary, dune and backroad for purposes of the study.

The island is divided into approximately 24 one-mile sections. These mile sections are measured and posted by the National Park Service. The main purpose of measuring and posting the mile sections is for orientation for recreational users of the beach. These mile sections were used to divide the study area for both human censuses and bird surveys. Miles 46 through 48 were eliminated from the study. These areas were not representative of oystercatcher habitat. They were also closed to vehicle traffic and therefore were not subject to the same human disturbances. Although not included in the human census, this area was checked periodically for oystercatcher activity.

The time frame of this study was based on the breeding season of the oystercatcher. Birds began to pair and pick nesting territories in March. Nests were first laid in mid-April and surveying began April 20. It was assumed that 90% of nesting and rearing was completed by mid-July, therefore surveying ended July 15. This assumption was based on a review of various studies that observed the reproductive phenology of the American oystercatcher (Bent 1929, Ehrlich *et al.* 1988, Nol 1989, Richards 1988, Lauro *et al.* 1992).

2.3 Human Census

Human censuses were conducted throughout the same period as the oystercatcher monitoring. They were completed by recording amount and type of human activity along a transect through each mile section along the beach front. They were scheduled in order to measure human activities throughout the day. Censuses took place between 0800 and 1800, lasting approximately two hours. The censuses were conducted Tuesdays through

Sundays, with no surveying on Mondays. The censuses were varied in starting points to account for directional bias (Appendix A).

Using an all-terrain vehicle, or ATV, the entire length of the study section was driven during the two-hour census period. Within each mile section, amount, location and types of activity were recorded. Location of activity within each mile section was described as either beach, beach/dune boundary, dune or backroad (Figure 2). Type of activity was characterized as either person, vehicle, ATV or tent. Each activity was classified as either moving or stationary. This classification was not used in the final analysis because all activities were assumed to provide disturbance to the oystercatchers.

2.4 Oystercatcher Monitoring

Pairs of oystercatchers display territorial behaviors such as distinct alarm calls and piping displays that are meant to distract, or lure away, potential predators, including humans, from the nest site or their young (Richards 1988). These behaviors were used to identify potential breeding territories. Trails of oystercatcher footprints were also clues as to the nest location. After the initial location of a nest, it was only viewed and monitored from afar with the aid of binoculars and a spotting scope. This was done to minimize human disturbance of the nest and human marking or scenting of the nesting area (Major 1990). Once located, a nest history was started and data collection began. Information collected included date of discovery, date of hatching, estimated laying date, date of mortality and possible causes, and date of fledging or hatchling mortality with possible causes (Appendix B).

Fledging success and hatching success rates were calculated. Hatching success is defined as the percentage of eggs that hatch. Fledging success is defined as the percentage of hatchlings that make it to fledging age. As in many field studies, nests are usually never found at the exact start of nesting (i.e., after eggs are laid, after eggs have hatched, etc.). In order to account for these missing data, estimates for probabilities of egg survival and hatchling survival can be calculated using the Mayfield method (Mayfield 1961).

2.5 Statistical Analysis

The analysis of the data was completed using three main methods. A graphical analysis of the raw data was done. The purpose of this was to identify any obvious trends in oystercatcher reproductive success or human activity. Within the examination of the raw data, hatching success and fledging success were also calculated. These trends were used to better understand the threats to the oystercatchers and to choose a statistical analysis.

A temporal analysis was also completed. This analysis examined the effects of high levels of human activity on egg or hatchling mortality on specific days. A Student's t-test was used to compare the mean number of mortality events between weekends and weekdays. This analysis was done using Lotus 1-2-3 for Windows.

Logistic regression was used to estimate the probability of a successful nest as a function of different levels and types of human activity. Logistic regression was also used to estimate the probability of egg and hatchling mortality as a function of days with high levels of human usage.

Unlike linear regression models, R^2 values are not readily calculated for logistic regressions. A pseudo R^2 value has been proposed (Aldrich and Nelson 1984) using the equation $X^2 / X^2 + n$, where X^2 (chi-squared) is the test statistic for the null hypothesis and n is the sample size. This value can used to interpret the relative fit of the model. A more common way to interpret a logistic regression is to use estimated likelihood (L), calculated from the estimated coefficients, to calculate an odds ratio (O) (Hamilton 1992). The equation to calculate the odds ratio is $O = e^{L}$. This analysis was done using S-Plus 3.1 for Windows.

3.0 Results

3.1 Human Activity - Spatial Distribution

Distribution of human activity on the island was based upon the recreational preferences of users and access points to the island. The highest total activity levels can be found near the fishing camp (where the vehicle ferry dock is located), the lighthouse (where the pedestrian ferry dock is located), and the two tips of the island (which are popular fishing destinations) (Figures 3 and 4). Total activity was reclassified into low (<50 observations) and high (>51 obs.) use groups, which were used in the temporal analysis. This classification was useful in separating the effects of weekend and weekday activity levels and the effects on oystercatcher reproductive success. This classification was chosen to emphasize the need for management to protect birds during high visitor days, which are usually weekends.

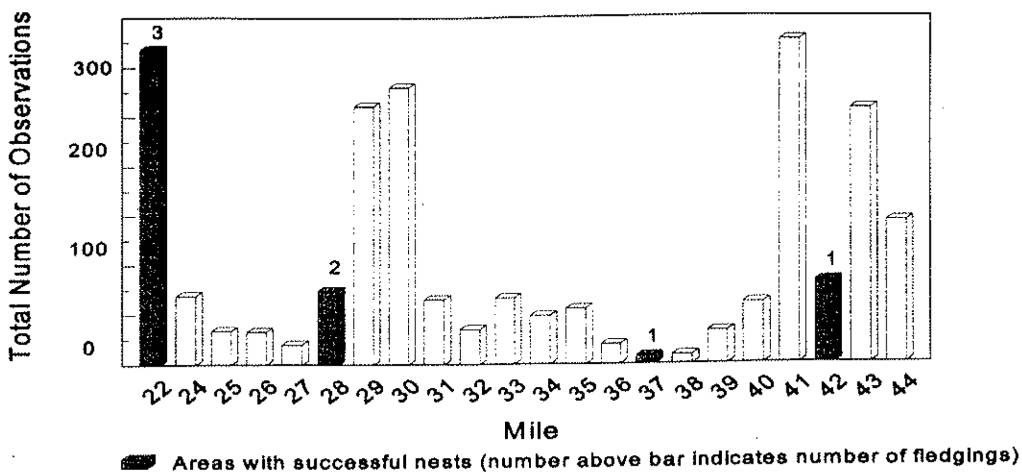


Figure 3. Distribution of total human activity on South Core Banks for the 1995 nesting season. Shaded bars show areas with successful nests, which occur predominantly in low use or protected areas. Protected areas were located within miles 22 and 42.

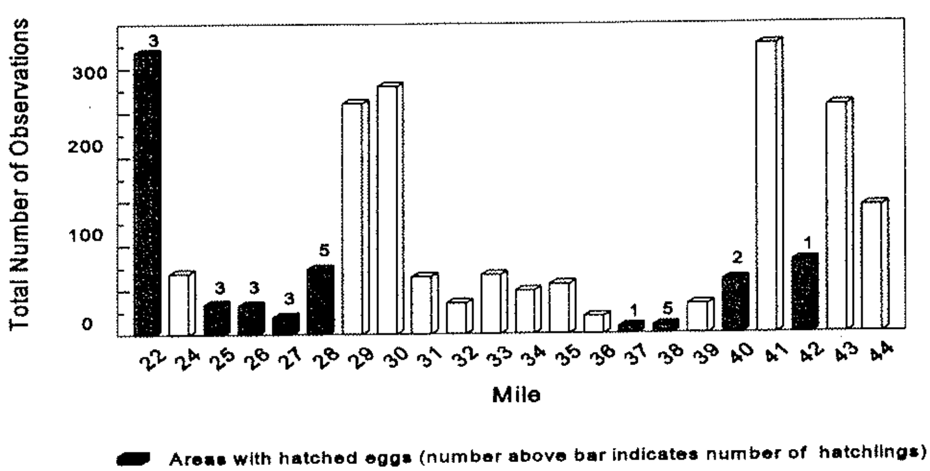


Figure 4. Distribution of total human activity on South Core Banks for the 1995 nesting season. Shaded bars show areas that had hatched eggs which, occur predominantly in low use or protected areas. Protected areas were located within miles 22 and 42.

3.2 Human Activity - Temporal Distribution

Human activity was concentrated mainly along the beach front as opposed to the beach/dune boundary, dunes or backroads (Figure 5). This was true for all types of activities except tents, which were highest in the dunes. The backroad system is rarely used for any types of activities. Most human activity was pedestrian use, followed by vehicle use, all-terrain vehicles (ATV's) and then camping.

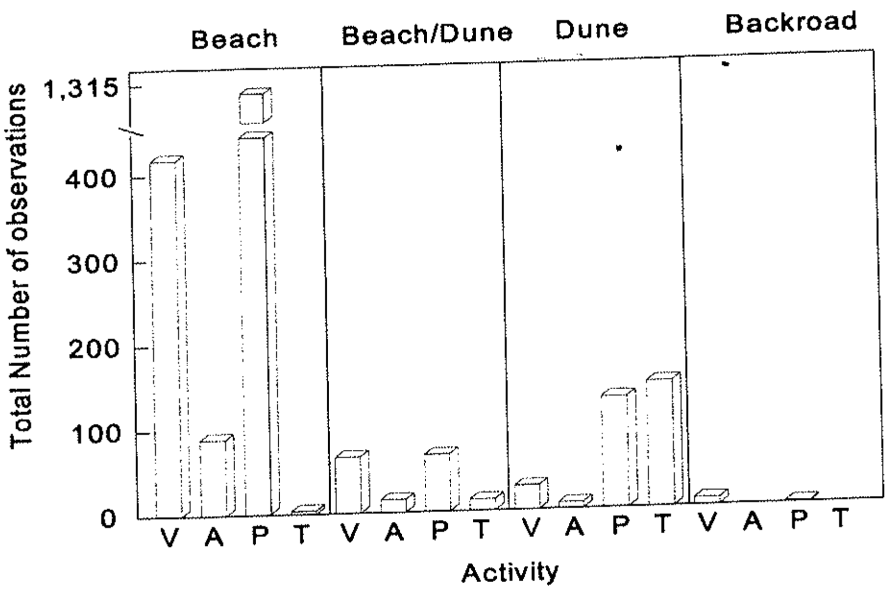


Figure 5. Type and location of human activity. The x-axis represents the type of activity with V = vehicle, A = all-terrain vehicle, P = pedestrian and T = tent.

Human activity was distributed fairly evenly throughout the day. There was slightly less activity from 0800 through 1200 as compared with 1200 through 1800 (Figure 6). There was also an increase of activity on the weekends, which includes Fridays, Saturdays and Sundays (Figure 7). Since there was little variation in activity

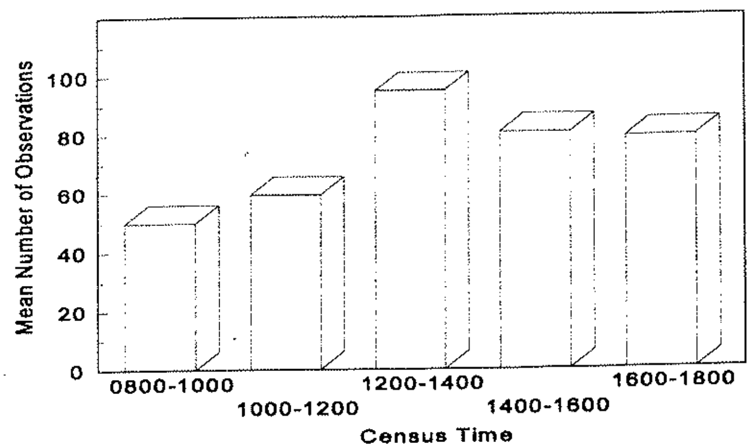


Figure 6. Distribution of human activity from 0800 to 1800.

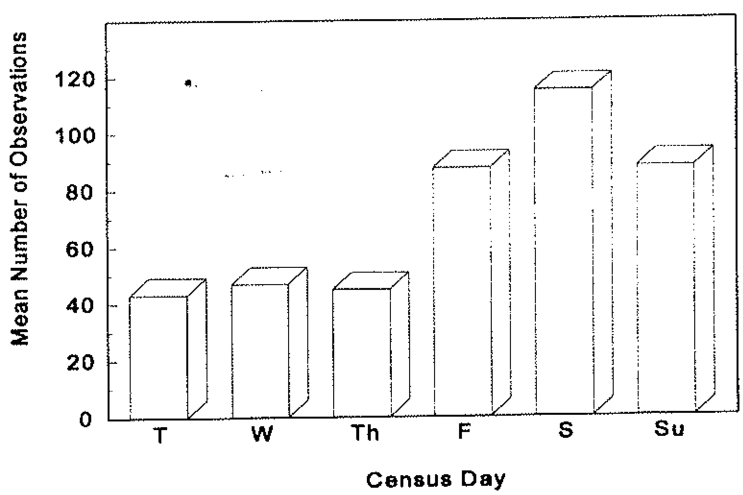


Figure 7. Distribution of human activity with respect to the day of the week. The x-axis represents days of the week with T = Tuesday, W = Wednesday, Th = Thursday, F = Friday, S = Saturday and Su = Sunday..

levels at different times of the day, the day of the week when activities occurred was used to assess effects on reproductive success.

3.3 Oystercatcher Reproductive Success

Oystercatchers paired up and began picking nesting territories in mid to late March. Territories were approximately evenly distributed along the study area (Figure 8). Most territories were approximately 0.5 mile from the adjoining territory. By April 20, oystercatchers had begun to lay the first clutch of eggs. The oystercatcher population, as a whole, had three main periods of egg-laying throughout the breeding season (Figure 9).

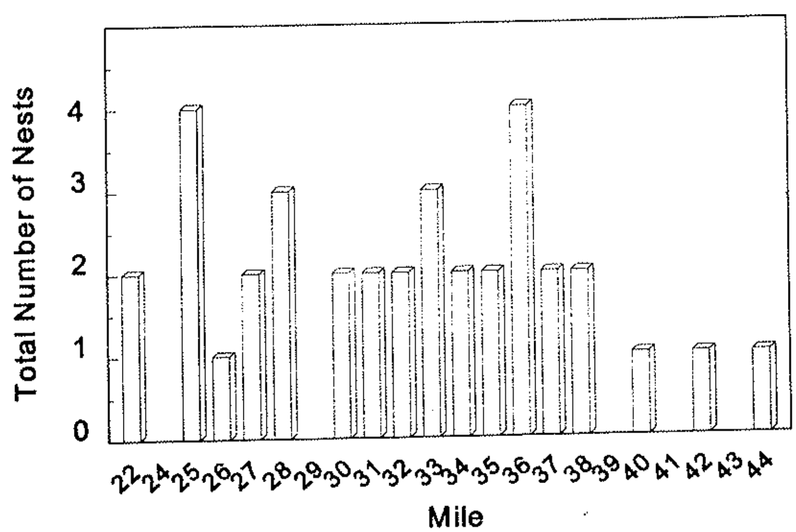


Figure 8. Distribution of nests in the study area.

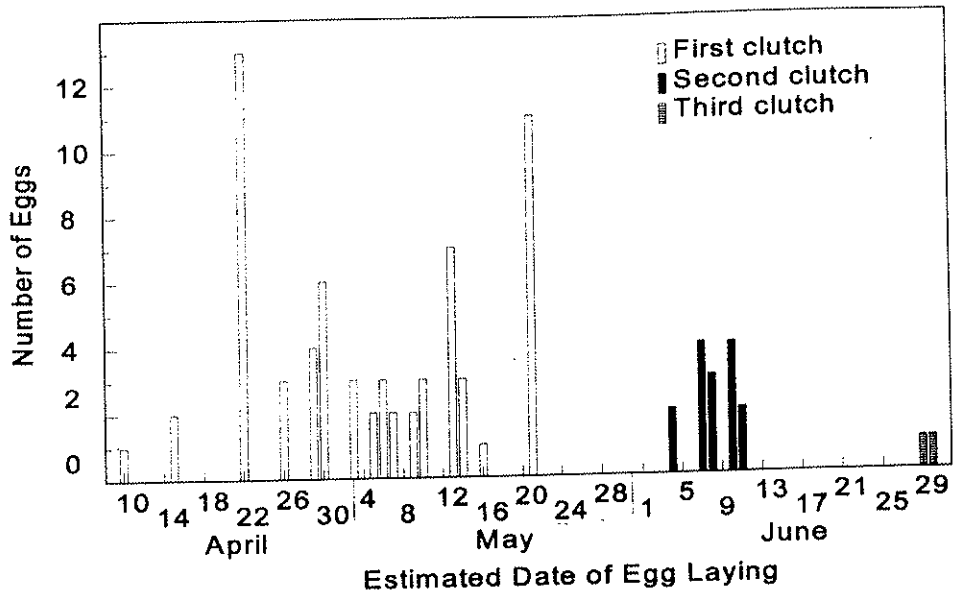


Figure 9. Nesting chronology of the American oystercatcher during the 1995 breeding season on South Core Banks.

The total number of nests within the study area was 36, with a total of 89 eggs. The nests had an average clutch size of 2.41 eggs. Total number of hatched eggs, or hatchlings, within the study area was 30. Hatchlings were not distributed evenly. They were clustered in areas of relatively low use (Figure 4). The hatching success for this population was approximately 34%. The fledging success for this population was 23.3%, which represents the seven birds that successfully made it from hatchling age to fledging age. Fledglings were not distributed evenly but were found in low use or protected areas (Figure 3). The percentage of eggs that became fledglings compared with the total number of eggs was 7%.

Egg mortality was approximately 65% and hatchling mortality was 76.7%. The causes are not well documented. Probable causes of egg mortality are raccoon predation, feral cat predation, avian predation, weather and/or high tides, disease and human disturbance. Causes of hatchling mortality were even less clear, except direct human-caused mortality. At least five hatchlings (16.7%) were run over by off-road vehicles. These hatchlings were found in tire tracks.

As in many field studies, nests are usually never found at the exact start of nesting (i.e., after eggs are laid, after eggs have hatched, etc.). In order to account for these missing data, estimates for probabilities of egg survival and hatchling survival can be calculated using the Mayfield method (Mayfield 1961). A modified version of the Mayfield method, as described in Bart and Robson (1982), was used to estimate daily survival rate (DSR) of eggs and hatchlings, from which the survivorship during an interval of any length can be estimated. Length was defined as the number of days between observations of eggs and/or chicks.

The results from these calculations show a probability of egg survival for the 28 day incubation period as 5%. This can be compared to the 35% hatching success calculated above. The Mayfield number is lower because it takes into account unobserved egg mortality. This is probably a more realistic percentage. The probability of hatchling survival (a hatchling reaching 35 days old or fledging age) was calculated as 7% using the Mayfield method. This can be compared to 23.3% fledging success calculated above. The difference, again, can be attributed to unobserved hatchling mortality. Nest survival from the start of incubation to fledging was calculated to be

0.33%. This can be compared to 7% calculated above. This new estimate may represent a more realistic picture of the reproductive success of the oystercatchers on South Core Banks.

3.4 Relationship Between Temporal Use and Reproductive Success

The timing analysis looked at the effects of specific high use days on egg and hatchling mortality. Weekdays were low use days and weekends were high use days. Most egg and hatchling mortality occurred on weekends as compared with weekdays. Egg mortality was determined to be significantly higher on weekends (45%) compared with 16.9% on weekdays (Student's t-test, $p = 0.047$). A similar, yet weaker, trend was observed in hatchling mortality. Hatchling mortality was 40% on weekends compared with 30% on weekdays (Student's t-test, $p > .10$, n.s.).

3.5 Relationship Between Spatial Use and Reproductive Success

This analysis looked at total activity per mile section and the reproductive success of nests within that mile section. Areas that fledged young successfully were characteristically in low use areas (Figure 3). Successful nests in high use areas, miles 22- 24 and 42 -43, are posted as protected areas, or "no drive" zones. These "no drive" zones were in place for nesting sea turtles and colonial nesting shorebirds. Protected areas for colonial birds were posted but human activity was allowed to occur up to and around the signs. This allowed small areas of the mile section (beach/dune boundary and dune systems) to be free from vehicular activity without hindering human activity within that section of beachfront. Areas protected for sea turtles allowed only foot traffic into these areas.

3.6 Logistic Regression Results

A logistic regression was used to estimate the probability of fledging success with respect to type and amount of activity. Through exploratory analyses, high levels of human activity, vehicular usage within the beach zone and protected areas ("no-drive" zones) were shown to be influential factors. Sample size (n) for both models is 37 nests. For each model, protected status (x) was entered first into the logistic regression.

The first model estimated the probability of a successful nest as a function of total activity and protected areas. The regression equation for this model is P(Success) = -2.61 +9.49*x + 0.01*y, where x = protected status and y = level of total human activity. Protected status is classified as either protected (1) or not protected (0). Total human activity has a p-value of 0.08.

The second model estimated the probability of a successful nest as a function of vehicle use and protected areas. The regression equation for this model is P(Success) = -3.86 +11.10*x + 0.26*y, where x = protected status and y = level of vehicular activity. Vehicle use has a p-value of 0.02.

In both models, there is a weak relationship between successful nests and human activity. The pseudo R^2 value for the total activity model is 0.39. For the total activity model, the odds ratio for total human activity level is 1.01 and the odds ratio for protected status is 13174. With all other variables fixed, the odds of having a successful nest are multiplied by 1.01 with each additional observation of human activity. With all other variables fixed, the odds of having a successful nest are multiplied by 13174 when a nest is located in a protected area.

The pseudo R^2 value for the vehicle use model is 0.35, showing a slightly worse fit than the total activity model. For the vehicle use model, the odds ratio for total human activity level is 1.29 and the odds ratio for protected status is 66452. With all other variables fixed, the odds of having a successful nest are multiplied by 1.29 with each additional observation of human activity. With all other variables fixed, the odds of having a successful nest are multiplied by 66452 when a nest is located within a protected area. Due to the small sample size, the odds ratios for protected status have become inflated. Although there is an exaggeration, one can see that nests located within protected areas have a much higher probability of being successful than those that are not within protected areas. The effect of protected areas is more influential than levels of human activity.

4.0 Discussion

4.1 Interpretation of Analysis

The main constraint of this analysis is the small sample size of both the oystercatcher reproductive success and human activity data. The oystercatcher sample size consists of approximately 40 nesting activities over one breeding season. The human activity data provides an initial estimate of human use on South Core Banks during the months of April, May, June and July. These limits allow only a glimpse into the reproductive success of the oystercatcher and possible factors influencing it.

The reproductive success, or fecundity, of the American oystercatcher seems to be very variable from year to year for the species as a whole. Hatching and fledging rates for South Core Banks are 35% and 23%, respectively. Using the Mayfield method estimates, these percentages are lowered to 5% and 7%, respectively.

Fledging success rates from similar studies were used as a comparison for the Cape Lookout population. The following studies did not use the Mayfield estimation method. In a Virginia study, in some years pairs will produce no young while other years the same pair will produce up to three young (Nol 1989). Nol (1989) cites the mean percentage success of hatching a chick as 14.0%, with a fledging success of approximately 25%. A study in New York reports a range of 54% to 80% fledging success for oystercatchers (Zarudsky 1985). Kersten and Brenninkmeijer (1995) report low reproductive success of oystercatchers, with only one out of four hatchlings fledged successfully. The range of hatching success and fledging success could be due to food supply, predator levels, weather conditions or levels of human disturbance for each study area and for each season.

Since CLNS has no shortage of habitat for oystercatchers, there are probably other reasons why the reproductive success was low for this breeding season. South Core Banks experiences pulses of human activity associated with weekends and holidays. Although no direct human destruction of eggs was observed, I believe that these increased levels of human activity cause the birds to flush from their nests more often and for longer periods compared to days with low levels of human activity. This increases the chances of the eggs succumbing to hyper- or hypothermia and predators (Anderson and Keith 1980).

South Core Banks supports a population of raccoons and feral cats. Based on observational data, the prints of these two species were often found adjacent to recently destroyed and predated eggs. I feel that the raccoon population may be artificially elevated due to increased food supply from humans. Raccoons could be seen routinely eating out of the dumpsters and being fed by humans at the fishing camp. Feral cats are a non-native species and a lethal threat to all bird populations on the island. These animals are a result of human introduction and were observed in greatest numbers near the fishing camp.

One of the most promising results of the analysis is the apparent positive effect of protected areas on the reproductive success of the oystercatcher. Two successful nests occurred in areas that were subject to extremely high levels of human activity. The difference was that these pairs were nesting within an area posted for colonial nesting shorebirds and within an area posted for nesting sea turtles. Although the human activity was high and nearby, the nests did not suffer from pedestrian, vehicle, ATV or tent usage right next to their nests. I believe that this allowed the birds to incubate their eggs and brood their young without as much disturbance as unprotected nest sites. This may have contributed to their success.

4.2 Sink and Source Population Dynamics

The American oystercatcher population within the United States is currently expanding its range. This expansion suggests that there may be both sink and source populations. A source population provides migrants to colonize new areas or augment sink populations, which are populations that do not meet their replacement needs.

The oystercatcher population on South Core Banks is just barely replacing itself, based on the observed 23.3% fledging success, ten years of available breeding for an adult bird, and high mortality for first year birds. If this replacement is based on the more realistic Mayfield estimate of 7%, this population seems to be acting as a sink for the 1995 season. Mortality rates for the European Oystercatcher (*Haematopus ostralegus*) have been estimated at 50 -60 % for first year birds and 5% for all other birds (Kersten and Brenninkmeijer 1995). No exact figures on population growth can be calculated, but the Cape Lookout population is probably not providing migrants for the expansion of the United States metapopulation of this species. Although I do not believe that the CLNS population is a sink, neither does it appear to be a source. This issue should be investigated further. As undeveloped coastline becomes increasingly rare, it should provide sanctuary where breeding species can flourish.

4.3 Extrapolation for Other Species

American oystercatchers share breeding characteristics with other solitary nesting shorebirds, such as the Wilson's plover (*Charadrius wilsonia*) and the willet (*Catoptrophus semipalmatus*). After their young are born, they also share breeding characteristics with colonial nesting shorebirds, such as the piping plover and various species of terns (*Sterna sp.*). These species use the beach-front extensively for part of their breeding season for either nesting, rearing their young, feeding or resting. Using the information from this study and other studies done for shorebirds on CLNS, management plans can be updated to protect these birds. By identifying crucial times during the breeding season and sensitive locations on the island, managers can better regulate human activity to accommodate these times and locations.

4.4 Errors and Weaknesses

Possible weaknesses and errors of this study include the small sample size, unobserved nesting activities, unobserved egg and chick mortality, and lack of certain details of human activity. Other human activity characteristics that could be collected include nighttime activity levels, better sampling of moving vehicles and more detailed activity information for each mile section with respect to nest location. These problems may have made the statistical analysis less powerful, but the qualitative results provide a good basis for assessing the reproductive success of the oystercatcher on South Core Banks in the 1995 nesting season.

4.5 Management Options

There are many things that could increase the reproductive success of the oystercatcher; the following suggestions are based on the budgeting and personnel constraints of CLNS and the National Seashore goal of providing recreational opportunities. A ban of vehicle use is not feasible because of the enabling legislation and public outcry over a vehicle ban (EIS 1982). Godfrey and Godfrey (1976) state that recreational uses have to be compatible with the island environment and that trying to make the island meet all desired uses will destroy the resource. With these constraints and thoughts, the following are my management suggestions.

Using existing educational resources, recreational users can be made aware of the problems facing solitary nesting birds on the island. By incorporating bird breeding information into existing interpretative programs and targeting these programs toward off-road vehicle users, visitors can be better informed. From informal interviews, I found that most off-road vehicle users were not aware that they were disturbing birds or running over chicks.

In place at both ferry docks on South Core Banks are outdoor wooden placards. Perhaps adding more information on solitary nesting bird activity would enlighten more recreational users. Another suggestion would be to create a small educational pamphlet including information on protecting nesting bird populations to be handed to the recreational user when the user registers an off-road vehicle. This pamphlet could target the direct effects of off-road vehicle use on the reproductive success of nesting birds and suggest ways for the off-road vehicle user to have lower impact.

Overall, only small portions of the island routinely have high levels of human use. I think that much of the disturbance to the birds is caused by recreational users driving to these "hot-spots" for surf fishing. Both ends of the islands seem to be very popular destinations for surf fishing. The vehicle ferry is approximately midway between these points.

Possible suggestions for lowering the impact of driving to these "hot-spots" could include directing the traffic to the backroad system and enforcing speed limits. There is virtually no human use of the backroad system. I believe that confining the vehicles to the backroad, at least during the height of the shorebird breeding system, would lessen the amount of human beach use and, thereby, lessen the human impact on oystercatcher reproductive success. There is also a National Seashore speed limit of approximately 30 miles per hour. This is rarely, if ever, enforced. Enforcing this existing regulation, or lowering the speed limit, would give the birds more time to run from oncoming vehicles so they are not forced to squat in place, usually in the path of the oncoming vehicle.

Another suggestion would be to limit nighttime activity. During a few informal surveys at night, there is much bird activity on the beachfront during the nighttime hours. Off-road vehicle users have no way of seeing eggs or chicks in the dark. Restricting nighttime activities might decrease egg and chick mortality.

There seems to be a decrease in surf fishing in late May, June and early July. The main surf fishing seasons seem to be in early spring and fall. This period of decreased activity coincides with the oystercatchers', and other shorebirds', breeding season. I feel that stricter regulation of off-road vehicles during this season would not be met with many complaints compared with the height of the surf fishing season. Overall, I feel that existing "no-drive" zone regulations and other regulations protecting nesting birds (i.e., no harassing, collecting, etc.) could be enforced better, giving better protection to nesting shorebirds.

With respect to predator populations, it is debated whether the raccoon is an introduced species. If considered a native species, there is little that can be done about its population numbers. National Seashore policy does not encourage manipulation of native predator population numbers. In contrast, feral cats are definitely an introduced species and should be eradicated humanely.

5.0 Conclusions

The results of this study indicate that the most significant factors adversely affecting American oystercatcher reproductive success on South Core Banks are days with high levels of activity (weekends) and human activity on the beachfront. In contrast, protected areas show a positive effect on the reproductive success of the oystercatcher population. Although Cape Lookout National Seashore must provide public recreational opportunities, slight changes in their management strategies could increase oystercatcher, and other shorebird, reproductive success without disrupting traditional human activities.

6.0 Acknowledgments

This study was conducted with permission and assistance from Cape Lookout National Seashore. I would like to Dr. Michael Rikard and Mr. Jeff Cordes for providing housing, transportation and field assistance. I would also like to thank Dr. David Higdon and Ms. Jenise Swall, from the Institute for Statistics and Decisions Sciences at Duke

University. Also deserving of thanks is Dr. Lynn Maguire, my advisor, who reviewed many versions of my proposal and draft for this project. Finally, I want to thank my fiance, Chuck Nace. This project would have not been a success without his continued support and hard work.

7.0 Literature Cited

Aldrich, John H. And Forrest D. Nelson. Linear Probability, Logit, and Probit Models. Beverly Hills, CA: Sage; 1984.

Anderson, Daniel W. and James O. Keith. 1980. The human influence on seabird nesting success: conservation implications. Biological Conservation 18: 65-80.

Barbee, Eric A. Effects of human disturbance on shorebird populations of Hatteras, Ocracoke, and North Core Banks, North Carolina. Wilmington: University of North Carolina at Wilmington; 1994. Thesis.

Bart, Jonathan and Douglas S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63(4):1078-1090.

Bent, Arthur Cleveland. Life Histories of North American Shorebirds. Washington: United States Government Printing Office : 1929.

Cape Lookout National Seashore, NC. February 1978. Environmental Impact Statement (EIS). Denver Service Center, National Park Service, United States Department of the Interior.

Cape Lookout National Seashore, NC. December 1982. Final Environmental Impact Statement (EIS). Denver Service Center, National Park Service, United States Department of the Interior.

Cape Lookout National Seashore, NC. December 1982. General Management Plan (GMP)/Development Concept Plan. Denver Service Center, National Park Service, United States Department of the Interior.

Clapp, R.B. *et al.* 1982. Longevity records. Journal of Field Ornithology 53(2): 110-111.

Cordes, Jeff and Michael Rikard. Cape Lookout National Seashore 1995 Sea Turtle Monitoring Program. Cape Lookout National Seashore, Harker's Island, NC.

Cordes, Jeff. Biological Technician. Cape Lookout National Seashore, 131 Charles Street, Harker's Island, NC. Personal communication, March 1995.

Ehrlich, Paul R., David S. Dobkin and Darryl Wheye. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. New York, NY: Simon and Schuster, Inc.; 1988.

Ens, Bruno J., Marcel Kersten, Alex Brenninkmeijer and Jan B. Hulscher. 1992. Territorial quality, parental effort and reproductive success of Oystercatchers (*Haematopus ostralegus*). Journal of Animal Ecology 61: 703-715.

Godfrey, Paul G. and Melinda M. Godfrey. Barrier Island Ecology of Cape Lookout National Seashore and Vicinity, North Carolina. Washington, D.C.: U.S. Government Printing Office; 1976.

Hamilton, Lawrence C. Regression with Graphics: A Second Course in Applied Statistics. California: Duxbury Press; 1992.

Kersten, Marcel and Alex Brenninkmeijer. 1995. Growth, fledging success and post-fledging survival of juvenile Oystercatchers (*Haematopus ostralegus*). Ibis 137: 396-404

Lauro, Brook and Joanna Burger. 1989. Nest-site selection of American Oystercatchers (*Haematopus palliatus*) in salt marshes. The Auk 106: 185-192.

Lauro, Brook, Erica Nol, and Mark Vicari. 1992. Nesting density and communal breeding in American Oystercatchers. The Condor 94: 286-289.

Major, Richard E. 1990. The effects of human observers on the intensity of nest predation. The Ibis 132: 608-612.

Mayfield, Harold. 1961. Nesting success calculated from exposure. Wilson Bulletin 73(3): 255-261.

Newton, Ian, ed. Lifetime Reproduction in Birds. London: Academic Press; 1989.

Nol, Erica. Reproductive Strategies in the Oystercatcher (Aves: Heamatopodidae). Toronto, Ontario: Department of Zoology, University of Toronto; 1984. Dissertation.

Nol, Erica. 1989. Food supply and reproductive performance of the American Oystercatcher in Virginia. The Condor 91: 429-435

Peterson, Roger Tory. Peterson Field Guides: Eastern Birds. Boston, MA: Houghton Mifflin Company; 1980.

Post, Peter. 1960. The American Oystercatcher in New York. The Kingbird 11:3-6.

Post, Peter W. and Gilbert S. Raynor. 1964. Recent range expansion of the American Oystercatcher into New York. The Wilson Bulletin 76(4): 339-346.

Rappole, John H. Management Possibilities for Beach-Nesting Shorebirds in Georgia. 1981. Proceedings of the Nongame and Endangered Wildlife Symposium. Georgia Department of Natural Resources, Technical Bulletin WL 5.

Richards, Alan. Shorebirds: A Complete Guide to Their Behavior and Migration. New York, NY: Gallery Books; 1988.

Robertson, Raleigh J. and Nancy J. Flood. 1980. Effects of recreational use of shorelines on breeding bird populations. The Canadian Field-Naturalist 94(2): 131-138.

Shields, Mark A. and James F. Parnell. 1990. Marsh Nesting of American Oystercatchers in South Carolina. Journal of Field Ornithology 61(4):431-433.

Watson, Justin. Effects of Vehicle Use on Shorebirds. Port Elizabeth, Republic of South Africa: University of Port Elizabeth; 1995. Thesis.

Zarudsky, John. 1985. Breeding Status of the American Oystercatcher in the Town of Hempstead. The Kingbird 35:105-113.

APPENDIX A

School of the Environment
Duke University
Durham, NC 27705

Beach Census Form

Date: ___/___/___ Time Begin: ________ Time End: ________

Mile	Beach							Beach/Dune Boundary							Dune							Backroad						
	VM	VS	AM	AS	PM	PS	T	VM	VS	AM	AS	PM	PS	T	VM	VS	AM	AS	PM	PS	T	VM	VS	AM	AS	PM	PS	T
24 to 25																												
25 to 26																												
26 to 27																												
27 to 28																												
28 to 29																												
29 to 30																												
30 to 31																												
31 to 32																												
32 to 33																												
33 to 34																												
34 to 35																												
35 to 36																												
36 to 37																												
37 to 38																												
38 to 39																												
39 to 40																												
40 to 41																												
41 to 42																												
42 to 43																												
43 to 44																												
44 to 45																												

Oystercatcher Monitoring Program
School of the Envrionment
Duke University
Durham, NC 27705

Nest Monitoring Form

Date: ___/___/___

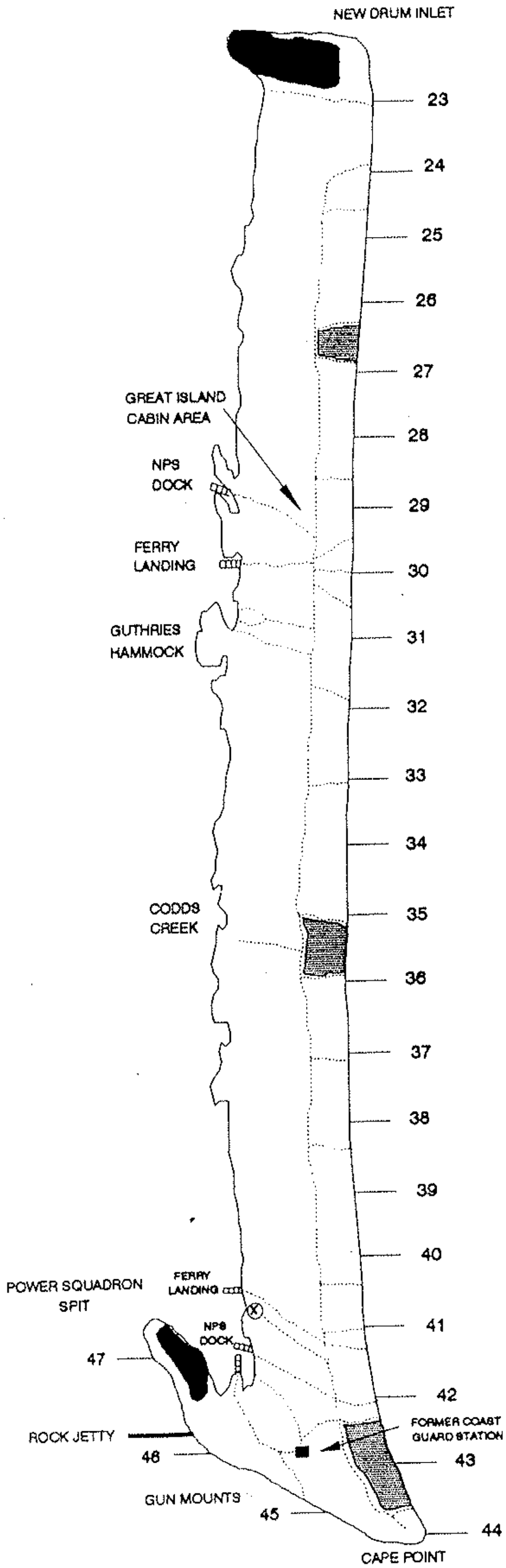
Nest ID Number	Number of Eggs	Number of Chicks	Number of Dead Chicks	Comments

Page ___ of ___

Oystercatcher Monitoring Program
School of the Envrionment
Duke University
Durham, NC 27705

South Core Banks Map

Date: ___/___/___



Comments: ____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

■ ENTRY PROHIBITED APRIL - AUGUST

▒ PEDESTRIAN ENTRY ONLY, CAMPING PROHIBITED JULY - OCTOBER

········ VEHICLE ROUTES

1-47 MILE MARKERS

Page ___ of ___

APPENDIX D

Summary of Oystercatcher Activity

Nest	Date Discovered	Total # of Egg	Observed Date of Predation or Hatching	# of Chicks Hatched	# of Chicks Fledged	Comments
22.5	13-May	4	H - 5/22	2	2	2 eggs never hatched.
23.5	11-Jun	1	H -? (L=4/10)	1	1	1 chick found after hatching
25	13-May	3	P- 6/22			Feral cat tracks, egg shell fragments
25.4	11-Jun	2	P - 6/14			Yolk in nest
25.5	30-Jun	1	P - 7/7			No clues
25.9	30-Apr	3	H - 5/9	3	0	At least 1 chick run over in tire tracks
Ramp 26A	06-May	3	H - 5/16	3	0	At least 1 chick run over in tire tracks
27.5	30-Apr	3	H - 5/17	3	0	At least 2 chicks run over in tire tracks
27.5A	08-Jun	3	P - 6/18			Human footprints around nest, yolk in nest
28.3	30-Apr	3	H - 5/5	3	1	No clues for 2 missing chicks
28.55	21-May	2	P - 6/2			Dried yolk in nest, unidentified mammal tracks around nest
Ramp 28	18-May	2	H - 5/18 (L=4/22)	2	1	No clues for missing chick
30.6	22-Apr	3	P - 5/5			No clues
30.95	29-Jun	1	?			Unsurveyed nest
31.3	07-Jun	2	P - 6/10			Some yolk in nest
31.8	29-Apr	3	P - 5/7			Yolk in nest
32.2	21-May	3	P - 6/7			Storm overwash covered nest site
32.4	21-May	3	P - 6/2			Feral cat prints around nest, dried yolk in nest
33.3	29-Apr	1	P - 5/6			No clues
33.45	05-May	2	P - 5/6			Raccoon tracks around nest site
33.45A	16-May	1	P - 5/19			Yolk in nest
34.15	21-May	3	P - 5/22			No clues
34.4	07-Jun	2	P - 6/23			No clues
35.1	22-Apr	3	P - 5/7			Raccoon tracks around nest site
Ramp 35B	09-May	2	P - 5/25			No clues
36.05	10-Jun	1	P - 6/24			Human prints through nest site
36.3	10-Jun	3	P - 6/16			Yolk in nest
36.4	22-Apr	2	P - 4/29			Raccoon tracks around nest site
36.6	06-May	3	P - 5/20			No clues
37.05	04-Jun	2	P - 6/21			Rain washed out all prints
37.55	14-May	3	H - 5/18	3	1	Raccoon and feral cat prints
38.2	13-May	2	H - ? (L = 4/15)	2	0	2 chicks found after hatching, I chick run over in tire tracks
38.5	01-Jun	3	H - 6/1 (L = 5/3)	3	0	No clues
Ramp 40	07-May	2	H - 5/16	2	0	Raccoon tracks
42.2	21-May	3	H - ? (L=4/22)	3	1	No clues for missing 2 chicks
44	10-May	3	P - 5/20			No clues
46.95	26-Apr	3	P - 4/30			No clues
		89			7	