Abstract

McGowan, Conor P. Factors affecting nesting success of American Oystercatchers (*Haematopus palliatus*) in North Carolina. (Under the direction of Theodore R. Simons)

American Oystercatchers are listed as a "Species of High Concern" by the U. S. Shorebird Conservation Plan, in part because of threats during the breeding season. Oystercatchers nest on the sandy beaches of the East Coast of the United States and their nesting habitat is under increasing threat from human development and human disturbance. In this study, I analyzed 8 seasons of reproductive success data for American Oystercatchers in North Carolina. I identified the primary causes of nest failure and I examined spatial and temporal patterns of hatching success. Hatching and fledging success were very low, but highly variable among years and locations. Mammalian predation accounted for 29% of nest failures, and mammalian predator control would likely increase reproductive success of American Oystercatchers.

I looked closely at the relationship between human disturbance and hatching success. Previous studies at Cape Lookout National Seashore showed that there were negative temporal and spatial associations between human disturbance and oystercatcher nesting success. I measured human disturbance three different ways; daily nest checks, beach surveys of human presence, and video monitoring at oystercatcher nests. I used logistic regression and 2x2 contingency table analyses to test for associations between higher levels of human disturbance and lower hatching success. Contingency table analyses of the daily nest check method showed that higher levels of human disturbance were associated with lower hatching success. There were no associations between human

disturbance and nesting success for the other two measures of disturbance, but the analyses were constrained by small sample sizes and lack of information on the distances to sources of disturbance.

I also tested the hypothesis that parental incubation behavior was a mechanism through which human disturbance lowered hatching success. I used video monitoring to record the behavior of American Oystercatchers during incubation. I calculated the rate of trips to and from the nest, and rate of movements while incubating, and the percent of time spent incubating. I assigned a cause for each trip away from a nest. Twenty-four percent of trips were associated with ATVs, 17% with trucks, 3% with pedestrians, 8% with territorial fighting, and 18% with exchanging incubation duties. I used linear regression to test for correlations between human disturbance and incubation behaviors. I also used logistic regression and 2x2 contingency table analyses to test for associations between varying levels of human disturbance and hatching success. Human disturbance, especially ATV traffic, was associated with more trips to and from nests and less time spent incubating. More frequent trips to and from the nests were associated with lower hatching success. It is probable that human disturbance reduces oystercatcher hatching success by increasing the activity of incubating adults.

FACTORS AFFECTING NESTING SUCCESS OF AMERICAN

OYSTERCATCHERS (*HAEMATOPUS PALLIATUS*) IN NORTH CAROLINA

By

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Chair of Advisory Committee

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Biography

Conor McGowan was born in Long Island, New York on May 26th in 1978. My family moved to London England in 1988 where my sister Colleen and I attended the American School in London. My family returned to Long Island five years later and I attended Garden City High school. I graduated in 1996 and went to Wake Forest University as an undergraduate Biology Major, where I had the distinct honor and pleasure of studying seabirds with Dr. David Anderson. After college, I worked as an intern for the Klamath Bird Observatory and the Maui Forest Bird Recovery Project but I soon returned to North Carolina to study these awesome birds, American Oystercatchers, with Ted Simons. In August of 2003, I married my best friend, Cate.

I have been fascinated with the natural world and wildlife my whole life. My fascination was always encouraged by my loving parents, and was cultivated by my Grandma Connors, My Uncle Harold and my Uncle John. I consider my self a well-rounded person. In addition to wildlife, I have always been fascinated with college basketball, which my father encouraged and cultivated. I am a musician and I play guitar, drums, and the ukulele in a band called Slicing Ginger with my wife.

This thesis took three years to complete, but a lifetime of preparation. I want to thank all of my teachers ever, for educating me. In particular, I am forever indebted to my mother and Mrs. St. Pierre, my childhood tutor in London. Both were instrumental in guiding me through the academic terrors of dyslexia. Without their patience and persistence I probably would have become a mechanic.

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This thesis is dedicated to my Grandmothers, Gertrude Connors and Elizabeth McGowan, who died during the completion of this research, and to my wife Cate.

I'd like to start by thanking my advisor, Ted Simons, for giving me this amazing opportunity. I am deeply indebted to my advisory committee Jaime Collazo and Ken Pollock, who, along with many other professors here at N. C. State, have taught me so much and so well. Thanks to the Zoology Department for supporting me over the last 6 semesters, especially Dr. Mozely and Dr. Heatwole, who I had the pleasure of "working" for over the years as a Teaching Assistant. Special Thanks to Wendy Moore in the NC Coop. Unit, and Susan Marschalk and Tracey Keeler in the Zoology Department. I would also like to thank the National Park Service, the U. S. Fish and Wildlife Service, the U. S. Geological Survey, and the National Audubon Society for financial and logistical support of this research. Special thanks to Michael Rikard, Jeff Cordes, Jon Altman, and Jerald Weaver at Cape Lookout National Seashore, Steve Harrison, Marcia Lyons, Karen Sayles, and Kristen Mazzarella at Cape Hatteras National Seashore, Walker Golder with the National Audubon Society, and the Jeff Hostetler for his assistance in the field and with computer programming. Additionally I'd like to thank the folks at Morris Marina for all their help, support, and jokes over the years, especially Waldo, Sue, Rick, Cari, Steve and Ward.

I could not have done any of this work with out the support of my family. Especially my wife, who let me run off to the beach to "work" three summers in a row, and was invaluable during the arduous task writing all this down, my parents who have always believed in me, my sister Colleen who is always offering to help me with Power

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Point and grammar, and my Uncle John who has been a mentor, coach, and great friend. You guys are the best support network anyone could ever ask for.

Lastly, but certainly not least, I want to thank all my friends, colleagues and co-workers here at NC State: Garth Herring, Sarah Mabey, Bill Pine, John Klimstra, Becky Browning, Caroline Stahala, Jeff Hostetler, Shiloh Schulte, and many others who have made life in Raleigh fun and exciting.

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Chapter 1

Nest monitoring and estimating productivity of American Oystercatchers

(*Haematopus palliatus*) in North Carolina.

Abstract:

In this Chapter I report on all American Oystercatcher nest monitoring data in North Carolina from 1995 – 2003. I estimate hatching success using the Mayfield method for estimating daily nest survival, and I estimate fecundity (chicks fledged/breeding pair) by location and by year. I also report productivity as the number of chicks fledged per clutch initiated, and describe the causes of nest failure and chick mortality.

Nine hundred and ninety six nests were monitored at Cape Hatteras National Seashore, Cape Lookout National Seashore, and Audubon-managed islands near Wilmington, North Carolina. Hatching success was very low and highly variable among locations and among years. The overall Mayfield estimate of daily nest survival was 0.94, and hatching probability was 0.20. Daily nest survival was lowest at Cape Lookout, intermediate at Cape Hatteras, and highest at Audubon managed sites. Mammalian predation accounted for 29% of nest failures. Overwash or weather accounted for 14% of nest failures and 7% were lost to a variety of other factors. The cause of the remaining 51 % of nest failures could not be determined. The causes of chick mortality are unclear. In 2003, 5 chicks were run over on the beach by vehicles. However, most chicks disappeared for unknown reasons. More work is needed to investigate the causes of chick mortality. Hatching success and fledging success was much higher on islands where there were no raccoons. Mammalian predator control, particularly raccoon control, would likely increase American Oystercatcher hatching success and fecundity in North Carolina. Demographic modeling suggests that even these low levels of reproductive success may be sufficient to maintain the population. Nevertheless there is

considerable uncertainty in those models because key demographic parameters have not been estimated directly.

Introduction:

American Oystercatchers (*Haematopus palliatus*) nest on beaches from Nova Scotia to Texas (Nol and Humphreys 1994). Like most shorebirds, they are long-lived birds that show high natural variability in their productivity from year to year (Evans 1991). This high annual variability in fecundity makes estimating the status of populations difficult. Data indicate that populations in the Mid-Atlantic States are in decline (Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). The breeding population of Virginia, a state that has long been a stronghold for oystercatchers, fell from 619 breeding pairs in 1979 to 255 breeding pairs in 1998 (Davis et al. 2001). At the same, time the species is expanding its breeding range to both the north and south (Davis 1999, Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001) and using non-traditional nesting habitat, such as dredge-spoil islands and marsh islands (Frohling 1965, Lauro and Burger 1989, Shields and Parnell 1990, Humphrey 1990, Toland 1992). The U.S. Shorebird Conservation Plan currently lists the American Oystercatcher as a "Species of High Concern" (Brown et al. 2001).

Novick (1996) began monitoring the nesting success of American Oystercatchers on South Core Banks, Cape Lookout National Seashore, in 1995. Davis (1999) continued the monitoring in 1997 and used nest monitoring and predator tracking stations to determine the causes of nest failure. Although the undeveloped beaches of the barrier islands that comprise the National Seashores were thought to be ideal breeding habitat for

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American Oystercatchers, this has not proven to be the case. Novick (1996) found that oystercatcher reproductive success was very low in 1995 and she believed that human disturbance was an important cause of the high rates of nest failure she observed. Davis (1999) determined that a large majority of nests were lost to mammalian predators. Monitoring of American Oystercatcher nesting success on the Outer Banks has continued without interruption since 1997. Study sites have expanded in recent years to include all of Cape Lookout, Cape Hatteras, and several islands managed by the National Audubon Society near Wilmington, North Carolina. Several of the Audubon sanctuaries constitute nontraditional breeding habitat for this species. In this chapter I summarize, analyze, and report all data on American Oystercatcher nesting success in North Carolina from 1995 to the present.

Study Sites:

We monitored American Oystercatcher productivity at several locations in North Carolina with the assistance of staff from the National Park Service and the National Audubon Society. Cape Lookout and Cape Hatteras National Seashores (Figure 1.1) comprise over 160 km of barrier island habitat that supports a population of approximately 90 breeding pairs. All work at Cape Lookout was done on the two main islands, North and South Core Banks (Godfrey and Godfrey 1973). Monitoring at Cape Hatteras was done on the three main islands; Bodie Island, Hatteras Island, and Ocracoke Island. The National Audubon Society manages several islands near Wilmington, North Carolina that provide habitat for an additional 48 pairs of breeding oystercatchers (Figure 1.2). Ferry Slip and South Pelican Islands, are dredge-spoil islands at the mouth of the

Cape Fear River where large colonies of Royal terns (*Sterna maxima*), Sandwich terns (*Sterna sandvicensis*) and Laughing Gulls (*Larus atricilla*) nest. A third island, Battery, is a natural island that has been armored with large sand bags to prevent erosion and over-wash. Battery Island is the site of a large wading bird colony comprised of White Ibis (*Eudocimus albus*), Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*) and Great Blue Herons (*Ardea herodius*). It also supports a substantial population of breeding Fish Crows (*Corvus ossifragus*). Oystercatcher nesting densities on these islands are much higher than those found on the barrier islands of the Outer Banks.

In 2003 the Audubon Society began monitoring oystercatcher nesting success on Lea and Hutaff Islands in Pender County, North Carolina. Lea and Hutaff are similar to the barrier islands in the national seashores, but they are privately owned, and public recreation is limited. The islands recently joined when Topsail Inlet closed to form one island 8 km long.

Monitoring methods:

We located nests by walking or driving vehicles along the beach and observing the behavior of adult birds (Novick 1996, Davis 1999). Breeding birds frequently flush from their nests when observers are up to a quarter of a mile away, so we often located nests by following the bird's footprints back to the nest. If a nest was not located quickly, we recorded the location and returned later to search again. We marked nest locations by placing a wooden stake three meters to the seaward side of the nest. Nests were visited every three to four days (Martin and Geupel 1993) until the chicks hatched or the nest failed. If a nest failed before hatching, we attempted to determine the cause of

failure. We estimated hatching success and fecundity separately. American

Oystercatcher chicks are highly precocial and leave the nest within a day or two of

hatching. Because they can be very difficult to locate after leaving the nest, we used nest

survival to hatching as our primary index of productivity.

Statistical Analysis:

I used the Mayfield method (1961, 1975) to estimate nesting success through

hatching. I compared observed hatching success, from a binomial proportion of

successful nests to failed nests, with our Mayfield nest survival parameter estimates. On

average, oystercatcher eggs require 27 days of incubation to hatch (Nol and Humphreys

1994). Therefore I calculated the probability of a nest's survival to hatching by raising

the daily probability of survival to the 27th power. I calculated the confidence interval for

the daily probability of survival and raised the upper and lower bound to the 27th power

to estimate the confidence interval for the estimate of nesting success (Hensler and

Nichols 1981). I assumed no heterogeneity in survival probabilities during the nesting

cycle. I used the midpoint rule to designate the time of failure or time of hatching for

nests that failed or hatched between visits, selecting the day halfway between visits as the

day of failure or hatching. I tested for differences in nest survival rates among study sites

and years by calculating Z statistics and 95% confidence intervals. I also compared nest

survival for nests on islands with and without raccoons to see how the presence of

raccoons affected hatching success. I report on 996 nests monitored from 1995 to 2003.

I calculated Mayfield rates for 852 nests because data from some nests in 1995 and 1998

were not collected in a way that could be used for Mayfield survival estimation. I

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calculated fecundity by dividing the number of chicks that survived to fledging by the number of breeding pairs each year. I also estimated productivity as the number of chicks fledged per nesting attempt. This estimate has the fewest assumptions about population size, within season site fidelity, and annual territory retention of breeding adults.

Results:

The observed hatching success from the beginning of egg laying through hatching was 23.8% (Table 1.2). That means 23.8% of the nests we found and monitored, survived to hatching. This binomial calculation is a simple and unrealistic model for estimating nesting success. The Mayfield method accounts for nests that are never found, or nests that fail before they are found. The Mayfield estimate for daily nest survival was 0.9428 (S.E. (S) = 0.0022). The probability of a nest surviving to hatching was 0.2038, meaning that an estimated 20.38% of all nests survive to hatching. Confidence intervals for the Mayfield estimate of hatching probability were calculated according to Hensler and Nichols (1981) as follows:

95% C.I. for the daily survival rate $= S \pm 1.96$ x (S.E.(S))

95% C.I. for the daily survival rate $= 0.9428 \pm 1.96$ x (0.0022)

95% C.I. for the daily survival rate $= [0.9385, 0.9471]$

Lower Bound for the Probability of survival to hatching:

$(0.9385)^{27} = 0.1801$

Upper bound for the Probability of survival to hatching:

$(0.9471)^{27} = 0.2304$

The entire 95% confidence interval for the Mayfield estimate of nest survival to hatching is lower than the observed hatching success rate. This means that the binomial success rate is biased high (approximately 3.5%) because it only considers nests that are found and monitored.

Hatching success was highly variable among locations. Cape Lookout National Seashore had the lowest overall hatching probability, followed by Cape Hatteras. The study sites in Wilmington had the highest over all daily survival (Table 1.1). Success was highly variable and unpredictable among years, and there was no discernable pattern or trend in overall probability of hatching (Figure 1.3).

Mammalian predation was the major identifiable cause of nest failure at our study sites accounting for approximately 29% of nest failures (Figure 1.4). Hatching probability on Hatteras Island fell from 0.92 in the period 1999–2001 to 0.8750, after foxes successfully colonized the island. An additional 14% of nests were lost to over-wash and other weather related causes. Approximately 7% of nests were destroyed by humans (usually vehicles), avian predators, ghost crabs or abandoned for unknown reasons (Figure 1.4). We could not identify the causes of failure for 51% of failed nests (Figure 1.4). Because we were not able to observe the causes of most nest failures directly, we had to rely on indirect evidence, such as eggshell fragments or the footprints left by predators, to infer the causes of nest failures. Nests failures reported as undetermined generally represent nests where wind or water erased any clues to the causes of failure.

Raccoons were the primary mammalian predator at our study sites (Davis 1999, Davis et al. 2001). Daily survival for nests not exposed to raccoons was significantly

greater than daily survival for nests exposed to raccoons ($Z = 7.87$, p> 0.0001). Nests on islands with raccoons had a 0.9335 (S.E. (S) = 0.0028, n = 676) daily survival rate, and nests on islands without raccoons had a 0.9668 (S.E. (S) = 0.0032, n = 176) daily survival rate (Figure 1.5). That means 15.6% of nests were expected to survive to hatching at sites with raccoons, and 40.2% of nests were expected to survive to hatching at sites without raccoons.

We estimated productivity from 996 nesting attempts. Only 118 chicks fledged at all our sites from 1995-2003. Fecundity was highly variable among years and among locations (Table 1.2). Sources of chick mortality are not well known. In 2003, 5 chicks from 3 nests in Cape Lookout and Cape Hatteras were run over by off road vehicles. Despite high hatching success for the Cape Fear River nests (Table 1.1, Table 1.2), the number of chicks known to have survived to fledging was very low. Over two years, 68 chicks hatched from 42 nests, but only 13 chicks are known to have fledged (Table 1.2). Lea and Hutaff Islands had very high hatching and fledging success in 2003.

Discussion:

Hatching success and fecundity were very low and variable for American Oystercatchers in North Carolina from 1995 - 2003. Davis (1999) used demographic modeling to show that high variability in annual productivity may be important to American Oystercatcher population viability. Her model showed that as variability decreased the probability of population decline increased. American Oystercatchers are known to live at least 17 years (Nol and Humphrey 1994) and they may regularly survive for 10 or 15 years. A closely related species, the European Oystercatcher (*Haematopus*

ostregalus) can live for as many as 40 years (Ens et al. 1996). Davis (1999) showed that if American Oystercatchers live for 15 years, even seemingly low levels of productivity are sufficient to maintain the North Carolina population. However, low annual productivity and high adult survival make it difficult to track population trends, because populations can appear to be stable for long periods time even though few new individuals are added each year. Continued low reproductive success warrants concern for American Oystercatcher populations North Carolina. Davis did not estimate juvenile survival and sub-adult survival directly, but used parameter estimates from demographic models of European Oystercatchers. Given the uncertainty in Davis' model, it is important to continue monitoring oystercatcher reproductive success and investigating ways to increase productivity.

Rates of hatching and fledging success at our study sites were comparable to those reported for other species of oystercatchers (reviewed by Hockey 1996). All oystercatchers exhibit low annual productivity and high adult survival (Hockey 1996). Nol (1989) reported high variability in the annual hatching and fledging success of American Oystercatchers in Virginia. However, overall productivity at her study sites was also low. More recently, Wilke (personal communication 2003) reports that nesting success and fledging success are quite high at Nature Conservancy managed Islands off Virginia's eastern shore. On some islands in her study, fecundity was over 1 chick fledged per pair for two successive years. Control of mammalian predators at these sites probably explains the high rates of success. Hockey (1996) suggests that predator free islands often serve as population sources for oystercatchers. George (2002) reported that hatching success and fledging success were highly variable among locations and among

years at several sites in Georgia, but over all productivity of 0.25 chicks fledged per pair in 2000 and 0.09 chicks fledged per pair in 2001 was low.

These data show that it is not sufficient to use a simple proportion to estimate hatching success. Mayfield estimates that simple proportions of successful to unsuccessful nests overestimates hatching success because some nests are not found before they fail. Fecundity estimates may show similar bias. However, fecundity estimates could also be biased low because it is often difficult to tell how many chicks fledge from multiple chick broods. We do not currently have methods for adjusting fecundity estimates to account for these probable sources of bias. In 2003 we began experimenting with methods for radio-tagging chicks to develop better estimates of chick survival, and to identify causes of chick mortality (Simons et al. 2004). We hope radio tagging will provide more accurate productivity estimates in the future.

Our data suggest that controlling mammalian predators may be the most effective management strategy for increasing the productivity of American Oystercatchers in North Carolina. Hatching success is significantly greater on islands where there are no raccoons. Overall fecundity for Ocracoke Island, where there are no raccoons was 0.45 chicks per pair per year during five years of consistent productivity monitoring. In 2003 hatching success was significantly greater on Hatteras Island than in 2002 ($Z = 3.19$, $p = 0.007$), after a newly established fox population was reduced by live trapping early in the breeding season. Other oystercatcher species show similar sensitivity to mammalian nest predators (Hockey 1996). African Black Oystercatchers suffered much higher nest predation rates after mammalian predators were introduced to Marcus Island, in South Africa (Summers and Cooper 1976, Hockey 1996). Nevertheless, fecundity is highly

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variable from year to year, and we do not understand how factors other than predation influence nesting productivity. We are continuing to investigate the factors affecting nesting success and are currently trying to determine the effects of human disturbance on parental behavior and nest survival.

Monitoring should continue at the Audubon managed sites in Wilmington. With only two years of data from these locations, it is too early to draw any conclusions about the overall importance of these sites to breeding oystercatchers. Oystercatchers nest at very high densities on the Cape Fear River islands, suggesting that these areas represent very high quality habitat. Nesting habitat for American Oystercatchers was historically restricted to ocean beaches (Bent 1929, Nol and Humphrey 1994), but in recent years the birds began to nest on dredge spoil islands (Humphrey 1990, Shields and Parnell 1990), marsh islands (Frohling 1965, Lauro and Burger 1989, Shields and Parnell 1990), forested areas (Toland 1992) and even on an abandoned river barge (McNair 1988). Since the 1950's the breeding range of American Oystercatchers has expanded northward from Virginia to Nova Scotia (Humphrey 1990, Nol and Humphrey 1994, Mawhinney and Bennedict 1999, Davis et al. 2001). It is possible that these new non-traditional habitats played a key role in the recent range expansion (Humphrey 1990). Use of new habitats may also explain the apparent population decline in the southeast, because birds nesting in non-traditional habitats may not be detected by breeding bird surveys. Birds at the Cape Fear river sites had much higher hatching success than those at either of the National Parks, however fledging success was similar at all sites. It is possible that chick predation at the Cape Fear sites was higher due to the large Laughing Gull colonies in the vicinity. Gulls are important predators of African Black Oystercatcher chicks in South

Africa (Summers and Cooper 1977, Hockey 1996) and American Oystercatcher chicks in

Virginia (Nol 1989). Laughing Gulls killed at least one chick on South Pelican Island

and a Fish Crow attacked a chick on Battery Island, but the crow was chased away by the

chick's parents. These attacks may have been precipitated by human observers who were

on the islands checking nests. Chick provisioning may also be a problem for birds

nesting on small isolated islands, because adults have to fly to distant salt marshes to find

food for their chicks. Ens et al. (1992) found that European Oystercatcher parents with

"leapfrog" territories (foraging grounds not contiguous with nesting grounds), had lower

reproductive success than birds in contiguous territories. They found that provisioning

rates and parental effort declined as distance to the foraging grounds increased. Nol

(1989) reported similar observations, but she attributed the differences to higher chick

predation on territories where parents were not continuously present to defend their

chicks. Furthermore, Khatchikian et al. (2002), showed that oystercatchers may suffer

from kleptoparasitism by gulls, which might further reduce chick provision rates. More

work is needed to identify the sources of chick mortality on small isolated island sites.

We hope that future studies of radio-tagged chicks will help to answer these questions

(Simons et al. 2004).

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Cape Hatteras National Seashore

Cape Lookout National Seashore
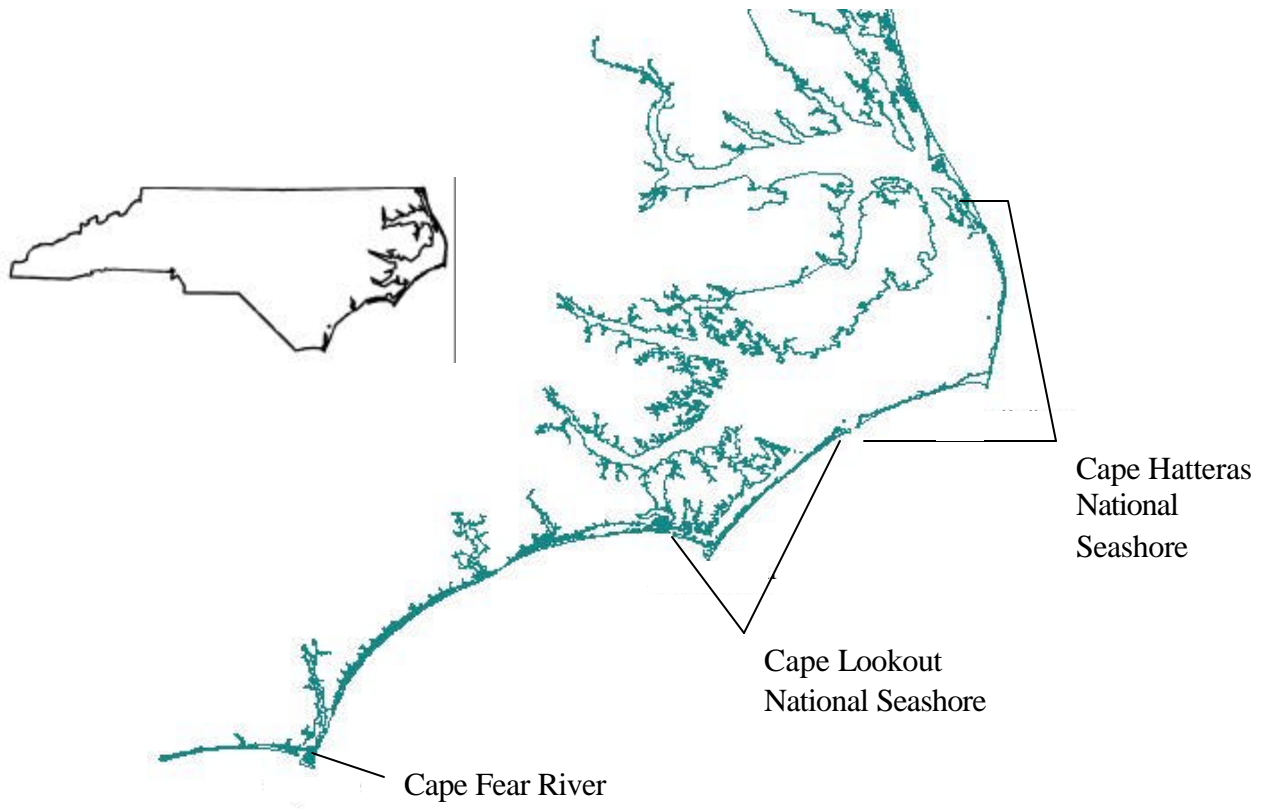
Cape Fear River

Figure 1. Eastern North Carolina
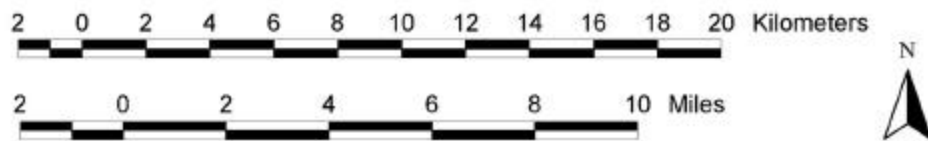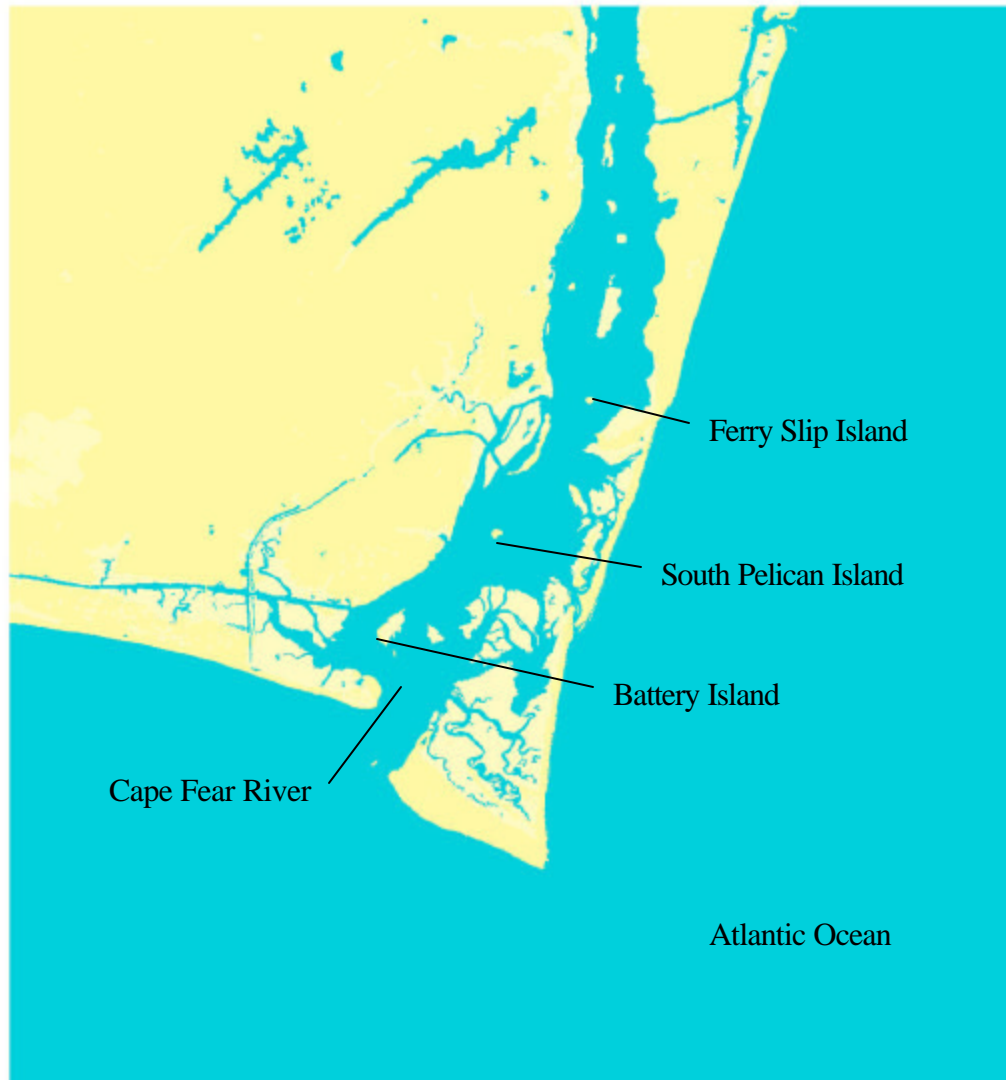
Figure 1.2: Map of the lower Cape Fear River, with the Audubon managed islands labeled.
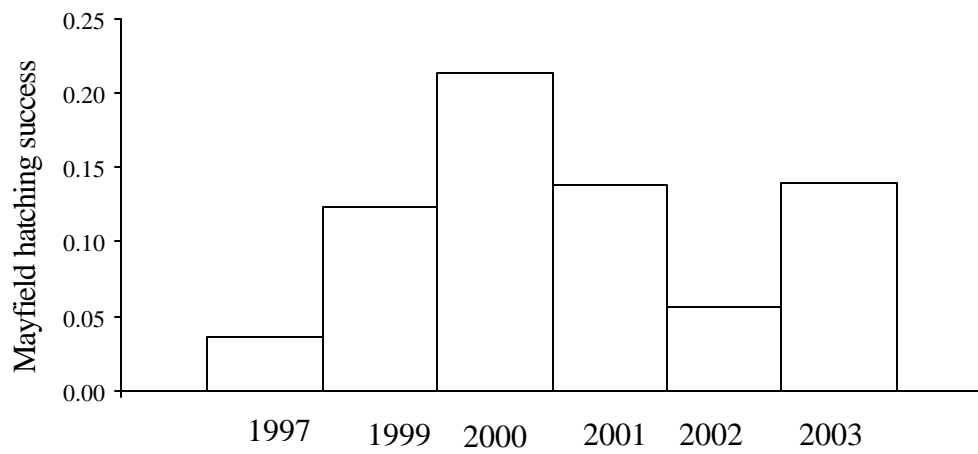
Figure 1.3: Annual variation in the Mayfield estimate of hatching success for South Core Banks in Cape Lookout National Seashore, shown here to exemplify overall annual variation.
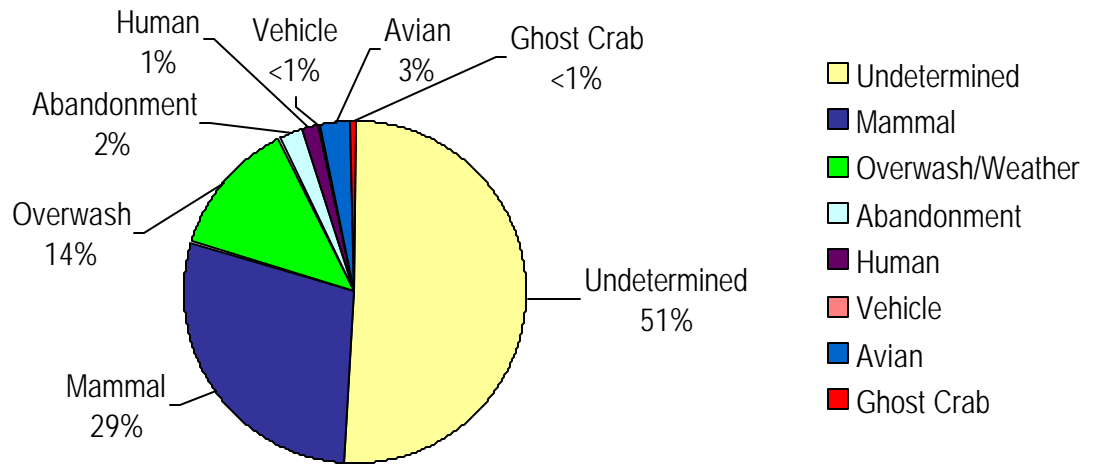
Figure 1.4: Causes of nest failure in North Carolina from 1995-2003 (n = 724).
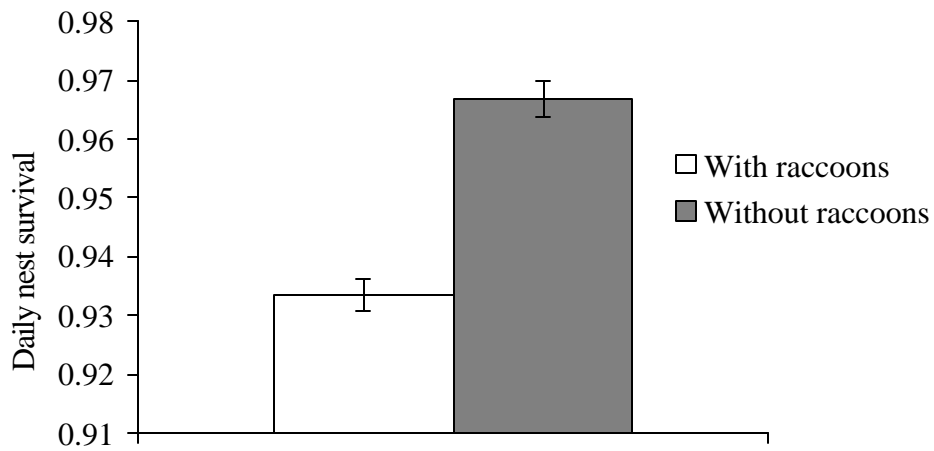
Figure 1.5: Comparison of the daily probability of survival for nests exposed to raccoons (n = 676) and nests not exposed raccoons (n = 176). Nests exposed to raccoons have significantly lower daily probability of survival (Z = 7.87, p< 0.0001).

Table 1.1: Daily survival rate comparisons among study sites.

Site	Daily Survival	Hypothesis	Z Statistic	P value
Cape Lookout	0.9281 (n= 517)	Wilmington > Cape Lookout	8.9676	< 0.0001
Cape Hatteras	0.9503 (n= 222)	Wilmington > Cape Hatteras	4.1303	< 0.0001
Wilmington Audubon	0.9720 (n= 113)	Cape Hatteras > Cape Lookout	4.3366	< 0.0001

Table 1.2: Observed Nest Success and Fecundity from 1995 - 2003

Year and location	No. of breeding pairs	No. of clutches	No. of nests hatched	% nests hatching young	No. of chicks fledged	Fecundity (Chicks fledged/ breeding pair)	Chicks fledged/ clutch (S.E.)
CAPE LOOKOUT							
South Core Banks							
1995	20	36	10	28	7	0.35	0.19 (0.078)
1997	22	34	4	12	2	0.09	0.06 (0.040)
1998	28	26	7	27	2	0.07	0.08 (0.053)
1999	28	52	5	10	1	0.04	0.02 (0.019)
2000	22	39	18	46	8	0.36	0.21 (0.066)
2001	24	57	8	14	1	0.04	0.02 (0.018)
2002	22	44	5	11	1	0.05	0.02 (0.022)
2003	21	59	9	15	6	0.29	0.10 (0.046)
North Core Banks							
1998	32	72	5	7	4	0.12	0.06 (0.034)
1999	33	61	11	18	5	0.15	0.08 (0.042)
2000	29	36	7	19	1	0.03	0.03 (0.028)
2001	27	52	10	19	2	0.09	0.04 (0.027)
2002	22	46	5	11	5	0.23	0.11 (0.064)
2003	19	37	7	19	2	0.11	0.05 (0.038)
CAPE HATTERAS							
Bodie Island							
1999	2	2	0	0	0	0	0 (0.0)
2000	2	3	0	0	0	0	0 (0.0)
2001	2	3	0	0	1	0.50	0.33 (0.333)
2002	3	5	1	20	2	0.66	0.40 (0.400)
2003	5	5	1	0	0	0	0 (0.0)
Hatteras Island							
1999	24	31	7	23	3	0.13	0.10 (0.054)
2000	23	29	10	34	2	0.09	0.07 (0.048)
2001	24	28	10	36	6	0.25	0.21 (0.079)
2002	21	25	3	12	4	0.16	0.16 (0.094)
2003	14	22	8	36	4	0.29	0.18 (0.107)
Ocracoke Island							
1999	15	17	7	41	2	0.13	0.12 (0.080)
2000	12	17	7	41	7	0.58	0.41 (0.193)
2001	13	15	10	67	14	1.07	0.93 (0.267)
2002	12	18	6	33	3	0.25	0.17 (0.090)
2003	8	12	3	25	1	0.13	0.08 (0.083)
WILMINGTON							
Cape Fear River							
2002	32	48	27	56	6	0.19	0.13 (0.048)
2003	34	49	15	31	7	0.21	0.14 (0.050)
Lea and Hutaff							
2003	16	16	11	69	9	0.56	0.56 (0.203)
Total/mean		996	237	24	118		0.12 (0.012)

Chapter 2

Assessing the effect of human disturbance on American Oystercatcher (*Haematopus palliatus*) hatching success.

Abstract:

American Oystercatchers are ground nesting shorebirds that breed throughout the East Coast of the United States. In this study, I measured human disturbance at oystercatcher nests on the Outer Banks of North Carolina using three different methods. I collected human disturbance data every time I visited a nest to monitor its daily survival. I also used video monitoring to record nest disturbance at randomly selected nests on randomly selected days. Finally, I conducted human disturbance surveys at points along beach transects, independent of oystercatcher nests. I assigned disturbance values to nests based on their location along those transects. I compared all three disturbance measures using linear regression models. I tested to see if human disturbance had any effect on hatching success using logistic regression models and 2x2 contingency table analyses.

Logistic regression analyses did not show any effect of human disturbance on hatching success. I suspect that sampling errors and limited sample sizes constrained these analyses. The 2x2 contingency table analyses showed a greater probability of hatching for low disturbance nests based on the daily nest disturbance method. The filming and the transect methods showed no clear association between human disturbance and hatching success. The strength of my conclusions was constrained by small sample sizes and measurement error, but these results add to the mounting evidence that human disturbance negatively affects the reproductive success of American Oystercatchers. This study only looked at associations between human disturbance and nesting success. I will discuss possible mechanisms in Chapter 3.

Introduction:

American Oystercatchers are listed as a species of high concern by the U.S. Shorebird Conservation Plan, in part because of threats during the breeding season (Brown et al. 2001). Current data indicate that breeding populations in the Southeastern United States are in decline (Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). There is evidence that human disturbance may be reducing American Oystercatcher reproductive success. It is well documented that human disturbance reduces the nesting success of colonial waterbirds (reviewed by Carney and Sydeman 1999). Oystercatchers nest in very similar habitats and have many of the same nest predators as colonial waterbirds, so they are likely to show similar responses to disturbance (Nol and Humphrey 1994). Both, Novick (1996) and Davis (1999) documented a connection between human activity and nest failure. Novick showed that the probability of nest failure was greater on "high use" days (eg. holidays, weekends) when many people were present in the park, than on "low use" days when fewer people were in the park. Novick documented the number of humans and vehicles per mile and per day on South Core Banks of Cape Lookout National Seashore. She found that nests located near areas of high human use had higher probabilities of failure. Davis (1999) found a similar trend in her data. Additionally, Davis (1999) and later George (2002) noted that the Oystercatchers avoided nesting in areas with high human activity.

Human disturbance has been shown to reduce fledging success in European Oystercatchers (*Haematopus ostralegus*) (Verhulst et al. 2001). Evidence also suggests that human disturbance reduces the nesting success and influences the geographic distribution of the African Black Oystercatcher (*Heamatopus moquini*) in South Africa

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(Leseberg et al. 2000). Jeffery (1987) reported that nesting success of African Black Oystercatchers in South Africa was negatively correlated with human recreational activity. In the seven-year study, Jeffery observed that the number of nesting attempts and the number of chicks fledged was negatively correlated with off road vehicle sales and use. Hockey (1987) reported findings that suggest human encroachment and disturbance may have driven the Canarian Black Oystercatcher (*Haematopus meadewaldoi* bannerman) to apparent extinction.

Both Novick (1996) and Davis (1999) suggested that human activity might result in artificially high populations of nest predators. Raccoons are the primary nest predator of American Oystercatchers at Cape Lookout. Raccoon population densities seem to be higher in areas of high human use (Novick 1996, Davis 1999). Feral cats (*Felis sylvestris catus*) were introduced to Cape Lookout by humans and they are now the second most important source of mammalian predation to oystercatcher nests (Davis 1999).

I readdressed the question of whether human disturbance affects nesting success of American Oystercatchers at Cape Lookout and Cape Hatteras National Seashores by measuring human disturbance and monitoring nesting success in 2002 and 2003. Both Novick (1996) and Davis (1999) had difficulty quantifying human disturbance and analyzing its affects on nesting success. Therefore, I used three different measures of disturbance; daily nest disturbance, filmed disturbance, and transect disturbance. In this chapter, I only address the association between human disturbance and nesting success. In chapter three, I investigate one possible mechanism for apparent associations by studying how human disturbance altered incubation behavior of oystercatchers.

<u>Study Sites:</u>

I monitored the nesting success of American Oystercatchers at Cape Lookout National Seashore in 2002 and 2003. Additional nest monitoring was done at Cape Hatteras National Seashore by National Park Service staff. Cape Lookout and Cape Hatteras National Seashores (Figure 2.1) comprise over 160km of barrier island habitat that supports a population of approximately 90 breeding pairs of oystercatchers. All work at Cape Lookout was done on the two main islands, North and South Core Banks (Godfrey and Godfrey 1973). Cape Hatteras has three main islands; Bodie Island, Hatteras Island and Ocracoke. I filmed nest disturbance on all five islands in both parks over the two-year period. All other disturbance sampling was done on North Core Banks (Figure 2.2).

<u>Methods for measuring disturbance:</u>

I monitored nesting success by locating nests and tracking their status every three to four days until the eggs hatched or the nests failed. I used the Mayfield method (1961, 1975) to estimate nest survival and hatching success. A nest was considered successful if at least one egg hatched, and a nest was considered failed when all eggs were lost. Partial nest failure was not considered in this study. I measured human disturbance on North Core Banks of Cape Lookout National seashore three different ways in both seasons. Human disturbance was defined as trucks, all-terrain vehicles (hereafter ATVs), and pedestrians, for all three methods of measurement.

I refer to the first method of measuring human disturbance as "daily nest disturbance." I recorded the number of human disturbances and the distance to each

disturbance from the nest scrape when I visited nests for regular nest checks. I created an index of disturbance at each nest using the following formula:

$$Disturbance = (H/n) \; x \; (1/d)$$

Where H is the total number of disturbances observed at a nest, n is the number of visits to that nest, and d is the average distance to all the disturbances observed from that nest. I used the inverse of the average distances to the disturbances because the effects of distance are likely to decrease with distance from the nest (Burger 1981, Burger and Gochfeld 1998, Rogers and Schwikert 2003). With this measure, I generated an independently measured disturbance index for each nest monitored on North Core Banks.

I based the second of measure human disturbance on video monitoring and called it "filmed disturbance." I filmed nests for four hour time blocks at least once during the incubation period using SONY HI-8 video cameras. The cameras were housed in a weather proof plastic container attached to a metal stand. I placed the cameras approximately 15 feet from the nest scrape. Most cameras faced the ocean recording the beach beyond the nest and any human disturbance that passed by. Some nests were located in dunes or other locations where the beach was not visible. In these cases cameras were positioned to record the most likely source of human disturbance (e.g. the dune road in Cape Lookout). Because of the landscape surrounding each nest was different, the effective detection radius for human disturbance was different for each nest. Therefore detection probabilities were heterogeneous among nests. I viewed all videotapes and counted the total number and type of disturbance recorded. I combined all disturbances observed and calculated an hourly rate of human disturbances for each nest. I was unable to measure distances to disturbance with this method.

I called the third measure of human disturbance "transect disturbance." This measure was derived from measurements at points along the beach on North Core Banks, similar to points along linear transects. I divided the island into six sections and subdivided each section in to six subsections (Figure 2.2). Each subsection was approximately one half mile long. On any day during the breeding season when time permitted me to conduct a survey, I randomly selected a subsection and surveyed the selected subsection of all six sections on the island for human disturbance. This resulted in to six point count transects, each with six survey points approximately three miles apart. At each point I recorded all human disturbance observed up to a half a mile away. I tallied up all the disturbances seen in each section and divided by the total number of visits to each section to obtain a disturbance index for all 6 sections of the island using the following calculation:

Disturbance = (Total disturbances in a section)/(# of visits to that section)

Nests were then assigned the overall disturbance index of their section. I assumed that detection probabilities were homogeneous for all survey points because the topography of the island is very flat and my vision was not restricted to less than one half mile at any of my points.

Statistical Analysis:

I used linear regression models to compare the daily disturbance indices, the filmed disturbance and the transect disturbance indices for nests where all three measures were estimated. Each disturbance variable was modeled as a dependant variable on the other two measures (Neter et al. 1996). I then used logistic regression models to

determine if human disturbance affected the probability of hatching (Neter et al. 1996).

Success was recorded as one and failure as zero. These data were modeled as the

dependent variable in logistic regression models with the three disturbance variables as

the independent variables (Neter et al 1996).

Because sample size constraints often make it difficult to detect trends in data

using logistic regression models, I also used 2x2 contingency tables and Z-tests to

determine if there were differences in the probability of nest success between low and

high disturbance nests. I defined three decision rules to characterize three levels of "low"

disturbance for each method of measuring disturbance. The first level for the daily nest

disturbance method was "low" ≤ 1.00 disturbance, the second level was "low" ≤ 1.50

disturbance, and the third level was "low" ≤ 2.00 disturbance. The first level for the

filmed disturbance was "low" ≤ 1.00 disturbances per hour, the second level was "low" $\leq$

2.00 disturbances per hour, and the third level was "low" ≤ 3.00 disturbances per hour. I

only defined two decision rules for the transect method because the total sample size was

37 nests. The first level was "low" ≤ 2.00 disturbances per visit, and the second was

"low" ≤ 2.5 disturbances per visit. Each rule allowed for progressively more disturbance

in the low disturbance group. I used multiple decision rules for each data set to test for a

threshold in the effects of human disturbance on hatching success and to see if hatching

probability changed with the level of human disturbance.

Results:

Linear regression models, detected no correlation between the daily nest

disturbance and the filmed disturbance methods (p= 0.2101). The daily nest disturbance

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and the transect disturbance method were strongly correlated ($\hat{a}_1 = 0.1433$, $p < 0.0001$). The filmed disturbance method did not correlate with either the daily nest disturbance method or the transect disturbance method ($p = 0.21$ and $p = 0.44$). The transect disturbance method was strongly correlated with daily nest disturbance ($\hat{a}_1 = 3.40$, $p < 0.0001$), but not correlate the filmed disturbance ($p = 0.44$).

Daily Nest Disturbance Results:

I measured daily nest disturbance for 76 nests over two seasons on North Core Banks (Appendix 2.1). The average daily nest disturbance was 1.272 and the indexes ranged from 0.000 to 12.382 (Appendix 2.1). I observed 298 trucks, 107 ATVs and 276 pedestrians. The average distance to the observed disturbances ranged from 20 meters to 1126 meters. There were no significant differences in daily nest disturbance measurements among years ($t = 0.67$, $p = 0.51$). There were 14 successful nests and 62 failures. Daily nest survival did not differ significantly between years. The predominant cause of nest failure was mammalian predation (Simons et al. 2004, Chapter 1).

Logistic regression models found no significant relationship between daily nest disturbance and the probability of hatching ($p = 0.32$). The 2x2 contingency analyses and Z-tests did show significant differences in the probability of hatching between low and high disturbance nests. Under rule one ("low" ≤ 1.00 disturbance), the probability of hatching was much greater for low disturbance nests (0.24, S.E. 0.059, $n = 51$) than for high disturbance nests (0.084, S.E. 0.054, $n = 25$) ($Z = 1.93$, $p = 0.014$) (Figure 2.3, Table 2.1). Under rule two ("low" ≤ 1.500 disturbance), the probability of hatching was greater for low disturbance nests (0.21, S.E. 0.053, $n = 58$) than for high disturbance nests (0.11, S.E. 0.074, $n = 18$), but the difference was not significant ($Z = 1.05$, $p = 0.074$)

(Figure 2.3, Table 2.1). Under rule three ("low" $\leq$ 2.00 disturbance), the probability of hatching was significantly greater for low disturbance nests (0.2063, S.E. 0.051, n = 63) than for high disturbance nests (0.08, S.E. 0.0734, n = 13, Z = 1.44, p= 0.038) (Figure 2.3, Table 2.1).

Filmed Disturbance Results:

I filmed 78 nests in the 2002 and 2003 seasons (Appendix 2.2). Twenty-two of those nests were successful and 56 failed. Daily nest survival did not differ significantly between years. There was no significant difference in human disturbance between years (t = 0.64, p= 0.52). I observed 1,495 trucks, 290 ATVs, and 110 pedestrians on all the videotapes. An average of 5.87 disturbances were filmed per hour, but the frequency of disturbance was highly variable (range = 0.0 to 139.84 disturbances per hour).

Logistic regression models found no correlation between human disturbance and nesting success (p= 0.31). There was no discernable pattern from the 2x2 contingency table analyses (Table 2.1). Under the first rule ("low" $\leq$ 1.00 disturbance per hour), the probability of hatching for low disturbance nests (0.21, S.E. 0.092, n = 19) was less than the probability of hatching for high disturbance nests (0.31, S.E. 0.060, n = 59), although the difference was not significant (Z = -0.85, p= 0.10). Under rule two ("low" $\leq$ 2.00 disturbances per hour), the probability of hatching was greater for low disturbance nests (0.31, S.E. 0.074, n = 39) than for high disturbance nests (0.26, S.E. 0.070, n = 39), but the difference was not significant (Z = 0.50, p= 0.155). Under rule three ("low" $\leq$ 2.00 disturbances per hour), the probability of hatching was less for low disturbance nests (0.25, S.E. 0.059, n = 53) than for high disturbance nests (0.36, S.E. 0.096, n = 25), but again the difference was not significant (Z = -1.02, p= 0.078).

In 2003 there were 37 nests on North Core Banks. Seven nests successfully hatched and 30 nests failed. All 37 nests were assigned a disturbance value from the independent disturbance surveys (Figure 2.2, Appendix 2.3). Logistic regression models found no correlation between transect disturbance indices and hatching success ($â_1$=0.20, p = 0.50). Neither of the 2x2 contingency table analyses showed an association between human disturbance and hatching success (Table 2.1). Under rule one ("low" $\leq$ 2.00 disturbances per visit) the probability of hatching was less for low disturbance nests (0.17, S.E. 0.088, n = 18) than for high disturbance nests (0.26, S.E. 0.101, n = 19), but the difference was not significant (Z = -0.72, p= 0.12). Under rule two ("low" $\leq$ 2.50 disturbances per visit), the probability of hatching was slightly greater for low disturbance nests (0.22, S.E. 0.086, n = 23) than for high disturbance nests (0.21, S.E. 0.110, n = 14) but the difference was not significant (Z = 0.02, p= 0.246).

Discussion:

Many previous studies of human disturbance have focused on the effect of scientific observers (Robert and Ralph 1975, Tremblay and Ellison 1979, Safina and Burger 1983). These studies experimentally manipulated the amount of disturbance at treatment and control nests. I attempted to study ambient levels of disturbance caused by park staff and recreational visitors. Quantifying the ambient levels of disturbance experienced by wild birds is difficult because disturbance is highly variable over space and time (Lambeck et al. 1996, Novick 1996, Davis 1999, George 2002).

My results provide evidence that human disturbance reduces hatching success for American Oystercatchers on the Outer Banks of North Carolina. Although the logistic regression analyses did not show any significant correlations, the 2x2 contingency analyses of the daily nest disturbance index revealed a negative correlation between human disturbance and nesting success. Logistic regression models require substantial sample sizes in order to distinguish trends in data. Although I filmed 78 nests, watched almost 400 hours of videotape over two seasons, and collected nest site disturbance data at 76 nests, the sample sizes were apparently insufficient to detect differences. Low power to detect differences is probably a function of the small number of successful nests. Only 18.4% of nests assigned a daily nest disturbance index hatched, 28% of the filmed nests hatched, and 18.9% of transect nests hatched.

The 2x2 contingency table analysis is likely a more robust test for these data because of the difficulty in measuring and understanding human disturbance. It is not possible to fully understand how each bird perceives disturbance, or how distance, size, speed, or loudness of human disturbance affects nesting birds. Additionally, measurement error would increase as disturbance increases because sampling was only done for a short period of the incubation cycle. Therefore a simple procedure for categorizing nests as high or low disturbance is likely more appropriate because it removes many potential sources of error and bias from the measuring process

The 2x2 contingency analyses showed that human disturbance was negatively associated with oystercatcher hatching success. The probability of hatching was low for all nests regardless of disturbance levels, but above certain thresholds of disturbance the probability of hatching declined. Decision rule one of the daily nest disturbance analysis

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showed the greatest difference in hatching success between low and high levels of disturbance. This rule allowed for the least amount of disturbance in the low category. Adding more disturbance to the low disturbance groups under rules two and three reduced the differences in hatching probability between low and high disturbance nests. However, in both case hatching probability was greater for low disturbance nests. Daily nest disturbance is an easy, efficient and seemingly effective method for measuring disturbance at American Oystercatcher nests. I recommend that other researchers studying the effects of ambient human disturbance on nesting success use this method of measurement.

The filming method showed no significant effect of human disturbance on hatching probability regardless of how low and high disturbance were defined. Disturbance measures for this method also did not correlate with either of the other two disturbance measures. This is probably because the filming method did not estimate the distance from the nests to the sources of disturbance. The other two measures used distance to the source of disturbance to calculate the nest disturbance index. Lack of a distance estimate is also probably why the filming method showed no effect of disturbance on hatching success. Several studies of the European Oystercatcher (*Haematopus ostralegus*) have show that the distance to disturbance is an important determinant of how birds respond to disturbance (reviewed by Lambeck et al. 1996). Many other studies have show that the distance to disturbance is inversely proportional the impact of the disturbance (Hunt 1972, Burger and Gochfeld 1998, Rodgers and Schwikert 2003, Stolen 2003). In this study, for example, 548 trucks passed one nest in the four hours of filming. Because of the camera orientation and the position of the nest,

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most of those trucks may have been over a half mile from the incubating bird. The

detection probabilities for disturbances among nests were heterogeneous because of the

landscape surrounding nests. Some cameras could record disturbance that was over a

mile away, while others only recorded disturbance that passed with in 20 meters. The

detection probability heterogeneity limited my ability to draw meaningful inferences

from these data. The inability to measure distance to disturbances was a major weakness

of the filming method and any further use of video monitoring to study the effects human

disturbance on nesting success should account for the distance to filmed disturbances.

The transect method simply did not have enough nests in the analysis to detect

any differences in hatching probability between low and high disturbance nests. There

were only seven successful nests and 30 failed nests on North Core Banks in 2003. A

volunteer conducted disturbance surveys on South Core Banks in 2003, but was unable to

do enough surveys to get a reasonable index of disturbance. Additionally, I would not

have been able to pool the data from two the islands, because sampling was only done on

weekdays on South Core Banks (Monday through Friday), when human disturbance is

generally low (Novick 1996). North Core Banks was sampled whenever time permitted

(including Saturday and Sunday), and thus disturbance estimates were much higher. This

sampling bias made the two data sets incomparable. Additionally. applying one

disturbance value to three miles of beach eliminates the heterogeneous spatial patterns of

human disturbance on smaller scales. More frequent sampling within smaller sections of

the island would more accurately characterize the spatial pattern of disturbance with

respect to nests.

Nevertheless, these finding support the mounting evidence that human disturbance negatively affects American Oystercatcher reproductive success (Novick 1996, Davis 1999, George 2002). In contrast to previous studies where disturbance was measured within a discrete area and then applied to all nests in that area (Novick 1996, Davis 1999, George 2002), my "daily nest disturbance" indicies and the filming methods measured disturbance at individual nests. The 2x2 contingency table analyses of the data from the daily nest disturbance measurements show clearly that higher levels of human disturbance reduced hatching success. The negative effects of human disturbance are probably even greater during the chick rearing stage. Several chicks have been killed by vehicles at Cape Lookout and Cape Hatteras (Novick 1996, Chapter 1). Verhulst et al. (2001) showed that human disturbance on foraging areas prevented European Oystercatcher parents from effectively feeding their chicks. The importance of disturbance during the nesting stage will require further research. The mechanism of the interaction between human disturbance and hatching success in this study is unclear, but human disturbance might be increasing parental activity and leading to increased nest predation (Skutch 1949, Martin et al. 2000, Tewksbury et al. 2002). In the next chapter I will examine the mechanism by which disturbance reduces hatching success.

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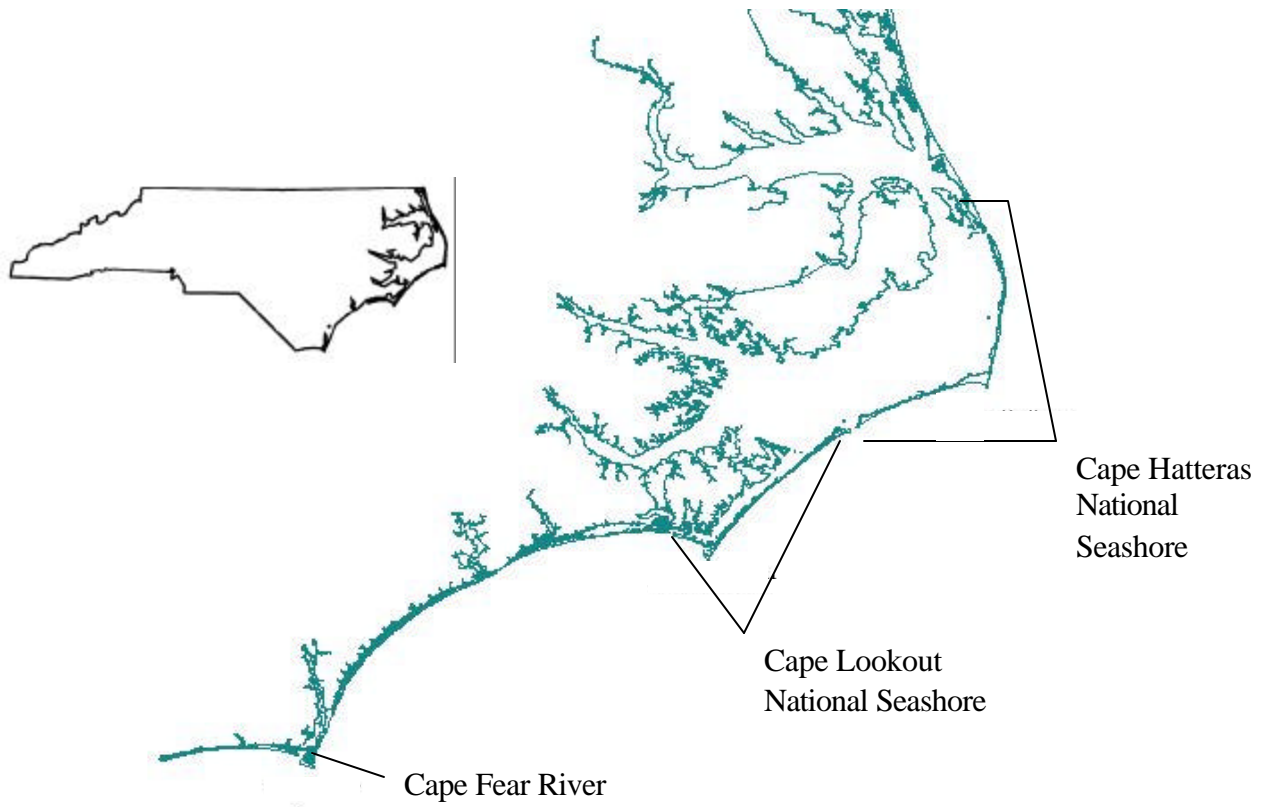
Figure 2.1: Map of North Carolina coast showing the barrier island system.

Cape Hatteras National Seashore

Cape Lookout National Seashore

Cape Fear River
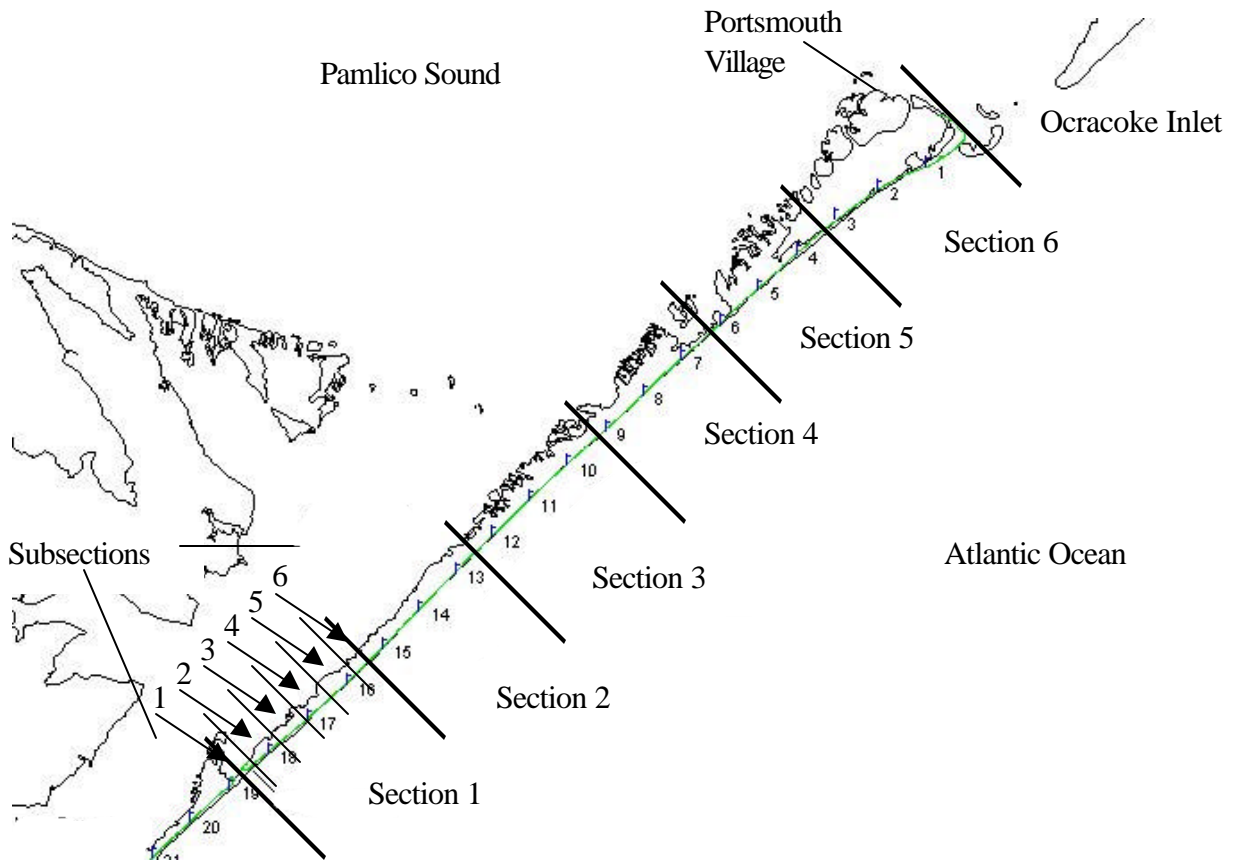
Figure 2.2: Map of North Core Banks, illustrating the survey sections and subsections for disturbance surveys. The subsections are only marked in section 1.
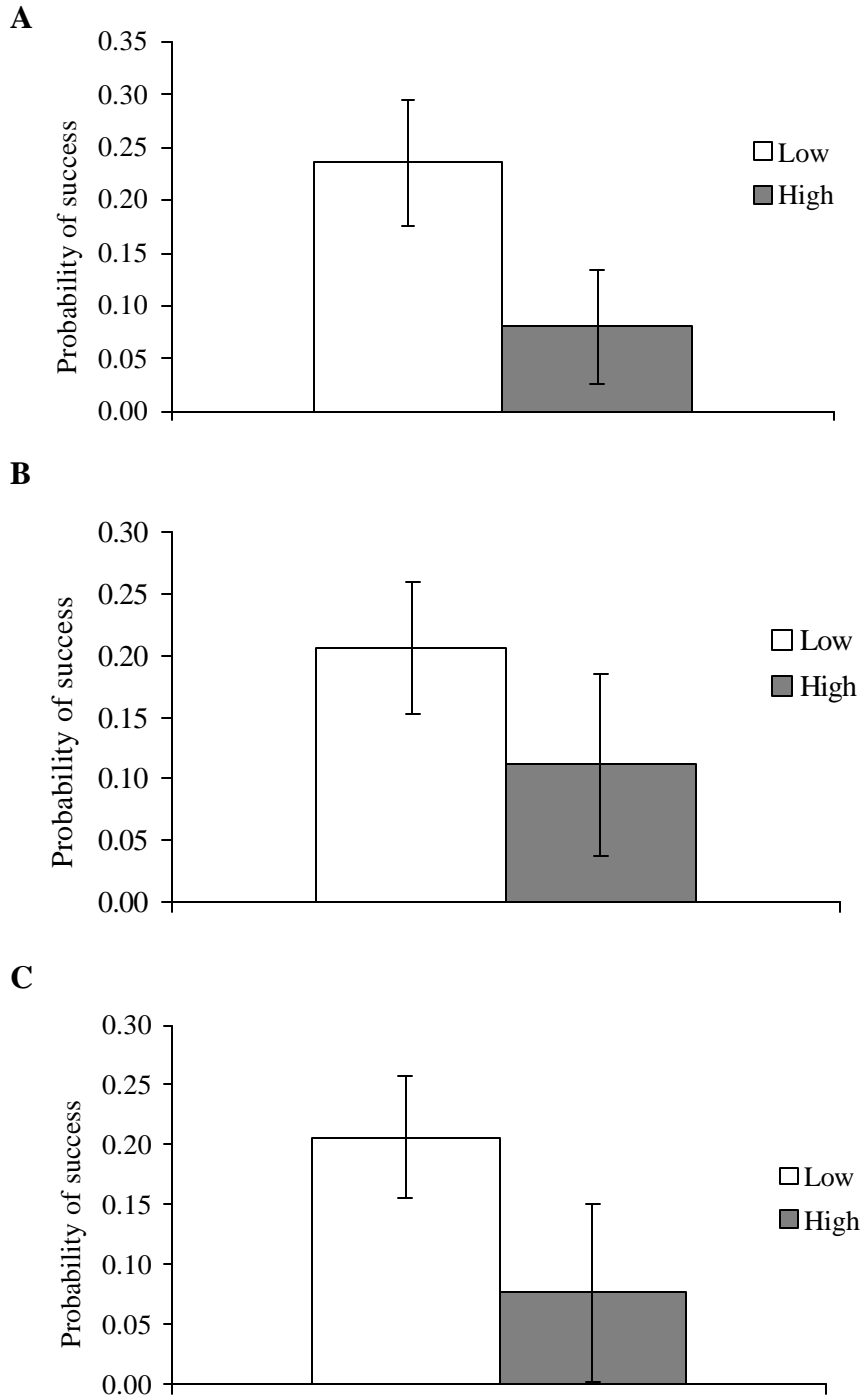
Figure 2.3: Comparisons of nest success (+/- S.E.) between low and high disturbance nests under (A) rule one, (B) rule two, and (C) rule three for the "daily nest disturbance method." The probability of hatching is significantly greater for low disturbance nests under rule one and rule three.

Table 2.1: 2x2 contingency table analyses of nest disturbance data

		Success	Failed	Total	Prob. Succ	Varience	Z-stat
Method 1, Daily nest disturbance							
Rule 1	Low < 1.00	12	39	51	0.235	0.004	1.930
	High > 1.00	2	23	25	0.080	0.003	p = 0.014
	total	14	62	76			
Rule 2	Low < 1.50	12	46	58	0.207	0.003	1.050
	High > 1.50	2	16	18	0.111	0.005	p = 0.074
	total	14	62	76			
Rule 3	Low < 2.00	13	50	63	0.206	0.003	1.441
	High > 2.00	1	12	13	0.077	0.005	p = 0.038
	Total	14	62	76			
Method 2, Nest filming method							
Rule 1	Low < 1.00	4	15	19	0.211	0.009	-0.851
	High > 1.00	18	41	59	0.305	0.004	p = 0.099
	total	22	56	78			
Rule 2	Low < 2.00	12	27	39	0.308	0.005	0.504
	High > 2.00	10	29	39	0.256	0.005	p = 0.155
	total	22	56	78			
Rule 3	Low < 3.00	13	40	53	0.245	0.003	-1.018
	High > 3.00	9	16	25	0.360	0.009	p = 0.078
	total	22	56	78			
Method 3, Independent survey method							
Rule 1	Low < 2.00	3	15	18	0.167	0.008	-0.721
	High > 2.00	5	14	19	0.263	0.010	p = 0.118
	total	8	29	37			
Rule 2	Low < 2.50	5	18	23	0.217	0.007	0.022
	High > 2.50	3	11	14	0.214	0.012	p = 0.246
	total	8	29	37			

Appendix 2.1: Daily nest disturbance at North Core Banks in 2002 and 2003

Year	Nest #	Succ	# visits	Truck	ATV	people	Ave. dist. (m)	Disturbance
2002	3	0	4	1	0	2	75.00	1.000
2002	4	1	4	2	0	0	210.00	0.238
2002	7	1	7	2	0	0	75.00	0.381
2002	8	0	5	4	0	0	337.50	0.237
2002	10	0	5	3	0	0	166.67	0.360
2002	12	0	4	0	3	0	50.00	1.500
2002	13	0	3	0	2	2	275.00	0.485
2002	14	0	3	2	0	0	62.50	1.067
2002	15	0	5	5	0	4	88.33	2.038
2002	16	0	7	9	0	11	183.25	1.559
2002	17	0	4	1	0	1	148.00	0.845
2002	18	0	2	0	0	0	0.00	0.000
2002	19	0	7	5	0	0	246.25	0.290
2002	20	0	5	1	4	2	357.14	0.392
2002	21	0	7	2	0	1	233.33	0.184
2002	22	0	3	1	0	0	400.00	0.083
2002	23	0	3	3	0	2	181.25	1.471
2002	24	0	7	5	0	4	46.67	2.755
2002	25	1	11	0	1	0	35.00	0.260
2002	26	0	5	44	6	30	148.90	10.745
2002	27	0	3	2	0	0	255.00	0.261
2002	28	0	3	0	0	0	0.00	0.000
2002	29	0	8	5	3	1	208.57	0.539
2002	30	0	2	0	0	0	0.00	0.000
2002	31	1	9	3	8	6	92.06	2.052
2002	32	0	4	6	0	4	201.50	1.241
2002	33	0	4	3	3	6	185.87	1.614
2002	34	0	2	4	3	10	68.65	12.382
2002	35	0	9	2	0	8	30.00	3.704
2002	36	0	5	4	0	0	337.50	0.237
2002	37	0	10	0	2	4	40.00	1.750
2002	38	1	5	2	0	0	55.00	0.727
2002	39	0	5	0	0	0	0.00	0.000
2002	40	0	4	0	0	0	0.00	0.000
2002	41	0	5	1	0	2	300.00	0.200
2002	42	0	2	3	0	0	31.67	4.737
2002	43	0	3	0	0	0	0.00	0.000
2002	44	0	3	1	1	0	40.00	1.667
2002	45	1	11	4	1	1	162.50	0.336
2002	46	0	5	6	1	5	53.75	4.465
2003	1	0	3	1	0	4	20.00	8.333
2003	2	0	2	0	0	0	0.00	0.000
2003	3	0	7	43	9	28	239.46	4.773
2003	4	1	10	0	0	0	0.00	0.000
2003	5	0	3	0	0	1	500.00	0.067
2003	6	0	10	0	1	2	259.33	0.116
2003	7	0	2	0	0	1	500.00	0.100
2003	8	1	12	10	4	7	349.70	0.500
2003	9	1	11	21	5	9	335.69	0.948
2003	10	0	3	7	0	6	188.46	2.299

Appendix 2.1(continued): Daily nest disturbance at North Core Banks in 2002 and 2003

Year	Nest #	Succ	# visits	Truck	ATV	people	Ave. dist. (m)	Disturbance
2003	11	0	3	3	0	2	500.00	0.333
2003	12	0	7	0	0	0	0.00	0.000
2003	13	0	7	3	1	4	300.00	0.381
2003	14	0	2	0	0	0	0.00	0.000
2003	15	0	2	0	0	0	0.00	0.000
2003	16	0	7	6	1	0	66.71	1.499
2003	17	1	13	8	13	6	314.67	0.660
2003	18	0	12	8	1	22	252.26	1.091
2003	19	1	6	9	1	18	257.43	1.813
2003	20	0	2	0	0	2	1126.00	0.089
2003	21	0	8	0	0	0	0.00	0.000
2003	22	0	13	0	0	0	0.00	0.000
2003	23	1	11	17	9	11	662.14	0.508
2003	24	0	3	4	0	4	101.33	2.961
2003	25	0	12	8	6	12	237.50	0.912
2003	26	0	3	2	2	15	434.74	1.457
2003	27	1	9	7	6	1	169.07	0.920
2003	28	1	16	1	2	5	94.29	0.530
2003	29	0	2	0	1	0	141.00	0.355
2003	30	0	3	0	0	0	0.00	0.000
2003	31	0	2	0	0	0	0.00	0.000
2003	32	0	1	0	0	4	131.25	3.048
2003	33	0	4	1	1	4	400.83	0.374
2003	34	0	5	0	1	0	67.00	0.299
2003	35	0	13	3	3	2	196.25	0.314
2003	36	0	5	0	2	0	240.50	0.166

Appendix 2.2: Filmed disturbance in 2002 and 2003

Year	Nest & Location	Success	# trucks	# ATVs	# Pedestrians	Hours obs	Disturbances/hour
2002	NCB4	1	2	1	0	4.078	0.736
2002	NCB07	1	7	5	0	4.018	2.987
2002	NCB17	0	11	6	0	4.094	4.152
2002	NCB20	0	4	1	0	3.979	1.256
2002	NCB16	0	16	2	1	4.029	4.715
2002	NCB25	1	10	7	0	4.052	4.196
2002	NCB3	0	4	0	0	4.079	0.981
2002	HAT13	0	37	0	3	4.073	9.821
2002	OCR03	0	1	0	0	4.042	0.247
2002	NCB28	0	10	5	0	4.068	3.687
2002	NCB31	0	10	1	0	4.062	2.708
2002	SCB16	1	19	18	0	4.026	9.190
2002	SCB26	0	16	17	0	4.074	8.100
2002	SCB25	0	3	1	0	4.020	0.995
2002	SCB32	0	4	2	0	4.067	1.475
2002	NCB38	1	12	9	0	4.053	5.181
2002	NCB35	0	2	6	0	4.066	1.968
2002	NCB39	0	1	2	0	4.055	0.740
2002	NCB36	0	1	2	0	4.054	0.740
2002	HAT19	0	87	1	2	4.010	22.446
2002	OCR16	1	0	0	0	4.076	0.000
2002	NCB37	0	0	0	0	4.071	0.000
2002	NCB43	0	1	0	0	4.054	0.247
2002	OCR15	0	0	0	0	3.904	0.000
2002	OCR14	0	0	0	4	3.861	1.036
2002	OCR17	0	1	0	2	4.033	0.744
2002	NCB42	0	8	0	0	4.021	1.990
2002	BOD5	1	548	0	15	4.026	139.838
2002	NCB45	1	6	2	0	4.051	1.975
2002	NCB24	0	5	3	1	3.954	2.276
2002	NCB44	0	6	3	0	4.039	2.228
2002	OCR18	1	24	0	5	4.006	7.238
2003	NCB 2	0	17	7	0	3.600	6.666
2003	HATT1	1	0	0	0	4.065	0.000
2003	HATT 2	1	0	0	0	3.796	0.000
2003	NCB 4	1	9	0	1	8.115	1.232
2003	NCB 7	1	4	1	2	6.220	1.125
2003	NCB 11	0	0	0	0	4.058	0.000
2003	NCB 10	0	5	3	0	4.063	1.969
2003	NCB 6	0	3	3	0	4.064	1.476
2003	NCB 5	0	7	2	0	4.056	2.219
2003	NCB 13	0	15	2	0	4.021	4.228
2003	NCB 16	0	2	4	0	4.064	1.476
2003	NCB 17	1	6	2	0	4.070	1.966
2003	NCB 22	0	1	0	0	8.119	0.123
2003	NCB19	0	8	12	33	4.035	13.136
2003	NCB 21	0	3	3	0	4.029	1.489
2003	NCB 25	0	7	11	1	8.130	2.337
2003	NCB 23	1	10	8	0	4.071	4.421

Year	Nest & Location	Success	# trucks	# ATVs	# Pedestrians	Hours obs	Disturbances/hour
2003	HATT 13	1	49	0	2	4.019	12.691
2003	HATT 11	0	79	0	0	4.096	19.288
2003	BOD 3	0	279	0	2	4.083	68.830
2003	HATT 4	1	21	0	11	4.061	7.881
2003	SCB 42	0	3	7	0	4.046	2.471
2003	SCB 40	0	11	10	0	4.055	5.178
2003	SCB 44	0	2	1	1	4.034	0.991
2003	SCB 39	0	6	5	0	3.950	2.785
2003	SCB 43	0	5	5	0	3.558	2.811
2003	NCB 28	1	5	4	2	8.113	1.356
2003	NCB 29	0	1	2	1	4.059	0.985
2003	NCB 31	0	3	1	0	4.046	0.989
2003	NCB30	0	3	1	0	4.088	0.979
2003	SCB 57	1	2	4	0	4.070	1.474
2003	SCB 49	0	2	10	0	4.080	2.941
2003	SCB 48	0	10	7	0	3.968	4.285
2003	SCB53	0	16	12	0	4.068	6.883
2003	NCB 35	0	5	7	0	8.142	1.474
2003	NCB 33	0	5	2	2	4.043	2.226
2003	NCB 34	0	10	2	2	4.072	3.438
2003	NCB 36	0	0	7	0	3.967	1.765
2003	NCB 37	0	3	2	0	4.057	1.233
2003	SCB55	1	2	3	0	4.066	1.230
2003	SCB 56	1	1	4	0	4.061	1.231
2003	NCB 3	0	7	4	7	8.064	2.232
2003	NCB 8	1	9	15	1	8.075	3.096
2003	NCB 26	0	2	16	2	4.030	4.963
2003	NCB 18	0	1	6	2	4.060	2.217
Total	78		1499	290	110	344.765	458.141
Average						4.420	5.874

Appendix 2.3: Transect disturbance in 2003

Section	# visits	Total Truck	Total ATV	Total People	Subsection Disturbance	Section Disturbance	# of nests	# hatched
1	13	44	8	77		9.92	5	0
1.1	2	23	2	32	28.50		2	0
1.2	3	5	0	0	1.67		0	
1.3	2	8	2	29	19.50		0	
1.4	2	2	1	4	3.50		0	
1.5	2	5	0	10	7.50		3	0
1.6	2	1	3	2	3.00		0	
2	14	16	7	16		2.79	3	0
2.1	2	0	0	1	0.50		0	
2.2	3	1	1	1	1.00		1	0
2.3	2	2	0	3	2.50		0	
2.4	2	0	0	0	0.00		0	
2.5	2	5	0	0	2.50		2	0
2.6	3	8	6	11	8.33		0	
3	14	12	7	11		2.14	5	2
3.1	2	6	3	11	10.00		0	
3.2	3	0	0	0	0.00		0	
3.3	2	0	1	0	0.50		0	
3.4	2	0	0	0	0.00		0	
3.5	2	2	3	0	2.50		3	1
3.6	3	4	0	0	1.33		2	1
4	14	10	2	7		1.36	8	0
4.1	2	3	0	3	3.00		0	
4.2	3	0	0	0	0.00		3	0
4.3	2	3	0	0	1.50		0	
4.4	2	0	1	0	0.50		0	
4.5	2	3	0	3	3.00		0	
4.6	3	1	1	1	1.00		5	0
5	14	8	4	2		1.00	10	3
5.1	2	1	0	1	1.00		2	0
5.2	3	1	0	0	0.33		3	0
5.3	2	0	0	0	0.00		0	
5.4	2	0	0	0	0.00		0	
5.5	2	4	1	1	3.00		0	
5.6	3	2	3	0	1.67		5	3
6	14	22	13	26		4.36	6	3
6.1	2	2	4	4	5.00		1	1
6.2	3	0	4	2	2.00		1	1
6.3	2	4	3	15	11.00		1	1
6.4	2	4	2	1	3.50		0	
6.5	2	1	0	2	1.50		0	
6.6	3	11	0	2	4.33		3	0

Chapter 3

Does human disturbance lower hatching success of American Oystercatchers

(*Haematopus palliatus*) by altering the incubation behavior of breeding adults?

Abstract:

American Oystercatcher reproductive success is very low on the Outer Banks of North Carolina. This species has been listed as a species of high concern by the U. S. Shorebird Conservation Plan in part because of "threats during the breeding season." I studied the effects of human disturbance on the behavior of incubating American Oystercatchers to see if there was an association between human disturbance, parental behavior at the nest, and hatching success. In 1949 Skutch hypothesized that as nest site activity increased, nest predation would also increase. I hypothesized that human disturbance increased the activity of incubating oystercatchers resulting in lower nesting success.

I monitored American Oystercatcher nesting success at Cape Lookout and Cape Hatteras National Seashores in 2002 and 2003. I used video monitoring at nests to measure the response of incubating birds to human disturbance. I calculated the number of trips to and from the nest per hour, the percent of time spent incubating, and the number of movements per hour while incubating. I used linear regression models to see if human disturbance affected parental behavior. I used logistic regression models and 2 x 2 contingency table analyses to see if parental behavior was associated with the probability of hatching.

Human disturbance was correlated with an increased number of trips to and from the nest per hour and less time incubating. ATV traffic had a greater positive association with trips, and negative association with incubation rate, than other forms of human disturbance. Logistic regression models showed no association between parental activity or nest attendance on hatching success. However, a 2 x 2 contingency table analysis,

which split the nests into groups of high and low activity, did show greater hatching success of low activity nests. There was no observed association between the percent of time spent incubating and nesting success. Based on these results, park managers may want to consider limiting ATV disturbance at oystercatcher nests during the breeding season.

Introduction:

Current data indicate that American Oystercatcher (*Haematopus palliatus*) populations in the Mid-Atlantic States are in decline (Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). The breeding population of Virginia, a state that has historically been a stronghold for oystercatchers, fell from 619 breeding pairs in 1979 to 255 breeding pairs in 1998 (Davis et al. 2001). The U.S. Shorebird Conservation Plan currently lists the American Oystercatcher as a "Species of High Concern" (Brown et al. 2001). American Oystercatchers lay one to four eggs in a shallow scrape in the sand on the beaches of the East Coast of the United States. Humans are rarely directly responsible of oystercatcher nest failure (Davis 1999, Simons et al. 2004, Chapter one of this thesis). However, evidence suggests that human disturbance is associated with lower oystercatcher reproductive success (Hockey 1987, Jeffery 1987, Novick 1996, Davis 1999, Leseberg et al. 2000, Verhulst et al. 2001, Chapter two of this thesis). We do not yet understand mechanisms by which human disturbance lowers American Oystercatcher reproductive success (Davis 1999, Chapter 2 of this thesis).

Skutch (1949) hypothesized that increased nest site activity and lowered nest attendance may lead to higher predation rates because nests become more obvious and

less well protected. I hypothesize that human disturbance alters parental nest-site behavior which results in higher predation rates. American Oystercatchers are easily flushed from their nests. If disturbance is frequent, increased trips to and from nests might make nests more obvious to predators as Skutch (1949) hypothesized. The Skucth (1949) hypothesis has been studied extensively and conclusions are mixed (Martin 1992, Roper and Goldstein 1987, Martin et al. 2000, Tewksbury et al. 2002). Roper and Goldstein (1997) found no evidence to support Skutch's hypothesis in their study of Western Slaty Antshrike nesting success in Panama. However, when Martin et al. (2000) controlled the confounding effect of nesting stage, higher parental activity did result in higher predation rates. Tewksbury et al. (2002) found that when parent birds increased activity to counteract cowbird parasitism, nest predation increased. This phenomenon has not been studied in shorebirds. Oystercatchers provide a good opportunity to test these hypotheses, because they are ground nesters, their nests are relatively easy to find, and they experience high nest predation rates (Nol and Humphrey 1994, Davis 1999, Simons et al. 2004, Chapter 1). Because, they are also a species of concern that may require intensive management in the near future, it is important that understand how human disturbance lowers nesting success (Nol et al. 2000, Brown et al. 2001, Davis et al. 2001).

In this study, I used video monitoring to record nest site behavior and human disturbance at American Oystercatcher nests on the Outer Banks of North Carolina. This study only deals with the association between human disturbance and incubation behavior, and the association between incubation behavior and nesting success. Chapter two described similar methods and statistical analyses to study the associations between

human disturbance and nesting success. In this chapter I asked if human disturbance altered the behavior of nesting birds, and if increased parental activity, or decreased nest attendance, resulted in higher rates of nest predation.

Study Sites:

I monitored nesting success of American Oystercatchers at Cape Lookout National Seashore in 2002 and 2003. Additional nest monitoring was done at Cape Hatteras National Seashore by National Park Service staff. Cape Lookout and Cape Hatteras National Seashores (Figure 1) comprise over 160km of barrier island habitat that supports a population of approximately 90 breeding pairs of American Oystercatchers. All work in Cape Lookout was done on the two main islands, North and South Core Banks (Godfrey and Godfrey 1976). Cape Hatteras has three main islands; Bodie Island, Hatteras Island and Ocracoke. I filmed nests on all five islands over the two years of the study.

Behavioral monitoring methods:

I located nests and checked their status every three to four days until they hatched or failed. I used the Mayfield method (1961, 1975) to estimate nest survival and hatching success. Nests were considered successful if at least one egg hatched, and a nest was considered failed when all eggs were lost. Partial nest failure was not considered in this study.

I used SONY HI-8 video cameras to record the incubation behavior of breeding adults at randomly selected nests. I filmed nests for four-hour intervals at least once

during the incubation period. I assumed that parental behavior was homogenous throughout the incubation period and throughout the breeding season. Video cameras were housed in weatherproof plastic containers attached to a metal stand. I placed the cameras approximately 15 feet from nests to avoid disturbing the incubating bird. Most cameras faced the ocean recording the beach beyond the nest, and any human disturbance in the vicinity of the nest. Some nests were located in dunes or other locations where the beach was not visible. In these cases cameras were directed toward the most likely source of human disturbance (e.g. the dune road in Cape Lookout). The effective detection radius was different for each nest because of differences in the surrounding landscape therefore detection probabilities were heterogeneous among nests. Tapes were reviewed to count the number of trips to and from the nest per hour, the number of movements while incubating per hour, and the percent of time spent incubating. Birds often stood to preen, change position, or move their eggs without leaving the nest. These movements were considered movements while incubating. I also counted the number of trucks, all-terrain vehicles (hereafter ATVs), and/or passing each nest per hour.

Statistical Analysis:

I attempted to assign a cause each time a bird flushed from its nest. For this study the term "flush" only refers to a bird leaving its nest and the term "trip" refers to movement to or from the nest. Possible causes of flushing included: ATVs, trucks, pedestrians, territorial fights, the exchange of incubation duties, unknown, and other. On a few occasions, birds appeared to flush in association with the passing of a low-flying airplane. These flushes were classified as "other". I calculated the proportion of flushes

associated with each type of disturbance. If a truck or ATV passed by a nest within10 seconds before or three minutes after a bird flushed, I considered the two events associated. The interval was shorter before and longer after flushing because birds usually flushed well before the disturbance was in the field of view. At a few nests, dunes or vegetation obscured the bird's view so they did not see people or vehicles until they were with in camera range. The time frame was extended to 10 seconds before flushing to account for those cases. I selected this time interval for characterizing associations because I wanted to limit the period during which a cause for flushing could be assigned. Longer intervals would increase the likelihood of incorrectly assigning a cause of flushing. Short intervals probably increased the number of unknown causes, but they minimized false association. The time interval for pedestrians was 10 seconds before to 10 minutes after flushing and was also designed to minimize false associations. I looked at each disturbance that passed to determine if each it was associated with a bird flushing. Using the same time interval described above, I calculated the proportion of each type of disturbance that caused flushes. Each disturbance was categorized as; causing a bird to flush, occurring while a bird was off its nest, or causing no response.

I used linear regression models (Neter et al. 1996) to determine if the human disturbance factors were correlated with parental activity and time budgets. Trips per hour, movements per hour, and percent of time spent incubating, were modeled as dependant variables on the number of trucks, ATVs, and pedestrians per hour.

I used logistic regression models (Neter et al. 1996) to test for associations between parental behaviors and hatching success. Success was recorded as one and failure as zero. Nest success was modeled as the dependent variable with trips per hour,

movements per hour, and percent of time spent incubating as independent variables. Because sample size constraints often make it difficult to detect trends in data using logistic regression, I also used 2 x 2 contingency tables and Z-tests to further analyze my behavioral data. I defined a three decision rules for each behavioral variable to, categorize all nests as; low and high activity, low and high incubation, and low and high rates of movement. Rule one for trips to and from the nest, was "low" $\leq$ 5.00 trips/hour, rule two was "low" $\leq$ 4.00 trips/hour, and rule three was "low" $\leq$ 3.00 trips/hour (Table 3.1). Rule one for percent of time spent incubating was "low" $\leq$ 90.0%, rule two was "low" $\leq$ 85.0%, and rule three was "low" $\leq$ 80.0% (Table 3.1). Rule one for movements while incubating was "low" $\leq$ 4.00 movements/hour, rule two was "low" $\leq$ 3.00 movements/hour and rule three was "low" $\leq$ 2.00 movements/hour (Table 3.1). Decision rules were designed to ensure adequate sample sizes in each group. I tested multiple decision rules for each variable because these behavioral variables were continuous and I wanted to see if the probability of hatching changed as the frequency of these behaviors increased or decreased.

Results:

I filmed 78 nests for an average of 4.42 hours each (S.E. 1.19) (Appendix 3.1). Most nests were filmed once for approximately fours hours, but I filmed some nests twice before they hatched or failed. I did not include in my analyses any nests where it appeared that parental behavior was affected by the presence of the video camera. Twenty-two nests successfully hatched and 56 failed. Sixty two percent of the nest failures were due to mammalian predation, 28.5 % failed for unknown reasons, and

approximately 11% were lost to weather, human destruction, or abandonment. The daily probability of survival did not vary significantly between 2002 and 2003. There were no significant differences in human disturbance or parental activity between years.

Twenty four percent of all flushes observed (n = 548) were associated with one or more ATVs passing the field of view (Figure 3.2). Seventeen percent of all flushes were associated with trucks, 3% with people, 8% with territorial fights, 18% with exchanging incubation duties, 1% were associated with other factors (airplanes). I could not assign a cause for the remaining 29% of flushing events (Figure 3.2). Sixty two percent of all ATVs that passed (n = 290) were associated with a flushing event (Figure 3), 23% of ATVs recorded passed the nest while the incubating bird was already off the nest, and 15% of ATVs had no apparent effect on parental behavior (Figure 3.3). Eleven percent of trucks recorded (n = 1499) were associated with a bird flushing, 7% passed while birds were already off their nests, and 82% passed with no apparent effect on the incubating bird (Figure 3.3). Approximately 33% of pedestrians recorded (n = 110) were associated with a bird flushing, 10% passed while the birds were already off their nests, and 57% had no apparent effect on the incubating bird (Figure 3.3).

Regression models showed that trucks had little or no effect on the rate of trips to and from the nest ($\hat{a}_1$= 0.0176, p= 0.0639), percent of time spent incubating ($\hat{a}_1$= 0.0006, p= 0.5647), or the rate of movement while incubating ($\hat{a}_1$= -0.0083, p= 0.6480). Pedestrians did not significantly reduced the percent of time spent incubating ($\hat{a}_1$= -0.0053, p= 0.7451), or increase the rate of movements while incubating ($\hat{a}_1$= 0.1522, p= 0.6031), and had no effect on the rate of trips to and from the nest per hour ($\hat{a}_1$= -0.2682, p= 0.0788). ATV's significantly reduced the percent of time spent incubating ($\hat{a}_1$= -

0.0370, p= 0.0253), and they significantly increased the rate of trips to and from the nest ($\hat{a}_1$= 0.7486, p< 0.0001) (Figure 3.4), but they did not have any effect on the rate of movements while incubating ($\hat{a}_1$= -0.1195, p= 0.6809).

Logistic regression models failed to identify behavioral variables significantly associated with the probability of hatching. The 2x2 contingency tables and Z-tests produced slightly different results (Figure 3.5, Table 3.1). None of the three decision rules tested showed a significant effect of the rate of movement or the percent of time spent incubating on hatching success (Table 3.1). The rate of trips to and from the nest, under both rule one ("low" $\leq$ 5.00 trips/hour) and rule two ("low" $\leq$ 4.00 trips/hour) showed no significant effect (p=0.24, p=0.15 respectively). However, the probability of hatching was higher for the "low activity" nests in both tests (Figure 3.5, Table 3.1). Under rule three ("low" $\leq$ 3.00 trips/hour) the probability of hatching was significantly higher for nests with low rates of trips (probability of hatching = 0.4138, S.E. 0.091, n = 29) than nests with high rates of trips (probability of hatching = 0.2041, S.E. 0.058, n = 49) (Z = 1.9404, p=0.013) (Figure 3.5, Table 3.1).

Discussion:

These data clearly show that human disturbance is affecting the parental behavior of breeding American Oystercatchers. ATV traffic increases the number of trips to and from the nest and reduces the amount of time spent incubating, while other forms of human disturbance have a smaller effect. If ATVs that passed while birds were already off their nests are excluded from the analysis, 80.4% of the ATVs that passed caused incubating birds to flush. Birds appear to have habituated to the presence of trucks

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(Whittaker and Knight 1998), but still view ATVs, and to a lesser extent pedestrians, as a

threat. ATVs are louder, and move faster than trucks and pedestrians which might

explain why the birds are affected more by ATV traffic (Burger 1981, Burger and

Gochfeld 1998). Trucks and pedestrians also tend to stay closer to the firm sand along

the water's edge which means trucks and pedestrians are generally farther from nesting

birds. ATVs are driven by park visitors, park staff, and wildlife researchers. Park staff

and wildlife researchers frequently stop their vehicles to search for sea turtle and bird

nests. It is possible that oystercatchers draw distinctions between ATVs and trucks

because ATVs are associated with people searching their nesting territories. The

National Park Service should consider using quieter ATVs or trucks to monitor nesting

oystercatchers and other birds in the National Seashores. Cape Hatteras uses trucks for

nest monitoring and those birds seem to be less sensitive than birds in Cape Lookout, but

I did not have enough data to draw statistical comparisons. Other studies have shown that

birds respond differently to different forms of human disturbance (Burger 1981).

However, most other studies have focused on the effects of human disturbance on

foraging behavior and efficiency (Burger and Gochfeld 1998, Rodgers and Schwikert

2003, Stolen 2003). This is one of the few studies to investigate how human disturbance

affects the parental behavior of nesting birds.

These data show that the more often birds flush from their nests, the lower their

nesting success. The probability of hatching is low for all nests regardless of parental

behavior, however above a threshold three trips to and from the nest per hour the

probability of hatching decreased. I cannot define the threshold more precisely and it

may vary with levels of habituation, but there is clearly an effect. American

Oystercatcher incubation behavior is one mechanism through which human disturbance is reduces nesting success because human disturbance increases the number of trips American Oystercatchers make to and from their nests. Logistic regression models showed no significant effects. Although over 400 hours of videotape were collected for this analysis, sample sizes lacked the power to discriminate differences. The small proportion of nests that survived to hatching (28%) also made it difficult to determine factors associated with nesting success. The 2 x 2 contingency table analyses are likely more robust tests of these data, because we cannot fully comprehend the effect of human disturbance on birds. The measurement error of human disturbance increased as human disturbance increased because I only sampled disturbance for a small proportion of the cycle. Furthermore the effect of human disturbance on incubation behavior changes as birds habituate to disturbance. Therefore, a simple system of categorizing nests into levels of parental activity eliminates most of the measurement error from these data and is therefore a more appropriate analysis.

Other studies of the effects of human disturbance on avian behavior have used experimental designs with defined treatment groups (Robert and Ralph 1975, Tremblay and Ellison 1979, Verhulst et al. 2001, Stolen 2003). I studied the effects of ambient human disturbance caused by park staff and recreational visitors to determine if it was linked to patterns of nesting success. Because this species is already a "species of concern," I did not want to further reduce hatching success by experimentally increasing human disturbance at some nests. Carefully designed experimental studies may alleviate the statistical limitations of this study. Such studies might experimentally reduce human disturbance by closing some sections of the seashore to traffic. Further research into

associations between human disturbance, incubation behavior and nesting success, is warranted.

The percent of time spent incubating does not appear to influence hatching success. Eggs left exposed for extended periods during the day will overheat and die. Conway and Martin (2000) showed that birds balance the costs of egg exposure with costs of high parental activity. Birds with high nest predation pressure minimize nest site activity by taking fewer, longer trips off the nest. This behavior helps reduce parental activity around the nest, but it also reduces the amount of time spent incubating. American Oystercatcher behavior may reflect the same trade off. American Oystercatcher eggs can tolerate extensive heating and cooling (Nol and Humphrey 1994). Several clutches exposed for approximately 1 hour during the middle of day hatched successfully. One video-taped nest hatched successfully even though the parents incubated for only 66.8% of the 4.070 hour observation period. Egg hardiness may reflect an adaptation to reduce nest site activity. Parents that flush from their nests and wait until all disturbances have passed may have higher success than parents that return to their nests quickly and flush repeatedly.

These results support Skutch's (1949) hypothesis that higher levels parental activity increase nest predation. Sixty two percent of the nest failures in my study were caused by mammalian predators. I did not directly study the effects of parental behavior on nest predation, but nest failure data from Cape Lookout and Cape Hatteras show that predation is the major identifiable cause of failure (Davis 1999, Simons et al. 2004, Chapter 1). Only 50% of nest failures were attributed to specific causes and 30% of those were predation (Simons et al. 2004, Chapter 1). My data do not prove Skutch's

hypothesis, but data on the causes of nest failure combined with my analysis of parental behavior do support predictions that higher levels of parental activity increase nest predation. ATV traffic was positively associated with the number of trips to and from the nest, which in turn was associated with decreased nesting success. Therefore, it may be prudent to limit ATV disturbance during the oystercatcher breeding season. Clearly, ATV traffic is not the only factor affecting oystercatcher nesting success on North Carolina's Outer Banks. Mammalian predator populations may be unnaturally high in areas of high human activity.

The primary weakness of my data from video monitoring derives from the difficulty of estimating detection probabilities for various forms of disturbance. My cameras sampled areas of different size for each nest and I was unable to control for these differences in my analyses. My inability to measure distances to sources of disturbance on film was another weakness of my study design. Several studies have shown that proximity of human disturbance has a major effect on the behavioral response of birds (Burger and Gochfeld 1998, Rodgers and Schwikert 2003). It is likely that the 20% of ATV traffic that did not cause birds to flush was too far away to elicit a response. Additionally, I believe that most of the pedestrian disturbance was too far away to have an effect. Video monitoring is an extremely useful tool for studying avian behavior, however future studies of human disturbance using video monitoring should endeavor to measure distances to sources of disturbance. It might be possible to place markers at pre-selected distance away from the camera, to facilitate distance estimation. Future studies should also include experimental manipulations. Combining beach closures with

controlled tests of the responses of American Oystercatchers to different types of

disturbance will improve our understanding of the patterns identified in this study.

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Cape Hatteras
National
Seashore

Cape Lookout
National Seashore

Cape Fear River
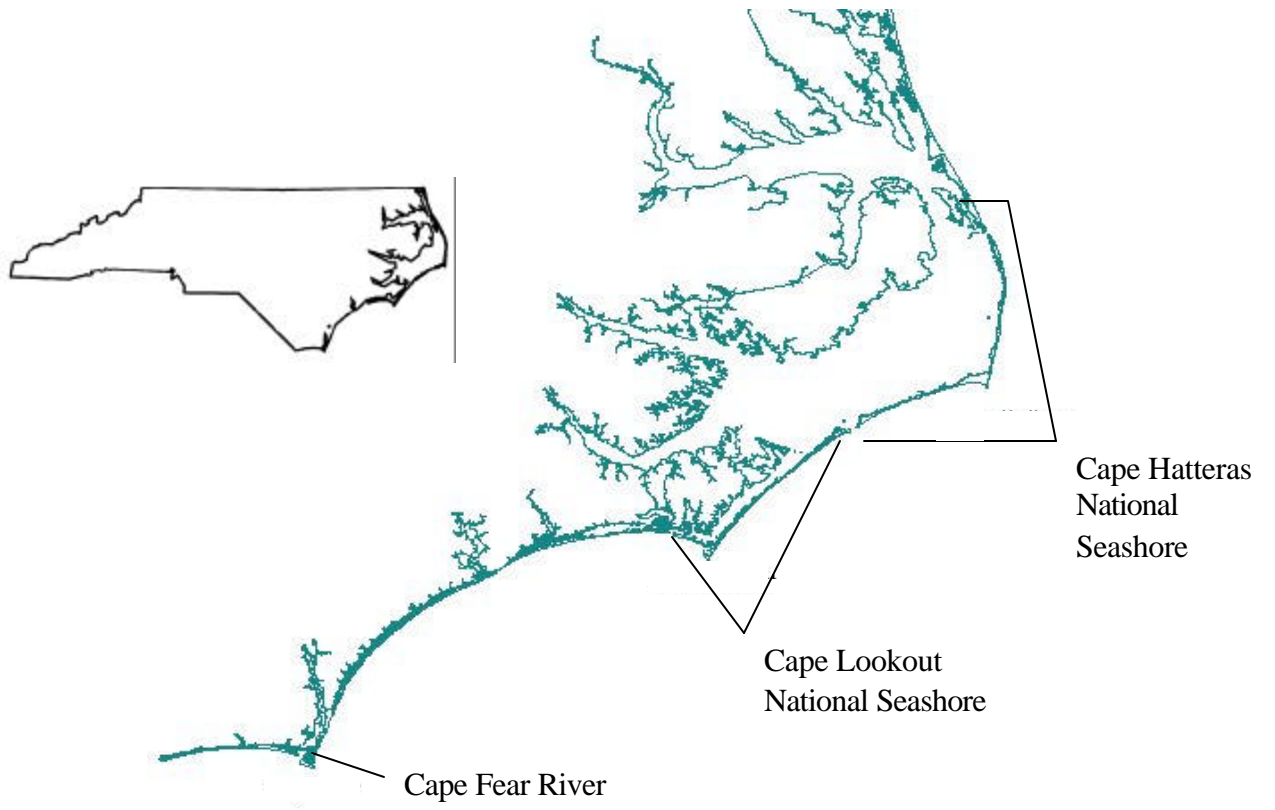
Figure 3.1: Map of North Carolina coast.
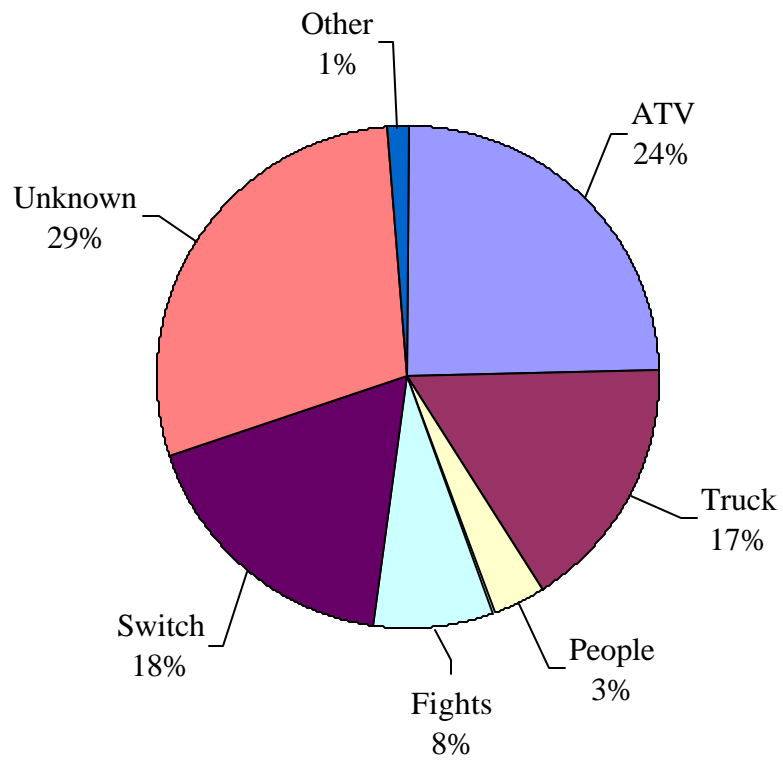
Figure 3.2: Proportion of flushes (n = 548) associated with ATVs, trucks, pedestrians, territorial fighting, exchanging incubation duties, unknown factors and other factors.

ATV Associations (n = 290)

No effect
15.2%

Already off
22.8%

With flush
62.1%

B)

Truck Associations (n = 1499)

With flush
11.3%

Already off
6.9%

No effect
81.7%

C)

Pedestrian Associations (n = 110)

With flush
32.7%

No effect
57.2%

Already off
10.0%
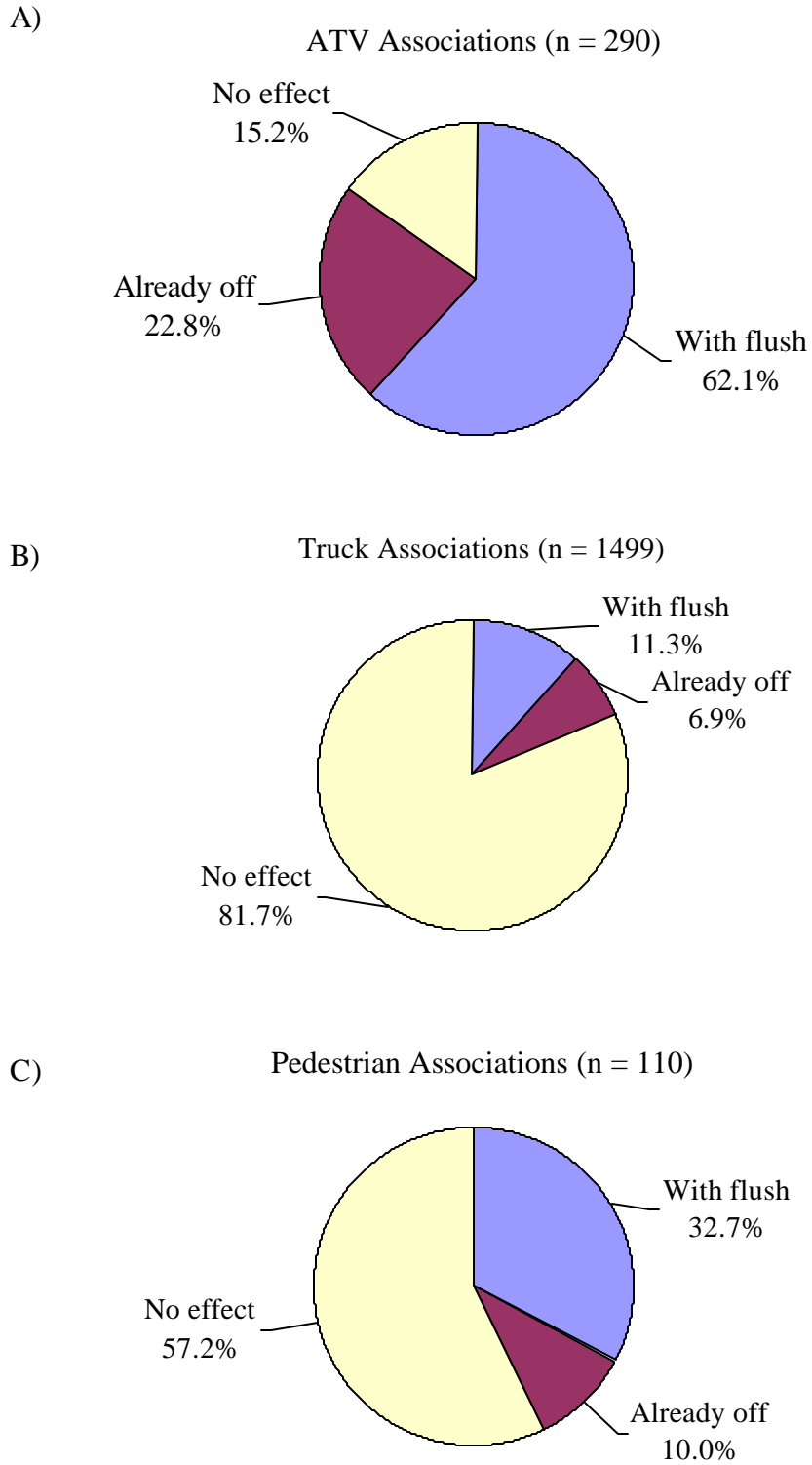
Figure 3.3: Percent of (A) ATVs, (B) trucks, and (C) pedestrians that were associated with a bird flushing from its nest.

A)

B)
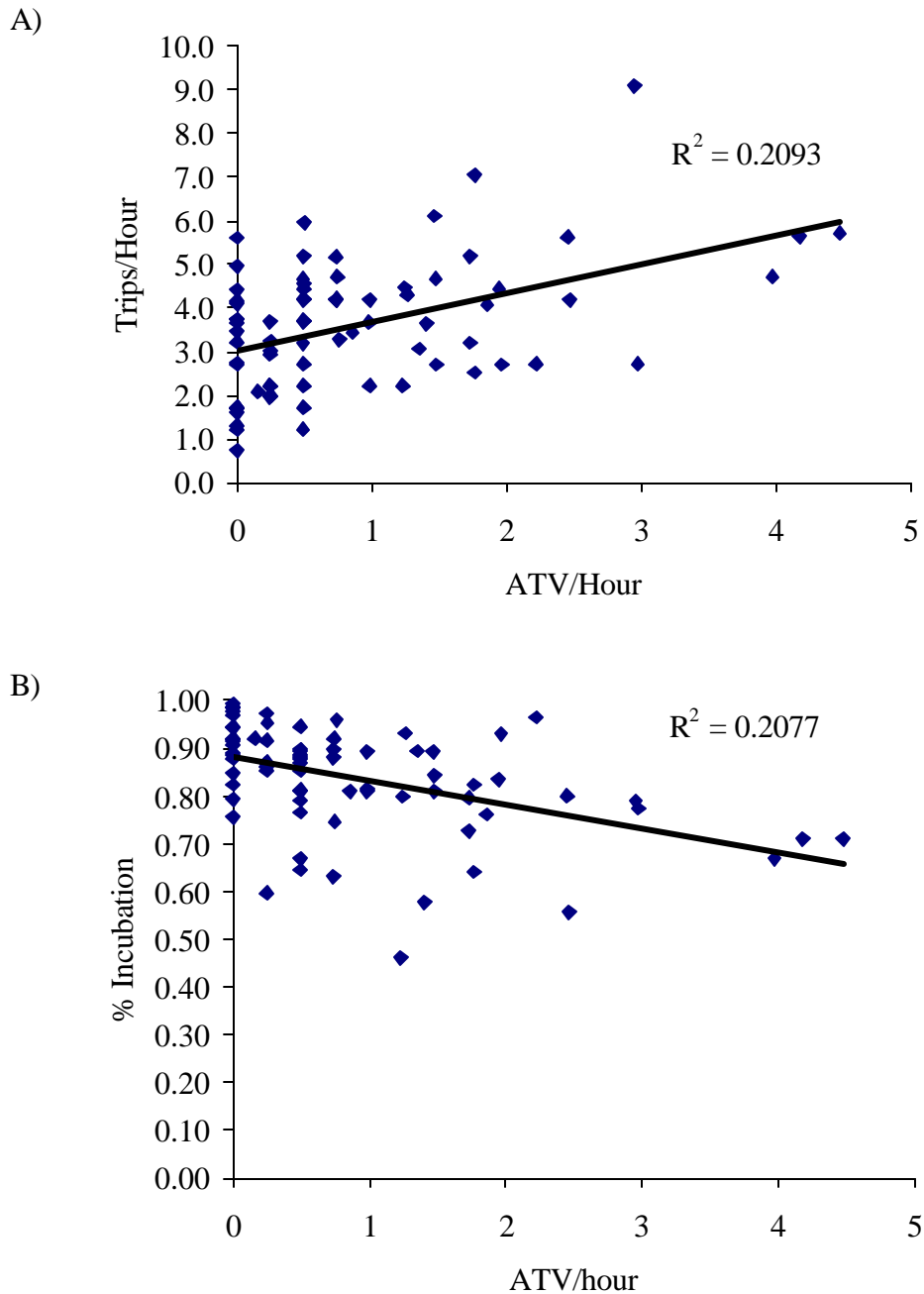
Figure 3.4: The effect of ATV beach traffic on parental behavior of American Oystercatchers. (A) The number of trips to and from the nest per hour verses the number of ATVs passing per hour ($\hat{a}_1 = 0.7486$, $p < 0.0001$). (B) Percent of time spent incubating verses the rate of ATVs passing per hour ($\hat{a}_1 = -0.0370$, $p = 0.0253$).
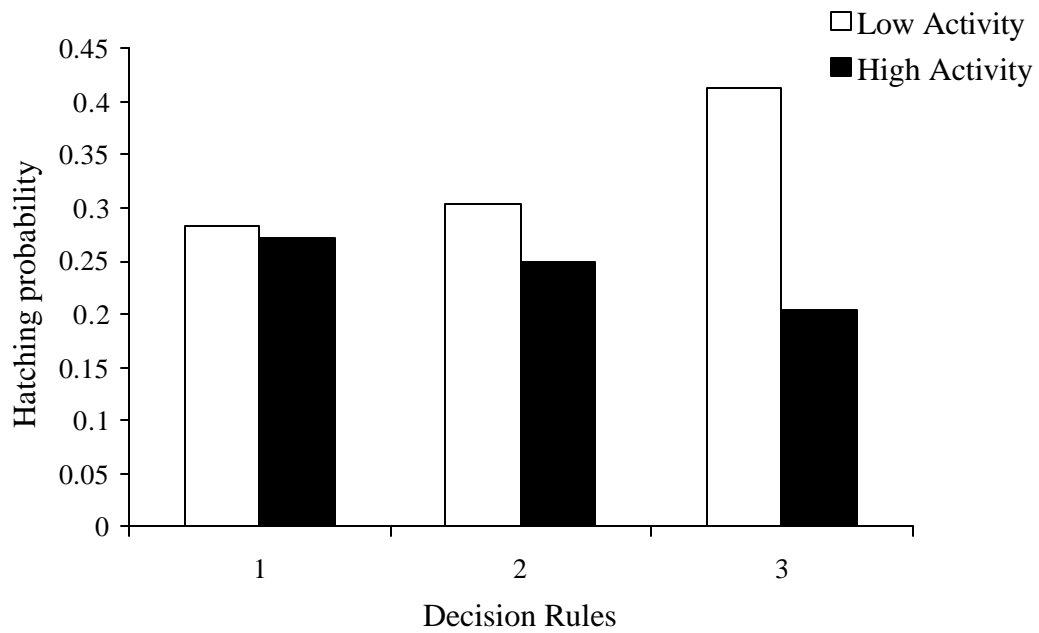
Figure 3.5: Comparison of hatching probability for nests with low and high rates of trips to and from the nest. For decision rule three the hatching probability for low trip nests is significantly greater than the hatching probability for high trip nests.

Table 3.1: 2x2 Contingencey table analysis of behavioral data

Trpis to and from the nest		Success	Failed	Total	P. Succ	Var. P. succ	Z-stat
Rule 1	Low ≤ 5.00	19	48	67	0.2836	0.0030	0.0748
	High > 5.00	3	8	11	0.2727	0.0180	p=0.236
	total	22	56	78			
Rule 2	Low ≤ 4.00	14	32	46	0.3043	0.0046	0.5313
	High >4.00	8	24	32	0.2500	0.0059	p= 0.149
	total	22	56	78			
Rule 3	Low ≤ 3.00	12	17	29	0.4138	0.0084	1.9405
	High > 3.00	10	39	49	0.2041	0.0033	p= 0.013
	total	22	56	78			

Percent of time spent incubating		Success	Failed	Total	P. Succ	Var. P. succ	Z-stat
Rule 1	High > 90%	8	15	23	0.3478	0.0099	0.8085
	Low ≤ 90%	14	41	55	0.2545	0.0035	p= 0.226
	total	22	56	78			
Rule 2	High > 85%	10	31	37	0.2703	0.0053	-0.2200
	Low ≤ 85%	12	25	41	0.2927	0.0050	p= 0.207
	total	22	56	78			
Rule 3	High > 80%	15	39	54	0.2778	0.0037	-0.1251
	Low ≤ 80%	7	17	24	0.2917	0.0086	p=0.105
	total	22	56	78			

Movements while incubating		Success	Failed	Total	P. Succ	Var. P. succ	Z-stat
Rule 1	Low < 4.00	13	40	53	0.2453	0.0035	-1.0176
	High > 4.00	9	16	25	0.3600	0.0092	p= 0.078
	total	22	56	78			
Rule 2	Low ≤ 3.00	11	28	39	0.2821	0.0052	0.0000
	High > 3.00	11	28	39	0.2821	0.0052	p= 0.250
	total	22	56	78			
Rule 3	Low < 2.00	7	16	23	0.3043	0.0092	0.2794
	High > 2.00	15	40	55	0.2727	0.0036	p= 0.131
	total	22	56	78			

Appendix 3.1: Disturbance and Behavioral data for 2002 and 2003

Year	Nest	Success	Hours obs	Time Inc.	%Inc	Trips/hour	Moves/hour	Truck/hour	ATV/Hour	Ped/hour
2002	BOD5	1	4.026	3.316	0.824	4.968	4.222	136.112	0.000	3.726
2002	Hat13	0	4.073	3.948	0.969	3.683	0.760	9.085	0.000	0.737
2002	HAT19	0	4.010	3.901	0.973	3.242	2.564	21.697	0.249	0.499
2002	HBD3	0	4.079	4.016	0.985	4.167	1.494	0.981	0.000	0.000
2002	NCB07	1	4.018	3.209	0.799	4.480	2.493	1.742	1.244	0.000
2002	NCB16	0	4.029	3.572	0.887	4.219	1.960	3.971	0.496	0.248
2002	NCB17	0	4.094	3.658	0.893	6.106	1.914	2.687	1.465	0.000
2002	NCB20	0	3.979	3.796	0.954	3.016	5.796	1.005	0.251	0.000
2002	NCB24	0	3.954	3.789	0.958	3.287	4.223	1.264	0.759	0.253
2002	NCB25	1	4.052	2.944	0.727	5.183	3.058	2.468	1.728	0.000
2002	NCB28	0	4.068	1.876	0.461	2.212	2.132	2.458	1.229	0.000
2002	NCB31	0	4.062	3.722	0.916	2.216	4.836	2.462	0.246	0.000
2002	NCB35	0	4.066	3.295	0.811	4.673	3.642	0.492	1.476	0.000
2002	NCB36	0	4.054	3.566	0.880	2.713	3.645	0.247	0.493	0.000
2002	NCB37	0	4.071	3.845	0.945	4.421	1.820	0.000	0.000	0.000
2002	NCB38	1	4.053	3.908	0.964	2.714	2.559	2.961	2.220	0.000
2002	NCB39	0	4.055	3.631	0.896	2.219	3.855	0.247	0.493	0.000
2002	NCB4	1	4.078	3.515	0.862	2.942	4.836	0.490	0.245	0.000
2002	NCB42	0	4.021	3.786	0.942	3.731	2.377	1.990	0.000	0.000
2002	NCB43	0	4.054	3.725	0.919	3.454	7.248	0.247	0.000	0.000
2002	NCB44	0	4.039	3.719	0.921	4.209	2.151	1.486	0.743	0.000
2002	NCB45	1	4.051	3.295	0.813	5.184	6.374	1.481	0.494	0.000
2002	OCR03	0	4.042	3.983	0.985	1.732	3.515	0.247	0.000	0.000
2002	OCR14	0	3.861	0.964	0.250	2.590	11.405	0.000	0.000	1.036
2002	OCR15	0	3.904	2.950	0.756	4.098	2.712	0.000	0.000	0.000
2002	OCR16	1	4.076	3.453	0.847	1.717	12.163	0.000	0.000	0.000
2002	OCR17	0	4.033	3.587	0.889	3.223	6.691	0.248	0.000	0.496
2002	OCR18	1	4.006	3.174	0.792	3.744	7.246	5.990	0.000	1.248
2002	SCB16	1	4.026	2.863	0.711	5.713	2.794	4.719	4.471	0.000
2002	SCB25	0	4.020	3.497	0.870	1.990	4.289	0.746	0.249	0.000
2002	SCB26	0	4.074	2.894	0.710	5.646	3.110	3.927	4.173	0.000
2002	SCB32	0	4.067	3.840	0.944	4.672	4.688	0.984	0.492	0.000
2003	NCB 35	0	8.142	6.594	0.810	3.439	1.517	0.614	0.860	0.000
2003	NCB 7	1	6.220	5.720	0.920	2.090	1.573	0.643	0.161	0.322
2003	NCB 3	0	8.064	7.090	0.879	3.720	2.116	0.868	0.496	0.868

Appendix 3.1 (Continued): Disturbance and Behavioral data for 2002 and 2003

year	Nest	Success	Hours obs	Time Inc.	%Inc	Trips/hour	Moves/hour	Truck/hour	ATV/Hour	Ped/hour
2003	NCB 4	1	8.115	7.359	0.907	2.711	3.805	1.109	0.000	0.123
2003	NCB 2	0	3.600	3.003	0.834	4.444	1.665	4.722	1.944	0.000
2003	NCB 5	0	4.056	3.108	0.766	3.698	0.644	1.726	0.493	0.000
2003	NCB19	0	4.035	3.108	0.774	2.726	4.484	1.983	2.974	8.179
2003	NCB 6	0	4.064	3.108	0.632	5.167	1.557	0.738	0.738	0.000
2003	NCB 8	1	8.075	3.108	0.761	4.087	1.302	1.115	1.858	0.124
2003	NCB 11	0	4.058	3.108	0.887	0.739	3.056	0.000	0.000	0.000
2003	NCB 33	0	4.043	3.108	0.809	4.453	2.753	1.237	0.495	0.495
2003	NCB 36	0	3.967	3.108	0.824	7.059	3.673	0.000	1.765	0.000
2003	NCB 25	0	8.130	3.108	0.894	3.075	3.714	0.861	1.353	0.123
2003	NCB 26	0	4.030	3.108	0.669	4.715	4.081	0.496	3.970	0.496
2003	NCB 13	0	4.021	3.108	0.854	5.969	3.785	3.731	0.497	0.000
2003	NCB 16	0	4.064	3.108	0.893	4.183	3.583	0.492	0.984	0.000
2003	NCB 17	1	4.070	3.108	0.668	1.228	1.470	1.474	0.491	0.000
2003	NCB 18	0	4.060	3.108	0.843	2.709	3.507	0.246	1.478	0.493
2003	NCB 29	0	4.059	3.108	0.898	1.724	1.646	0.246	0.493	0.246
2003	NCB 21	0	4.029	3.108	0.745	4.716	1.999	0.745	0.745	0.000
2003	NCB 23	1	4.071	3.108	0.930	2.702	1.320	2.456	1.965	0.000
2003	NCB 22	0	8.119	3.108	0.915	1.601	1.615	0.123	0.000	0.000
2003	NCB 28	1	8.113	3.108	0.644	4.561	4.973	0.616	0.493	0.247
2003	NCB 24	0	4.063	3.108	0.853	3.692	2.885	0.985	0.246	1.231
2003	NCB 34	0	4.072	3.108	0.868	3.193	2.262	2.456	0.491	0.491
2003	NCB 10	0	4.063	3.108	0.896	4.184	3.020	1.231	0.738	0.000
2003	SCB 42	0	4.046	3.108	0.796	3.213	2.174	0.741	1.730	0.000
2003	SCB 40	0	4.055	3.108	0.556	4.192	2.660	2.712	2.466	0.000
2003	SCB 39	0	3.950	3.108	0.932	4.303	1.087	1.519	1.266	0.000
2003	NCB 37	0	4.057	3.108	0.790	4.191	1.872	0.740	0.493	0.000
2003	NCB 31	0	4.046	3.108	0.596	2.225	9.948	0.742	0.247	0.000
2003	NCB30	0	4.088	3.108	0.868	1.957	2.255	0.734	0.245	0.000
2003	SCB 49	0	4.080	3.108	0.801	5.637	8.877	0.490	2.451	0.000
2003	SCB 57	1	4.070	3.108	0.810	3.685	5.156	0.491	0.983	0.000
2003	SCB 48	0	3.968	3.108	0.641	2.520	8.263	2.520	1.764	0.000
2003	SCB53	0	4.068	3.108	0.789	9.095	7.479	3.933	2.950	0.000
2003	SCB 43	0	3.558	3.108	0.578	3.654	1.460	1.405	1.405	0.000
2003	SCB 44	0	4.034	3.108	0.263	0.991	7.539	0.496	0.248	0.248

Appendix 3.1 (Continued): Disturbance and Behavioral data for 2002 and 2003

year	Nest	Success	Hours obs	Time Inc.	%Inc	Trips/hour	Moves/hour	Truck/hour	ATV/Hour	Ped/hour
2003	SCB55	1	4.066	3.578	0.880	4.181	7.826	0.492	0.738	0.000
2003	SCB 56	1	4.061	3.304	0.814	2.216	4.237	0.246	0.985	0.000
2003	HATT 13	1	4.019	3.965	0.987	2.737	1.009	12.193	0.000	0.498
2003	HATT 11	0	4.096	3.596	0.878	5.616	7.231	19.288	0.000	0.000
2003	BOD 3	0	4.083	4.050	0.992	1.715	1.728	68.340	0.000	0.490
2003	HATT 4	1	4.061	3.734	0.920	1.724	1.607	5.172	0.000	2.709
2003	HATT1	1	4.065	4.006	0.985	1.230	0.499	0.000	0.000	0.000
2003	HATT 2	1	3.796	3.714	0.978	1.317	2.692	0.000	0.000	0.000
Ave:			4.420	3.481	0.824	3.553	3.669	4.687	0.858	0.329