American Oystercatcher (*Haematopus palliatus*) research and monitoring in North Carolina

2008 Annual report

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EXECUTIVE SUMMARY

Natural communities in coastal regions are under increasing pressure from human use, introduced predators, and habitat change. The American Oystercatcher *Haematopus palliatus* is a useful focal species to study the effect of rapid anthropogenic change on coastal ecosystems. American Oystercatchers are long-lived shorebirds that breed from Maine to Florida and are closely tied to intertidal ecosystems throughout the year. Recent evidence of population declines in several states is raising concern over the status of their populations.

Our research objectives were: (1) understand the factors affecting American Oystercatcher breeding success in North Carolina, (2) develop population models that incorporate human and natural influences on population trajectories, and (3) understand migration and dispersal using mark-recapture methods.

Nest survival monitoring began on Cape Lookout in 1995 and quickly expanded to include all of Cape Lookout and Cape Hatteras National Seashores. Nests were located and monitored by NCSU grad students and NPS field staff. Nest survival was highly variable, but overall survival was low (0.246 SE 0.011). Raccoons and other mammalian predators were the primary cause of nest failure, accounting for 54% of identified failures. Overwash and drifting sand accounted for an additional 29% of identified failures. Human disturbance directly caused only 3% of identified failures, but disturbance increased the risk of nest loss to predators. In 2005 we initiated a three year study of Oystercatcher chick behavior and survival using radio telemetry. We found that Oystercatcher chicks move extensively and use the entire beach and dune system. Daily movements of 500 meters were common. This behavior often placed them at risk from vehicles on the beach, and several chicks were killed by vehicles during the course of the study. Since 1999, 47% of chicks in full beach closures on Cape Hatteras survived to fledging, while 27% survived when vehicles were allowed on nesting territories. Chicks in full beach closures used the beach and intertidal zone more than chicks on beaches with vehicles, and spent less time hiding in the dunes. Cats and ghost crabs were identified as important predators during the nestling stage.

Hurricanes are also a significant factor affecting reproductive success. Hurricane Isabel altered the landscape of the Outer Banks, flattening dunes and creating overwash flats. Nesting success increased by 400% on North Core Banks of Cape Lookout National Seashore the year after Hurricane Isabel made landfall. The storm improved nesting habitat and appeared to reduce mammalian predator populations on islands in the direct path of the storm. The islands of Cape Hatteras National Seashore did not see the same sustained increase in nesting success, possibly because much of the new habitat was lost to road reconstruction and the larger islands provided better refuge for predators. We analyzed the effect of the storm on North Core and South Core Banks on Cape Lookout National Seashore. For each study island, we compared alternative models in an information theoretic framework to identify those that best explained the changes in nest survival and the temporal extent of any hurricane effect. The ecological effects of the hurricane varied between islands. Both islands experienced extensive habitat change during the storm, but nest survival only increased on the island where predator activity declined. When predator activity was high or low there was no observed effect of habitat on nest survival. At intermediate predator levels

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nests on open flats survived at a higher rate than nests on dunes and beaches. Periodic years with elevated nest survival can help compensate for low annual productivity and may be important for the growth and stability of Oystercatcher populations.

We developed a set of demographic models for the American Oystercatcher (*Haematopus palliatus*) population in North Carolina to assess the effects of periodic hurricanes on population growth. Nesting success, which averaged 20%, increased to 80% on Cape Lookout National Seashore after a category two hurricane crossed the island in 2003. We constructed a baseline population model without hurricane effects and two alternative parameter sets (10 and 15 year hurricane events) based on hurricane strike probabilities for North Carolina counties. Model parameters (survival, fecundity, age of first breeding), were estimated from mark-recapture data, a twelve year breeding study, and the literature. The baseline model had the lowest population growth rate ($\lambda = 0.984$) with an average population decline of 54% over 50 years. The 15 year hurricane model limited population decline ($\lambda = 0.999$) with an average decrease of 4.6% over 50 years. When hurricane frequency increased to 10 years, the Oystercatcher population increased by 31.7%, $\lambda = 1.006$. Only in the most optimistic scenario (hurricane renewal event every 10 years) did the population increase. Our predictions are consistent with the overall decline in Oystercatchers pairs observed on Cape Hatteras and Cape Lookout National Seashores in the past decade. Oystercatcher pairs have declined 16% at Cape Lookout and 42% at Cape Hatteras since 1999. Our results show that hurricane frequency affects population growth and suggest that the life history attributes of American Oystercatchers may have been shaped by periodic hurricanes which improve habitat, and reduce predator populations.

We have banded 366 individually color-marked American Oystercatchers in North Carolina since 1999. Through resightings of individually marked birds we estimated an annual adult survival rate of 92% and an age of first breeding of approximately 4 years. Working in cooperation with other researchers and volunteers we have identified wintering sites for these banded birds from South Florida to Virginia. Oystercatchers with a breeding or natal site in North Carolina disperse in winter from Virginia to Florida. We found that 32% of the North Carolina Oystercatchers that were resighted in North Carolina for the winter, 2% were observed wintering in Virginia, and the remainder split up among South Carolina, Georgia, and the Gulf Coast of Florida.

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INTRODUCTION

American Oystercatchers (*Haematopus palliatus*) are large, conspicuous shorebirds that are strictly tied to the coastal zone throughout the year. Unlike many shorebirds that breed in the Arctic and migrate to coastal regions in the winter, Oystercatchers breed along the Atlantic Coast from Cape Cod to Florida, and along the Gulf Coast from Florida to Mexico. The winter range extends from central New Jersey south through the Gulf of Mexico. An aerial survey of the species' winter range resulted in a population estimate of 10971 individuals (+/-298), with 7500-8000 wintering on the Atlantic Coast (Brown et al 2005). The survey estimated a winter population of Oystercatchers in North Carolina at 647 birds. A 2007 breeding season survey estimated North Carolina's summer population at 717 individuals, with 339 breeding pairs (Cameron and Allen 2007).

American Oystercatchers are listed in both Georgia and Florida as "threatened", and as a "species of special concern" in North Carolina (North Carolina Wildlife Resources Commission 2008). The US Shorebird Conservation Plan lists American Oystercatchers as a high priority species (Brown et al 2001), in part because of significant threats from development and heavy recreational use of coastal breeding habitats.

Human population density in the United States is highest in coastal regions. The rate of population growth is expected to increase substantially, particularly in the southeastern states (Crossett et al 2004). As more humans inhabit the coastal zone, recreational use of beaches, salt marshes, and waterways will continue to rise as well. Many visitors to the coast seek out undeveloped beaches. As coastal islands and

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beaches are developed, more visitors are concentrated onto the remaining undeveloped areas. Coastal development, recreational activity, and altered predator communities have substantially reduced the amount of suitable nesting and foraging habitat for beach nesting birds in North Carolina. Roads and artificial dunes along nesting beaches can limit access to sound-side marshes and flats that are important foraging habitats for beach nesting species like Piping Plovers (*Charadrius melodus*) and American Oystercatchers. Nesting and roosting sites can also be lost when jetties and revetments alter the normal process of longshore transport of sand and accelerate erosion of adjacent beaches.

A study of breeding American Oystercatchers was initiated on South Core Banks, Cape Lookout National Seashore in 1995 to document nesting success (Novick 1996). Subsequent research expanded the study area to include all nesting Oystercatcher pairs on Cape Lookout and Cape Hatteras National Seashores and expanded the scope of the work to investigate survival, fidelity, movement, disturbance and depredation. This report summarizes the Oystercatcher monitoring and research data from 1995 to 2008 on Cape Hatteras and Cape Lookout, as well as data from islands in the Cape Fear area managed by North Carolina Audubon.

Like many long-lived species, Oystercatcher reproductive rates tend to be highly variable but generally low (Evans 1991). Thus, the species is unable to recover quickly from population declines. These traits make it difficult to assess the status of a population because populations can persist for many years, even if reproductive success is low. Recent surveys indicate that populations in the Mid-Atlantic States are declining (Mawhinney and Bennedict 1999, Nol et al 2000, Davis et al 2001). The

breeding population of Virginia's barrier islands, a historical stronghold for Oystercatchers, fell from 619 breeding pairs in 1979 to 255 breeding pairs in 1998 (Davis et al 2001). A 2004 survey that covered the same region estimated the population at 302 breeding pairs (Wilke et al 2005). This survey also covered lagoon and marsh habitat and found an additional 223 pairs. These results suggest populations may be moving into non-traditional habitats, and they highlight the need for additional surveys in marsh and upland habitats not normally associated to Oystercatchers. During the period of apparent decline in the mid-Atlantic, the species expanded its breeding range into the northeastern United States (Davis 1999, Mawhinney and Bennedict 1999, Nol et al 2000, Davis et al 2001). Understanding the causes of local, regional, and continental population trends will require region-wide studies of the species' population structure and demographics.

The objectives of our research are:

I)   Understand the factors affecting the reproductive success of American Oystercatchers in North Carolina.

II)   Develop models of population dynamics that incorporate the effects of humans, predators, and environmental conditions on population trends.

III) Understand patterns of adult migration and juvenile dispersal through a large scale mark-recapture study.

STUDY SITES

We are currently monitoring American Oystercatcher productivity at several locations in North Carolina in cooperation with staff from the National Park Service and the National Audubon Society. Cape Lookout and Cape Hatteras National Seashores (Figure 0.1) comprise over 160 km of barrier island habitats that support a population of approximately 90 breeding pairs. The National Audubon Society manages several islands in the Cape Fear region (Figure 0.1) that provide habitat for an additional 32 pairs of breeding Oystercatchers. 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 is also host to 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 nesting success on Lea and Hutaff Islands in Pender County North Carolina. Lea and Hutaff are barrier islands similar to the 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 (McGowan et al 2005a).
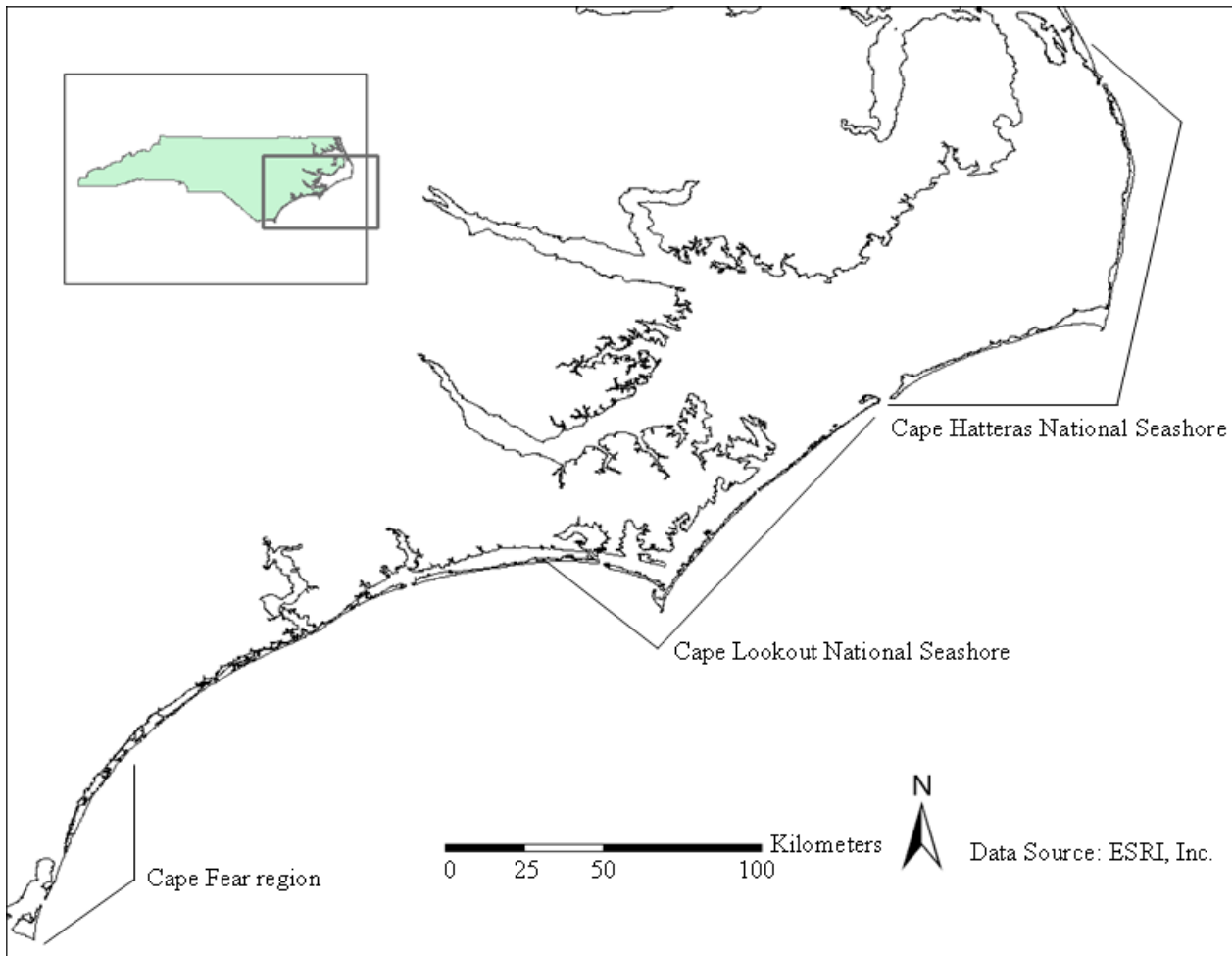
Figure 0.1. American Oystercatcher study sites in North Carolina.

SECTION 1 – FACTORS AFFECTING AMERICAN OYSTERCATCHER NEST SURVIVAL

A study of breeding American Oystercatchers was initiated on South Core Banks, Cape Lookout National Seashore in 1995 to document nesting success (Novick 1996). The scope of the original study has expanded to include all of the islands of Cape Lookout and Cape Hatteras National Seashores. The study of Oystercatcher breeding success further expanded in the state in 2002 and 2003 when the North Carolina Audubon Society initiated nest monitoring on dredge spoil islands at the mouth of the

Cape Fear River, and on Lea and Hutaff Islands. Although the undeveloped barrier islands that comprise the National Seashores were thought to be ideal breeding habitat for American Oystercatchers, nest survival was much lower than expected. Novick (1996) attributed low hatching rates to human disturbance. Davis (1999) continued the work on Cape Lookout and used nest monitoring and predator tracking stations to determine the causes of nest failure. Davis determined that a majority of nests were lost to mammalian predators. Subsequent studies in North Carolina have supported the conclusion that mammals are the primary nest predators, but they also suggested an interaction between human disturbance and nest predation rates (McGowan 2004, McGowan and Simons 2006). McGowan and Simons (2006) found an inverse relationship between the number of visits an Oystercatcher made to the nest and the nest survival rate, suggesting that more disturbed nests are more likely to be found by predators.

METHODS

Surveys of breeding Oystercatchers on the Outer Banks began in early April each year. Nests were located by walking or slowly driving along the barrier beach and back-road system. When an adult Oystercatcher was located, observers watched for behavioral cues that indicated the bird had a nest. Although nesting Oystercatchers do not usually employ "broken-wing" distraction displays typical of smaller shorebirds, they do exhibit easily identifiable behaviors such as false incubating and alarm calling. When breeding behavior was observed, scrapes were found by following the tracks of the adult birds, or by systematic searches. Once located, nests were marked with a small wooden stick placed near the nest, or by using adjacent natural landmarks like

driftwood, shells, etc. as a reference. The location of each nest was recorded with a handheld GPS. Nests were checked every 1-4 days until hatching or failure. We made every effort to minimize disturbance and reduce the effect of our observations on nesting success. If a bird is seen incubating from a distance, the nest was considered active and it was only checked to determine if the chicks had hatched. We avoided walking directly to nest sites, and spent a minimal amount of time in the vicinity of the nest to minimize cues for predators. If a nest failed, we attempted to determine the cause of failure by searching the area for signs of predators, overwash, or other sources of nest failure. For example, when a storm event washes out a nest, the nest scrape is usually gone and the debris line is evident above the nest's original location. Unfortunately, such evidence does not last long on a barrier beach, so it was not always possible to determine the causes of nest failure.

Previous analyses compared estimates of apparent nesting success using the binomial proportion of successful nests to failed nests, with Mayfield nest survival estimates (Mayfield 1961, 1975, Davis, 1999, McGowan 2004). As expected, these results showed that apparent nest success overestimated survival because of nests that failed and were never found. We have reevaluated the nest survival database using the nest survival module in Program Mark (White and Burnham 1999). This method is similar to the Mayfield method in that a daily survival rate is calculated from nest observation days and thus accounts for missed nests. Program Mark uses a maximum likelihood method to estimate the nest failure date when the time between nest checks is greater than 1 day, and it allows for modeling covariates to explain variations in nest success and the comparison of alternative models using Akaike's Information Criteria

(AIC) (Akaike 1973, Burnham and Anderson 2002). The average incubation period for Oystercatcher nests is 27 days (Nol and Humphrey 1994). To obtain nest survival probabilities we raised estimates of daily survival rates (DSR) to the 27th power. For the purposes of these analyses we assumed no within-habitat heterogeneity in survival probabilities throughout the incubation period. In future work we may be able to test this assumption by calculating the age of nests when they are found, and modeling survival trends across the incubation and nesting periods. Here, we report on 1581 nests monitored from 1995-2008. We used 1381 nests in the Program Mark analysis because data for some nests were not collected in a manner consistent with this format.

RESULTS

Overall observed hatching success from the beginning of egg laying through hatching for all years was 0.288 (SE 0.011), and ranged among sites and years from 0.0 to 1.00 (Appendix 1). The adjusted Program Mark estimate for daily nest survival was 0.949 (SE 0.002). The probability of a nest surviving to hatching was $0.950^{27} =$ 0.246 (SE 0.011), which means that an estimated 24.6% of all nests survived to hatching.

Hatching success was highly variable among years and locations. Model results showed that nest survival rates were different among study sites. We evaluated two models in Program Mark to compare overall nest survival rates from Cape Lookout, Cape Hatteras and the Cape Fear region. The first model used a separate parameter for each site while the second model combined all sites. The delta AIC for the separate model was 50 points lower than the combined model, indicating that there are differences among the sites. In addition, the confidence intervals of the nest survival

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rates for the three sites did not overlap, indicating significant differences in nest survival.

(Table 1.1). Nests on Cape Lookout National Seashore had the lowest overall daily

survival rate, followed by Cape Hatteras. The study sites in the Cape Fear estuary had

the highest overall daily survival rate.

Table 1.1. American Oystercatcher nest survival rates for study sites in North Carolina.

Site	Nest Survival (SE)	95% CI	Nests
Cape Lookout (1997-2008)	0.181 (0.012)	0.158-0.205	1057
Cape Hatteras (1999-2008)	0.341 (0.024)	0.295-0.387	449
Cape Fear (2002-2003)	0.463 (0.046)	0.371-0.550	113

Mammalian depredation was the major identifiable cause of nest failure at our

study sites from 1995-2008, accounting for approximately 54% of identified nest failures

(Figure 1.1). Over-wash and other weather related causes accounted for 29% of

identified failures. The remaining identified failures (17%) were caused by human

activity, avian predators, ghost crabs, or unknown reasons (Figure 1.1). Human activity

was defined as a human action directly leading to nest failure, such as physical

destruction of the eggs, and did not include indirect effects of disturbance. We could

not identify the causes of failure for 52% of failed nests. The sources of nest mortality

were similar on Cape Hatteras and Cape Lookout, but the relative proportion of nests

lost to each source varied between year and location (Figure 1.2 and 1.3),
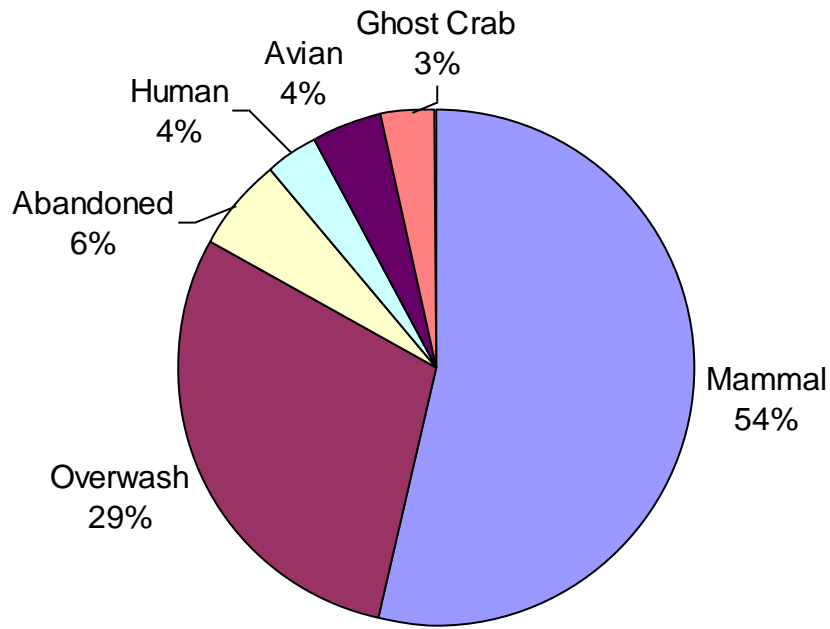
Figure 1.1. Sources of American Oystercatcher nest failure on the Outer Banks of North Carolina from 1998-2008 where cause of failure could be determined (N=481). Cause of failure could not be determined for 49% of nest failures (N=464).
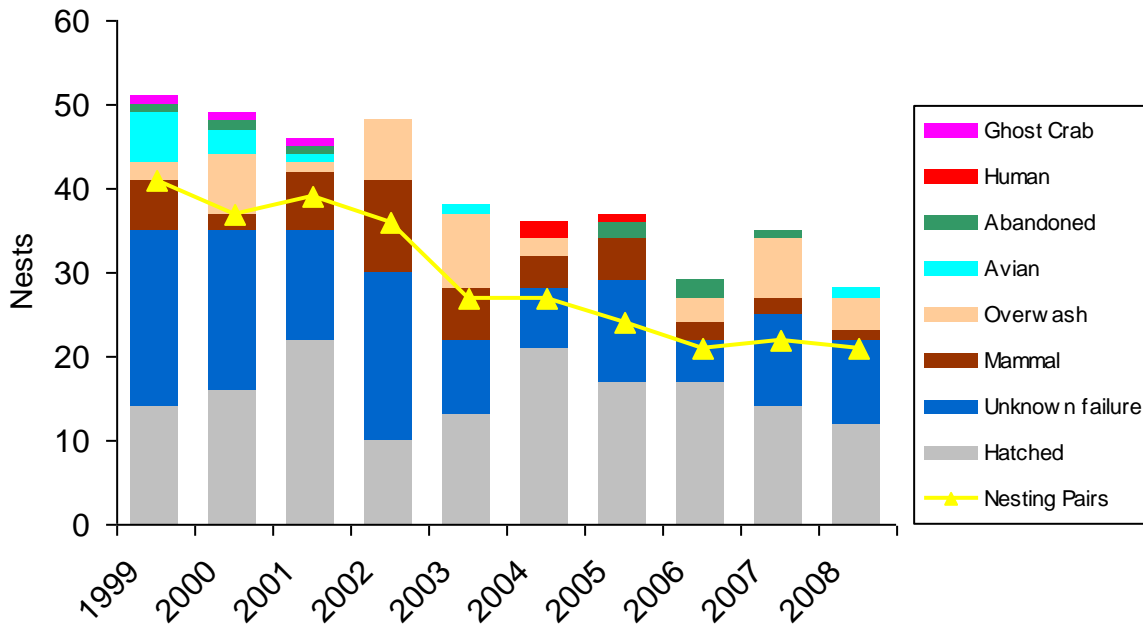
Figure 1.2. Nest fates for American Oystercatcher nests on Cape Hatteras National Seashore from 1999 to 2008. Column segments represent the number of nests in each outcome category.
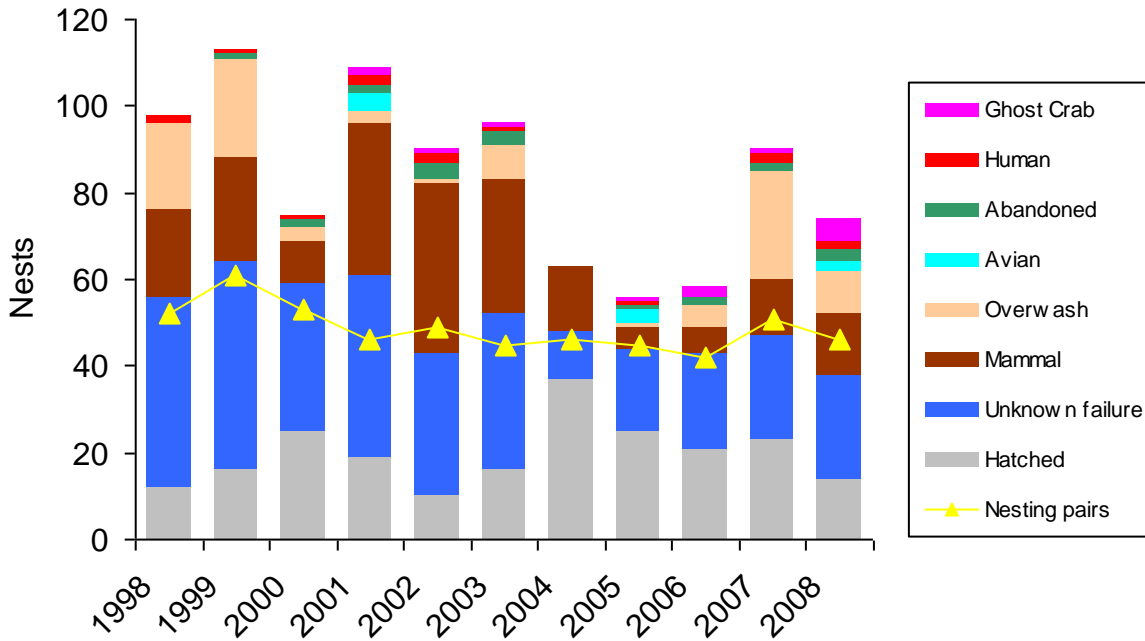
Figure 1.3. Nest fates for American Oystercatcher nests on Cape Lookout National Seashore from 1998 to 2008. Column segments represent the number of nests in each outcome category.

Oystercatcher pairs initiated between one and five nests per season (1.55, SE 0.01) with an average of 2.35 eggs/nesting attempt (0.01). A nesting attempt was defined as a nest with at least one egg. Pre-nesting scrapes were not considered nesting attempts. The number of nesting attempts per pair for a given area was dependent on the nest survival rate. When a nest failed, Oystercatcher pairs waited 9-14 days before initiating a second clutch. If a nest hatched successfully pairs did not re-nest unless the chicks were lost while still very young (<7 days). Oystercatcher pairs routinely made two or three nesting attempts per season, with a maximum of five attempts recorded in a single season. The average number of clutches per pair was logarithmically related to overall nest survival (y = -0.375Ln(x) + 1.0873, Figure 1.4).
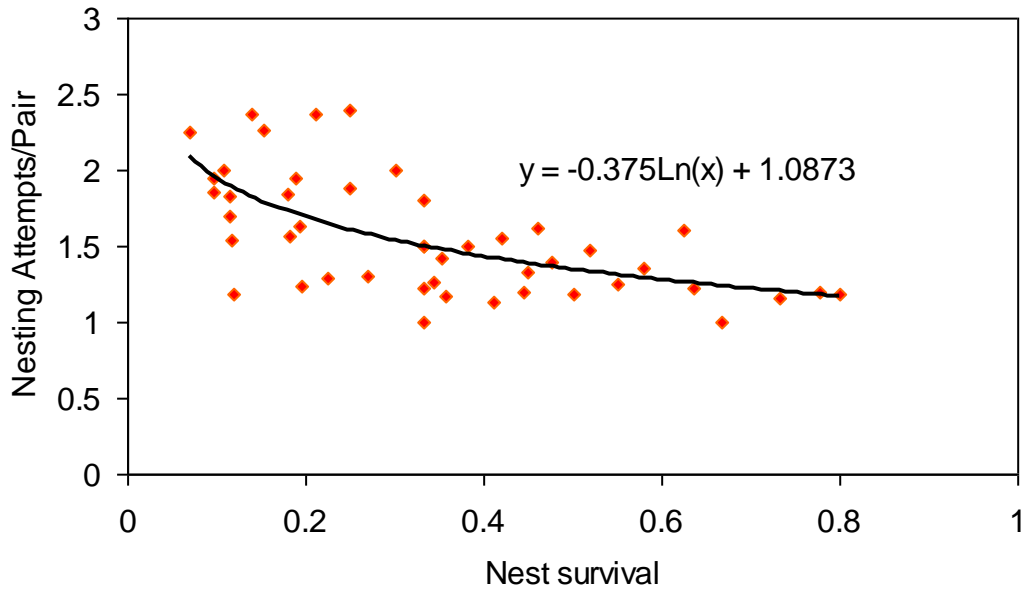
Figure 1.4. The number of nesting attempts per pair as a function of nest survival on Cape Lookout and Cape Hatteras National Seashores.

DISCUSSION

Of all the Oystercatcher nests we monitored from 1995 to 2008, 28.8% survived to hatching. This binomial calculation is a simple and unrealistic model for estimating nesting success. The Program Mark nest survival module accounts for nests that are never found, or nests that fail before they are found. The Program Mark estimate for daily nest survival was 0.949 (SE 0.002). The probability of a nest surviving to hatching was $0.950^{27} = 0.246$ (SE 0.011), which means that an estimated 24.6% of all nests survived to hatching. The entire 95% confidence interval for the Program Mark estimate of nest survival to hatching is lower than the observed hatching success rate. This means that the binomial success rate is biased high because it only considers nests that are found and monitored by observers. Whenever possible we used the adjusted nest survival estimate to compare between sites and years.

Nest survival and the sources of nest mortality varied between year and location (Figure 1.2 and 1.3), but overall nest survival in both parks was strongly affected by mammalian predators and storm overwash. Mammalian predators were the primary source of nest failure. Human actions that affect predator populations or the ability of predators to locate nests will have the greatest effect on nest survival. McGowan and Simons (2006) found that nests that were frequently disturbed were more likely to be depredated. Frequent disturbance may make the nest more visible to avian predators and increase the number of scent trails leading to the nest. On Hatteras Island, Cape Hatteras National Seashore, the nest survival rate fell from 0.272 (SE 0.048) in the period 1999–2001 to 0.030 (SE 0.023) in 2002, after foxes colonized the island. Predator control measures were initiated in 2003 and the nest survival rate increased to 0.506 (SE 0.050) from 2003-2008. On Cape Lookout National Seashore, the proportion of nests positively identified as lost to predators dropped from 0.31 to 0.10 after Hurricane Isabel flooded the island in September 2003, and apparently reduced predator populations (Section 3, Schulte and Simons, in revision). It is important to draw a distinction between breeding season storms and overwash and post-breeding storm events. Breeding season storms can result in significant nest loss as nests are flooded out or sanded over. A strong storm at the wrong time of year can eliminate most of the active nests, which sets back the reproductive cycle by 2-6 weeks. Hurricanes and strong winter storms do not directly affect nest success because they usually occur outside of the breeding season. These storms can have beneficial effects as they create new nesting habitat and may reduce predators.

We were not able to observe the causes of most nest failures directly. We relied

on indirect evidence, such as eggshell fragments, or predator tracks, to infer the causes of nest failures. Nests reported as undetermined generally represent nests where wind or rain erased any clues of the causes of failure. We believe that the vast majority of our unidentified failures are a result of nest predators. Storm losses were usually easy to identify as the tide line following the storm was often evident above the level of the nest, or the nests were completely sanded over. Identification of different nest predators was much more difficult. Avian predators can leave little or no sign at the nest, and the tracks of mammals such as raccoons and cats are quickly blown away. Even during calm weather, predator tracks were often obscured by Oystercatcher tracks as the pair returned and walked around the nest scrape after a predation event. The difficulty of identifying different sources of failure suggests that storm losses may be over-represented in our estimates of identified nest failures (Figure 1.1). It is also possible that avian predators are under-represented in these estimates because these predators often leave little evidence. Losses from avian predators usually result in clutch reductions as often only a single egg is taken. Most nest failures occur overnight with the loss of an entire clutch of eggs, suggesting mammalian depredation.

SECTION 2 – BEHAVIOR AND SURVIVAL OF OYSTERCATCHER CHICKS

Although a considerable amount of research has been conducted on nesting American Oystercatchers, relatively few studies have focused on chick survival. The sources and timing of mortality are very difficult to determine for precocial shorebird chicks (Nol 1989; Ens et al 1992). Chicks often leave the nest within a few hours of hatching, after which they are cryptic and highly mobile. When chicks are lost to predators, exposure, or other factors, it is usually impossible to determine the cause of

death. Because many breeding attempts fail at this stage, several recent studies have stressed the need for a better understanding of the factors affecting chick mortality (Davis et al 2001, McGowan et al 2005a). In 2004 we initiated a study of American Oystercatcher chick behavior on Cape Hatteras National Seashore. Relatively little was known about how Oystercatcher broods used their habitat and responded to human activity. Anecdotal observations suggested that breeding adult Oystercatchers altered their behavior in the presence of humans and vehicles by hiding their chicks in the dunes and keeping them off the beach. The objectives of this study were to identify patterns of chick behavior and habitat use, quantify the effects of vehicles on Oystercatcher chick behavior, and compare the effects of two management actions (full versus partial beach closures).

In 2005, 2006 and 2007 we used radio telemetry to track Oystercatcher chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore to identify the timing and sources of chick mortality. This section examines factors affecting the survival of Oystercatcher nests and chicks in North Carolina from 1997 through 2008.

METHODS

When a nest hatched, the young were observed every 1-4 days until fledging, or until all the chicks died or disappeared. With careful monitoring it was possible to determine annual breeding success, or the number of chicks fledged per pair, per year, although it was not always possible to determine the cause or exact timing of chick mortality. Adult Oystercatchers exhibit markedly different behavior patterns when they have chicks. They are much more aggressive toward intruders, and they give distinct

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alarms calls. It was generally possible to determine whether a pair of adult birds had chicks by observing adult behavior, even if we could not locate the chicks. In most cases chicks were located by observing adults from a distance using a spotting scope, and occasionally a portable blind. On the rare occasion that a chick was found dead, we attempted to determine the cause of death. We calculated overall breeding success or productivity by dividing the number of chicks that survived to fledging by the number of breeding pairs for each year for each location.

We documented habitat use and behavior of Oystercatcher broods on Cape Hatteras National Seashore from 2004 to 2007 using behavioral observations. We did not have the option of experimentally manipulating the disturbance level or closed/open status of the beach (see Simons and Tarr 2008), so this was strictly an observational study. We conducted observations in hour-long intervals, taking instantaneous behavior and location information at two minute intervals. Broods were observed through scopes from a distance where observer presence did not affect the bird's behavior. Locations were designated as; below the tide line, open beach, and dunes/grass. Behavior was designated as: resting, foraging (chicks searching for food), locomotion, feeding (parents bringing food for their chicks), and out of sight. Behavior watches continued if the birds went out of sight as long as we could still determine the habitat type. This prevented a negative bias for dune/grass habitats where the birds are less visible. We observed chicks of all ages from hatching through fledging at all times of day and stages of the tide. We were not able to conduct behavior watches at night, but we did periodically check on the location of broods at night to document habitat use. Observation windows were randomly assigned to active Oystercatcher broods

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throughout the nesting season.

From 2005 to 2007 we radio tagged a total of 121 chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore. Chicks were radio tagged as soon as they were mobile, usually within 24-48 hours of hatching. We attached ATS A2420 transmitters (1.3 grams) to the scapular region of the chick using surgical grade skin glue (Figure 2.1). Chicks were checked every 24 hours for the first week, and every 1-3 days thereafter. Transmitter range was 400-1000 meters depending on terrain. When a chick died, we tried to locate the remains and determine the cause of death. In 2005 and 2006 we exchanged the ATS transmitters for larger PD2 model transmitters from Holohil Systems when the chicks reached four weeks of age. These transmitters were designed to last at least six months and were attached to a permanent leg band (Figure 2.2).

Figure 2.1. Recently hatched American Oystercatcher chicks. Lower chick is wearing a radio transmitter.

Figure 2.2 Juvenile American Oystercatcher with color bands (J7) and a leg band radio transmitter. Note antenna extending from the transmitter on the bird's left leg.

RESULTS

Chick survival was estimated from 859 chicks hatched from 439 successful nests in North Carolina from 1997 to 2008. Average chick survival was 0.360 (SE 0.016), but survival varied among sites and years (Figure 2.3 and 2.4). Despite high hatching success for the Cape Fear River nests in 2002 and 2003 (0.443, SE 0.049, Appendix 1), the survival of the chicks after hatching was very low (0.206, SE 0.049). Lea and Hutaff Islands (barrier islands) had very high nest (0.617 SE 0.133) and chick (0.391 SE 0.102) survival in 2003. Data for nests on the Cape Fear River and Lea and Hutaff islands in subsequent years were not available.
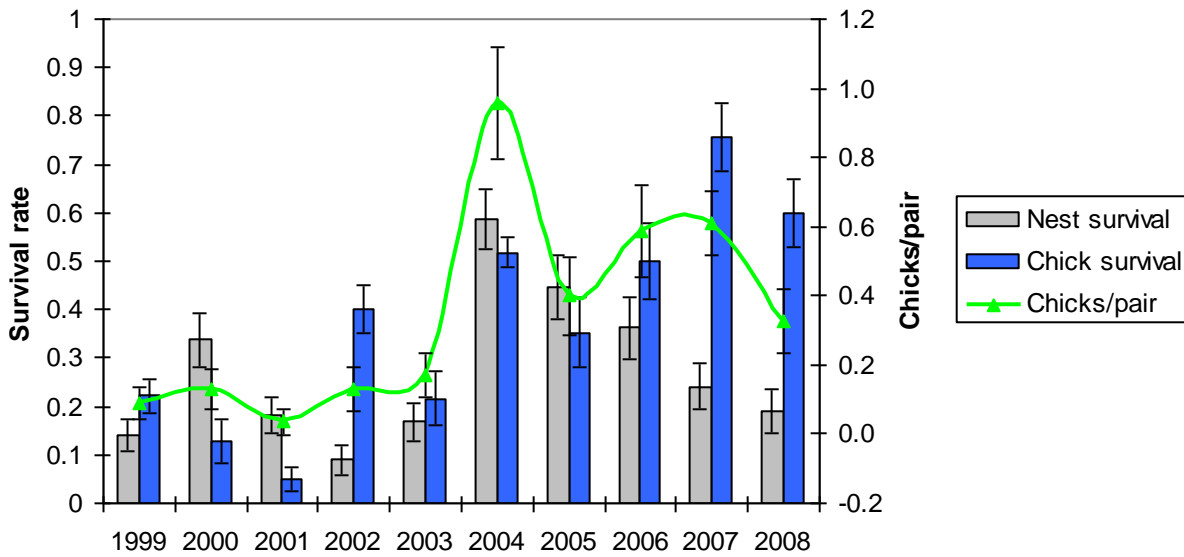
Figure 2.3. Breeding success of American Oystercatchers on Cape Lookout National Seashore from 1999 to 2008. Error bars represent one standard error.
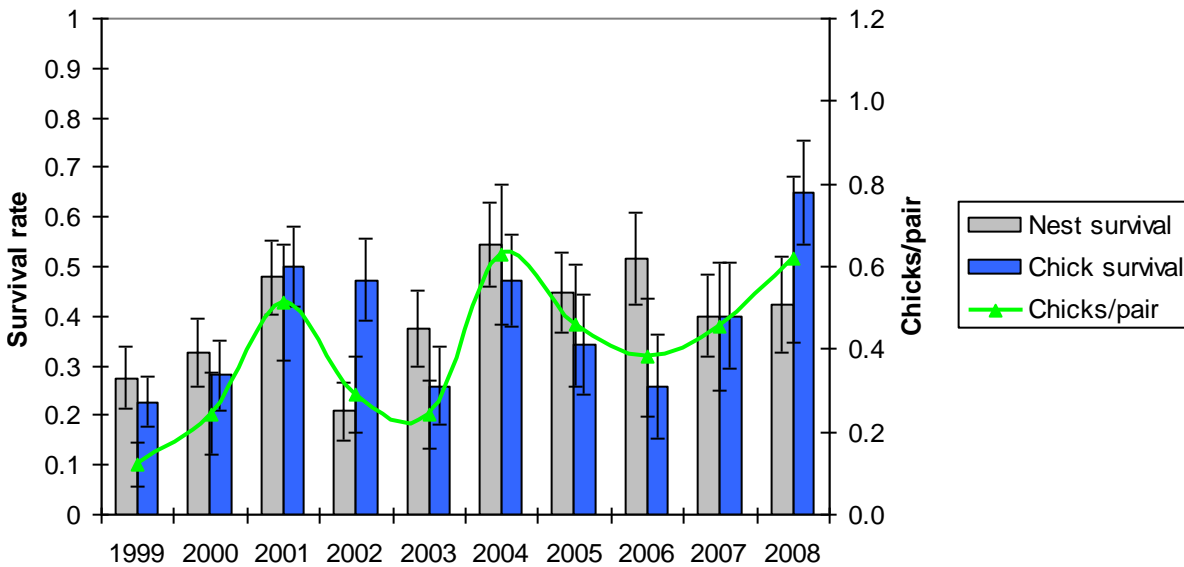
Figure 2.4. Breeding success of American Oystercatchers on Cape Hatteras National Seashore from 1999 to 2008. Error bars represent one standard error.

Immediately after Hurricane Isabel (fall 2003), chick survival increased on Cape Lookout from an average of 0.165 (SE 0.026) to 0.523 (SE 0.054), possibly because of reduced predation on some islands and increased foraging opportunities. In 2007 and 2008 chick survival on Cape Lookout increased again to 0.662 (0.058) after the Park

Service closed to driving sections of the beach with Oystercatcher chicks. On Cape

Hatteras From 1999 to 2009, chick survival in full beach closures was 0.482 (SE 0.056),

while survival was 0.236 (SE 0.038) when the beach had an open lane for vehicles and

pedestrians (Figure 2.5).
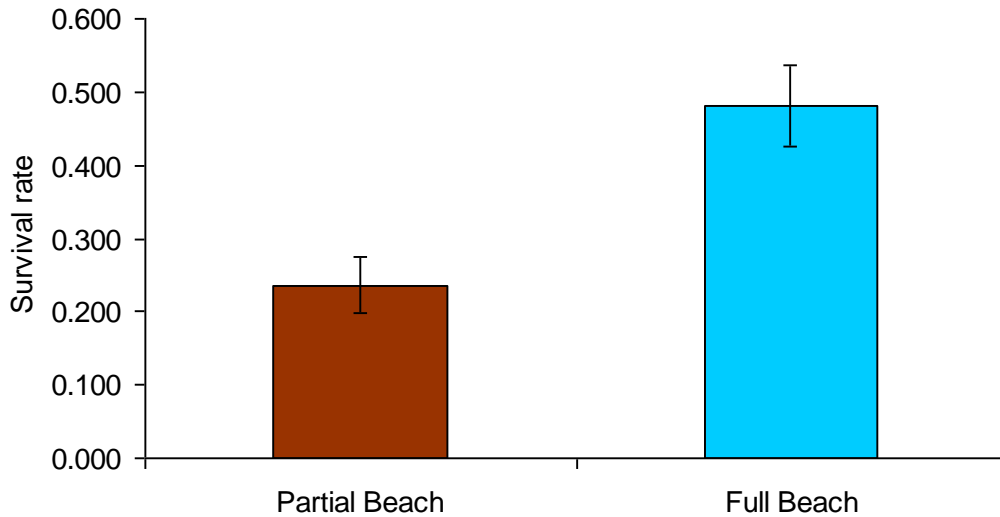
Figure 2.5. Chick survival by closure type on Cape Hatteras National Seashore from 1999-2008 (N = 291 chicks). Error bars represent one standard error.

Sources of chick mortality were determined from the radio telemetry study. One

hundred and twenty-one chicks were tracked from hatching to fledging or death. Chick

predators included Great Horned Owls (*Bubo virginianus*), Fish Crows (*Corvus*

ossifragus), Feral Cats (*Felis catus*), Raccoons, *(Procyon lotor)*, American Mink

(*Mustela vison*), and Ghost Crabs (*Ocypode quadrata*) (Figure 2.6). Human activity

(vehicle collisions and disturbance) was directly responsible for 16% of known chick

mortality. Several chicks died of exposure during storm events shortly after hatching.

The majority of chick mortality occurred in the first week after hatching, but there was

also a smaller spike in mortality around fledging at 30-40 days (Figure 2.7). We were

unable to determine the cause of mortality in 51% of the cases (N=39). Typically this

was because both the chick and transmitter had disappeared.
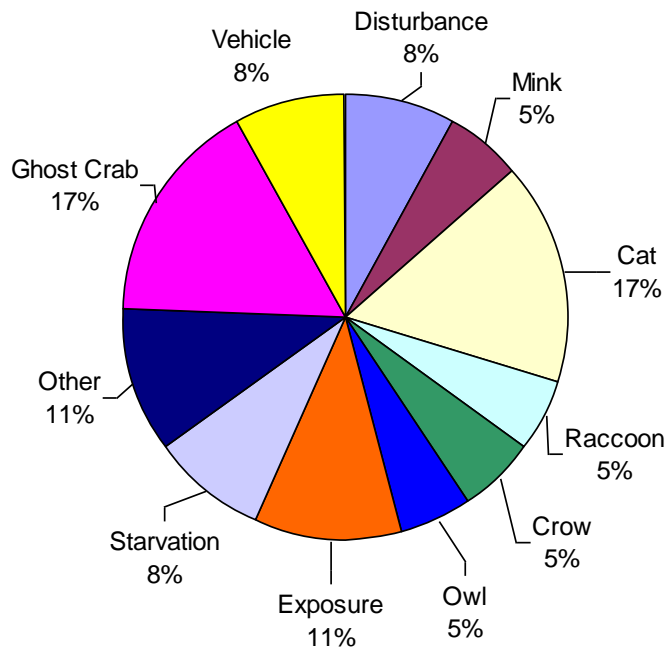
Figure 2.6. Identified sources of pre-fledging American Oystercatcher chick mortality at Cape Hatteras and Cape Lookout National Seashores from 2005-2007 (N=37). Source of mortality could not be determined for 51% of chick deaths (N=39 chicks).
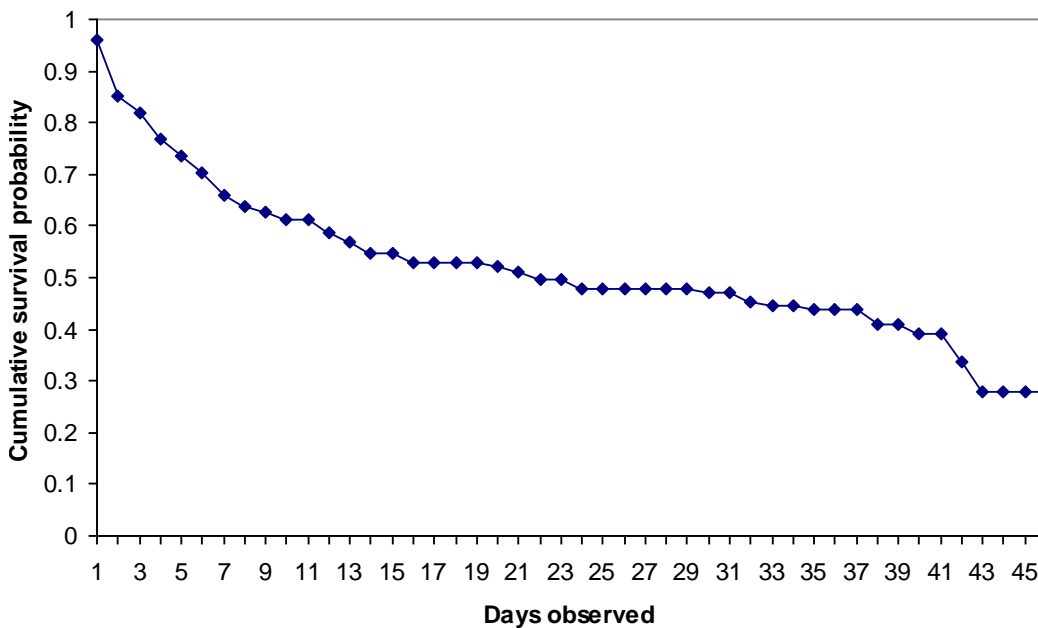
Figure 2.7. The Kaplan-Meier survival curve for pre-fledging American Oystercatcher chicks on Cape Hatteras and Cape Lookout National Seashores from 2005 through 2007 (N=121 chicks).

After fledging, radio-marked chicks were tracked daily until mid-August, when field personnel were no longer available. No fledgling mortality was documented during this time. Survey flights in late August and early September in 2005 and 2006 covered the Outer Banks from Nags Head to Morehead City. The oldest chicks began to migrate out of the study area by the end of August, but several still remained at their natal sites on the last survey flight on September.

We conducted 160 hours of behavioral observation of chicks on Cape Hatteras National Seashore over four years (2004-2007). Over 90% of the observations were of chicks in full-beach closures because most of the locations where chicks hatched were subsequently closed under Park Service policy. Chicks in full beach closures spent 43% of their in the dunes, 36% on the upper beach, and the remaining 21% at or below the high tide line (Figure 2.8). Chicks with partial beach closures spent 74% of the time in the dunes and 26% of the time on the open beach. Some behavioral differences were evident as well. Chicks in full beach closures spent more time resting and foraging and less time out of sight, due to less time spent in the dunes, (Figure 2.9). Chicks in partial closures often ran back and forth from the beach to the dunes in response to vehicles, humans and dogs. Oystercatchers with chicks showed a stronger reaction to humans with dogs than to humans alone. We did not document any dog-related mortality, but dogs were observed chasing adult Oystercatchers on several occasions. Adults begin to bring their chicks to the waterline to forage within 24 hours of hatching. Broods ranged up and down the beach from their nest sites, often moving 500 meters or more each day. This pattern continued throughout the chick-rearing stage. Night observations of chicks invariably found the broods on the open beach or

below the tide line on both open and closed sections of beach. During the day chicks

spent most of their time hiding in the dunes, particularly in areas open to vehicles.

Parents always brought their chicks to the beach around sunset. We observed

Oystercatchers of all ages that became disoriented by bright (vehicle?) lights at night

and walked, ran, or flew toward the light source. We observed adult Oystercatchers on

open sections of the beach became disoriented by headlights and abandoned thier

chicks until the vehicles had passed. In most cases adults returned quickly to their

chicks, but in at least one case the adults were kept away by multiple vehicles passing,

which resulted in the deaths of their young chicks, presumably due to exposure or lack

of food.
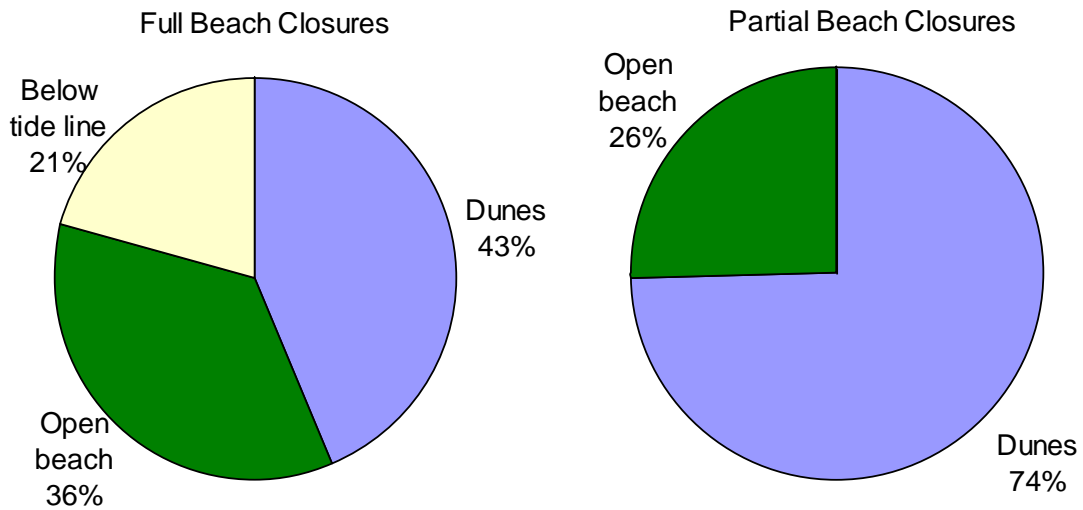
Figure 2.8. Habitat use by American Oystercatcher chicks on Cape Hatteras National Seashore in full and partial beach closures (2004-2007).150.5 observation hours in full closures, 12 observation hours in partial closures
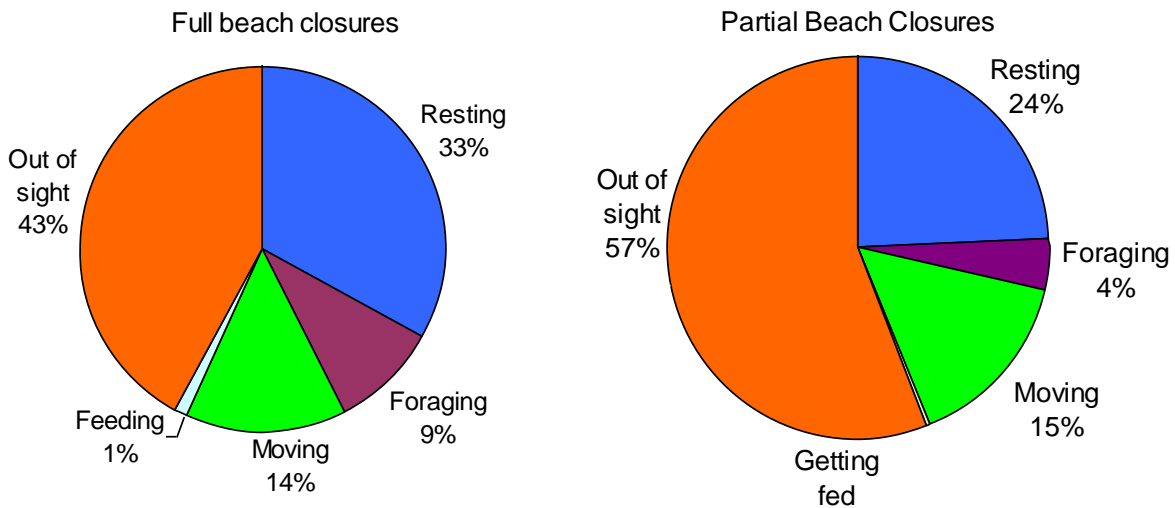
Figure 2.9. American Oystercatcher chick behavior in full and partial beach closures on Cape Hatteras National Seashore (2004-2007).150.5 observation hours in full closures, 12 observation hours in partial closures

We estimated total productivity as the number of chicks fledged per nesting pair, from 1036 pairs and 1581 clutches monitored between 1995 and 2008. Productivity was highly variable among years and among locations (Appendix 1). A total of 320 chicks fledged from all study sites between 1995 and 2008. On average, 0.309 (SE 0.020) chicks fledged per nesting pair. Total productivity (P) is a function of nest survival (S_N), chick survival (S_C), chicks hatched per successful nest (H_C), and total nests per breeding pair. As we have seen, the number of nests per pair is a function of nest survival (Figure 1.4), so the equation for productivity can be written as:

Equation 1: $\quad\quad S_N * S_C * H_C * (-0.04139(LN\ S_N) + 1.1099) = P$

This equation is useful because it allows us to separate the components of overall productivity and therefore to predict the effect of a change at each stage of the nesting season.

DISCUSSION

Estimates of fledging success and sources of mortality are difficult to obtain for cryptic, highly mobile Oystercatcher chicks. The radio tagging study revealed the relative importance of different predators. Unsurprisingly, feral cats were found to be important predators. Avian predators and ghost crabs played a larger role than previously known. Both Great Horned Owls and Fish Crows were identified as chick predators. Chicks were most vulnerable during the first week after hatching when they are most susceptible to exposure and ghost crab depredation.

Radio tracking also provided new insights about chick behavior. Very young chicks are highly mobile, much more so than previously believed. Movement between the dunes and the waterline places young chicks at considerable risk from vehicle traffic. We regularly observed chicks hiding in vehicle tracks in response to adult alarm calls and also observed chicks, and even some adults, running or flying directly at the headlights of oncoming vehicles at night. This study highlighted the difficulty of documenting the mortality of young Oystercatcher chicks. Without radio telemetry keeping track of broods can be difficult, and locating dead chicks is almost impossible. Even with radio tags we were only able to identify the source of mortality about 50% of the time. Many chicks simply disappeared from one day to the next. We suspect that predators carried these chicks out of range of our receivers or the remains washed away if they died below the high tide line.

Prior to our telemetry study, sources of chick mortality were not well known, but they included starvation, exposure, and vehicle traffic. Mortality from vehicles was first documented in 1995, when three chicks on Cape Hatteras were found crushed in

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vehicle tracks.   Shortly after we initiated the radio tracking study in 2005, we documented the mortality of a brood of two-day old chicks that were run over by an ATV on North Core Banks. We radio-tagged the recently hatched brood at the nest on June 16 2005. That same evening the chicks were relocated hiding in seaweed at the tide line with the adult pair. The following morning we tracked the transmitter signals to a nearby location and found two of the chicks crushed in a fresh ATV tire track, just above the high tide line (Figure 2.10).

Figure 2.10. Radio-marked Oystercatcher chicks crushed by a vehicle June 16 2005, Cape Lookout National Seashore.

On 23 May 2006 two three-day old chicks near Hatteras inlet on Cape Hatteras National Seashore died of exposure and depredation after their parents were disturbed by vehicle traffic after dark. The parents brought the chicks down to the tide-line at sunset and were subsequently disoriented and frightened off by vehicle headlights. One of the chicks was found the next morning nearly dead of hypothermia, while the other had been killed by a ghost crab. In 2007 one radio tagged chick on Cape Hatteras was run over by a Turtle Patrol ATV. The driver of the ATV was trained to watch for chicks on the beach, and still missed seeing the chick. These incidents highlight the vulnerability of shorebird chicks to vehicle traffic.

Overall chick survival was almost twice as high in full beach closures on Cape Hatteras as in areas open to vehicle traffic. Cape Hatteras implemented a policy of completely closing sections of beach with Oystercatcher broods in 2005 and no chick mortality due to vehicles was documented. In 2006 this policy was changed to allow vehicle traffic past some of the broods and two chicks died following repeated disturbance by vehicles at night. In 2007 Cape Hatteras returned to the policy of full beach closures for Oystercatcher broods. In 2008 the seashore increased predator trapping efforts and expanded buffer zones for chicks to 300 meters. Chick survival on Cape Hatteras in 2008 was the highest recorded during the study period (0.81 chicks fledged per breeding pair).

After two chicks were killed by a vehicle in 2005, Cape Lookout National Seashore initiated a policy under which they closed sections of beach with unfledged chicks to vehicle traffic, and re-routed traffic around the birds via the interdune road. After the beach sections were closed, chicks were regularly observed on the open beach and at the tide line during daylight hours, suggesting that vehicle traffic was altering chick behavior and foraging patterns. This conclusion was supported by behavioral observations of Oystercatcher chicks on Cape Hatteras. Our data indicate that human and vehicle disturbance of Oystercatchers during the chick-rearing phase produces measurable differences in chick behavior, habitat use, and chick survival. Despite limitations on our ability to observe chicks in partial beach closures, the differences in habitat use between birds in full and partial beach closures are very apparent. In addition to being at risk from direct mortality from vehicles, chicks in partial closures spend more time in the dunes, which subjects them to greater heat stress,

limits feeding opportunities, and may expose them to greater risk from predators such as cats, mink, and raccoons. The predator risk increases at night, which probably explains why the adults bring their chicks out onto the beach every night even if vehicles are present.

SECTION 3 – EFFECTS OF HURRICANE ISABEL ON NEST SURVIVAL

The North Atlantic region is currently in a period of increased hurricane activity which is likely to continue for another one to four decades (Goldenberg et al 2001). Ocean surface temperatures are predicted to increase, driven by multi-decadal oscillations in the North Atlantic and increasing levels of atmospheric greenhouse gases (Emanuel 2005). An increase in ocean temperature is likely to result in increased frequency and intensity of tropical storm systems and could extend the current active hurricane period (Goldenberg et al 2001; Emanuel 2005; Webster et al 2006).

On 18 September 2003, Hurricane Isabel made landfall on the Outer Banks of North Carolina as a strong category two hurricane with winds up to 165 km/h, a 2.5 m storm surge, and 4-6 m waves on top of the surge (Bevin and Cobb 2004). Hurricane force wind extended from Morehead City, NC to the southern Virginia coast. This hurricane substantially altered the physical structure of some barrier islands of the Outer Banks, flattening dunes and opening wide overwash flats. The eye of the hurricane and the strongest winds in the Northeast quadrant of the storm passed over the island of North Core Banks, part of Cape Lookout National Seashore. Storm intensity was somewhat reduced on islands to the south, including the island of South Core Banks (Bevin and Cobb 2004).

We studied the effects of Hurricane Isabel on the nesting success of American

Oystercatchers on North Core and South Core Banks, the two largest islands of Cape Lookout National Seashore. Prior to the storm we collected five years of nest survival data on American Oystercatchers on Cape Lookout National Seashore, identifying mammalian predators as the primary source of nest failure (Novick 1996; Davis 2000; McGowan 2004, McGowan et al 2005a). Demographic modeling based on mark-recapture and pre-hurricane nest survival data from the Outer Banks projected a high risk of population decline (Schulte and Simons in prep.). We hypothesized that the local population must persist through immigration or occasional high productivity years. During the 2004 nesting season following Hurricane Isabel, Oystercatcher nest survival on North Core Banks increased to 475% of the average rate before the storm.

We developed a set of models to evaluate the temporal extent of any hurricane effect and proposed a set of competing hypotheses to explain any changes in nest survival following the hurricane. We monitored breeding Oystercatchers on Cape Lookout through 2007 to track nest survival in the years following the hurricane. We did not, of course, plan for a strong hurricane to hit our study site so much of the design of this study was necessarily developed after the event. We used the hurricane to learn as much as possible about the response of Oystercatchers to a sudden change in their environment.

Our null hypothesis was that estimates of the probability of nests surviving to hatching stage would not differ between pre-hurricane and post-hurricane years. Alternatively, we suspected that we might detect differences in estimates of probabilities of nest success among years. We constructed a set of models with different temporal patterns of nest survival to evaluate how long any effects of the hurricane would last.

Next, we proposed three hypotheses about the mechanisms that may have affected the different probabilities of nest survival. Hypothesis 1: Oystercatchers shifted their nest locations to higher quality habitat, leading to decreased depredation rates. Hypothesis 2: The spatial arrangement of Oystercatcher nests became more variable after the habitat changed and resulted in lower depredation rates. Hypothesis 3: Predator populations were directly reduced by the hurricane, resulting in lower depredation rates.

METHODS

The breeding season for American Oystercatchers in North Carolina begins in late March and runs through early August. Nests were located by systematic searching and behavioral observations. Once located, nests were monitored every one to three days until hatching or nest failure. If a nest failed, the observer attempted to determine the cause by searching the nest area for signs of predators, flooding, human activity, or other evidence associated with the failure. The proportion of unidentified nests in each year varied due to differences in observers and frequency of nest checks between years and islands. To facilitate comparison between years and islands, unidentified failures were allocated proportionally to known sources of failure. Unidentified nest failures were not allocated to the storm overwash category because storm losses were usually easy to identify and did not substantially contribute to the unidentified nest pool.

We modeled daily nest survival on North Core and South Core Banks from 1999 through 2007 to evaluate the temporal and spatial extent of any hurricane effects across the study area. We compared five alternative models in Program Mark (White and Burnham 1999) including three proposed hurricane effects models. Model one (S.) was

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a null model of constant survival. Model two (S_{time}) was a fully time dependant model with separate parameters for each year. Model three ($S_{base + hurricane}$) had two nest survival parameters; a baseline survival rate (all non-hurricane years), and a single year increase in 2004 after the hurricane. Model four ($S_{base + hurricane + post1}$) included an additional parameter for a "carry-over" year of intermediate nest survival following the initial increase. Model five ($S_{base + hurricane + post2}$) allowed a two–year carryover effect before returning to the baseline survival level. We assessed the effect of the hurricane on nest survival on both of our study islands. We constructed five models with data pooled from both islands, then included every combination of temporal models for both islands separately. We used Program Mark to rank and compare all 30 alternative models using Akaike's Information Criteria (AIC) (Akaike 1973) in an information theoretic framework. The nest survival model in Program Mark uses a maximum likelihood method to estimate daily survival rates when time between nest checks is greater than one day. This method is less biased than apparent nest survival (successful nests divided by total nests monitored) as it accounts for nests that failed and were never found. The average incubation period for Oystercatcher nests is 27 days (Nol and Humphreys 1994). To obtain nest survival probabilities we raised estimates of daily survival rates to the 27th power. We report on 699 nests monitored from 1999-2007.

We quantified habitat change from Hurricane Isabel using orthorectified aerial photos of Cape Lookout (USGS 1998, NCDOT, 2003) to delineate the extent of open sand flats before and after the storm. A complete aerial survey of the Seashore was conducted in January 1998 and again in September 2003 shortly after Hurricane Isabel.

The extent of the open sand flat habitat available for nesting was calculated by heads-up digitizing of open sand habitat using ArcGIS Desktop version 9.1 (ESRI 2006)

For each year and island we calculated the proportion of Oystercatcher nests on sand flats and in the relatively linear habitat of the upper beach and dunes. We then compared nest survival for each habitat type using the best temporal nest survival model. For the purpose of this analysis we assumed no within-habitat heterogeneity in survival probabilities throughout the incubation period.

We measured variability in nest placement using the mean deviation of the distance of nests to the high tide line. For each year we calculated the mean distance of nests to the high tide line for each island, and found the mean of the absolute value of the residuals, or mean deviation. We used mean deviation instead of standard deviation to minimize the effect of the skewed distribution of distance values resulting from the habitat bounded on one side by the ocean and broken occasionally by large flats on the other.

Although we did not have quantitative estimates of predator abundance on the island during the study period, we took note of predator sign (tracks, scat, and sightings) during the nesting season. Tracks from mammalian nest predators are easily visible on the sandy beaches and flats of Cape Lookout, but they are quickly erased by wind and rain. We assumed that tracks observed during subsequent nest checks were newly created. We did not assume that the abundance of predator sign was a direct indicator of true predator abundance, but that it provided some indication of the overall predator activity level for each island and year in the habitat where Oystercatchers were nesting. Reliable, quantitative estimates of predator populations would have been preferable, but

our observations allowed us to document presence/absence and some idea of the relative abundance of predators on the islands. We used our observations to generate qualitative estimates of predator activity during each breeding season.

RESULTS

Our model results indicated that the effect of Hurricane Isabel on nest survival varied between islands. The best model with 60% of model weight indicated that North Core Banks experienced a hurricane effect with a two-year carry-over effect, while nest survival on South Core Banks was best described by a simple year effects model (Table 3.1). Nest survival on North Core Banks increased from the baseline rate of 0.170 (SE 0.021) to 0.772 (SE 0.090) in 2004. Nest survival averaged 0.43 (SE 0.081) for two years after the initial increase. Nest survival did increase on South Core Banks after the hurricane, but the increase was not outside the range of annual variation (Figure 3.1).

Table 3.1. Model ranks for the top five models for temporal effects of Hurricane Isabel on American Oystercatcher nest survival, Cape Lookout National Seashore, North Carolina

Model	AICc	ΔAICc	Weights	Likelihood	K	Deviance
$(S_{NCB(base+hurricane+post2)} + SCB(year))$	2892.79	0	0.602	1	12	2868.76
$(S_{NCB(base+hurricane+post2)} +$ $SCB(base+hurricane+post2))$	2895.78	2.988	0.135	0.224	6	2883.77
$(S_{NCB(base+hurricane+post2)} +$ $SCB(base+hurricane+post1))$	2896.22	3.426	0.109	0.180	6	2884.21
$(S_{NCB(base+hurricane+post1)} + SCB(year))$	2897.72	4.929	0.051	0.085	12	2873.69
$(S_{NCB(year)} + SCB(year))$	2898.61	5.817	0.033	0.055	18	2862.53
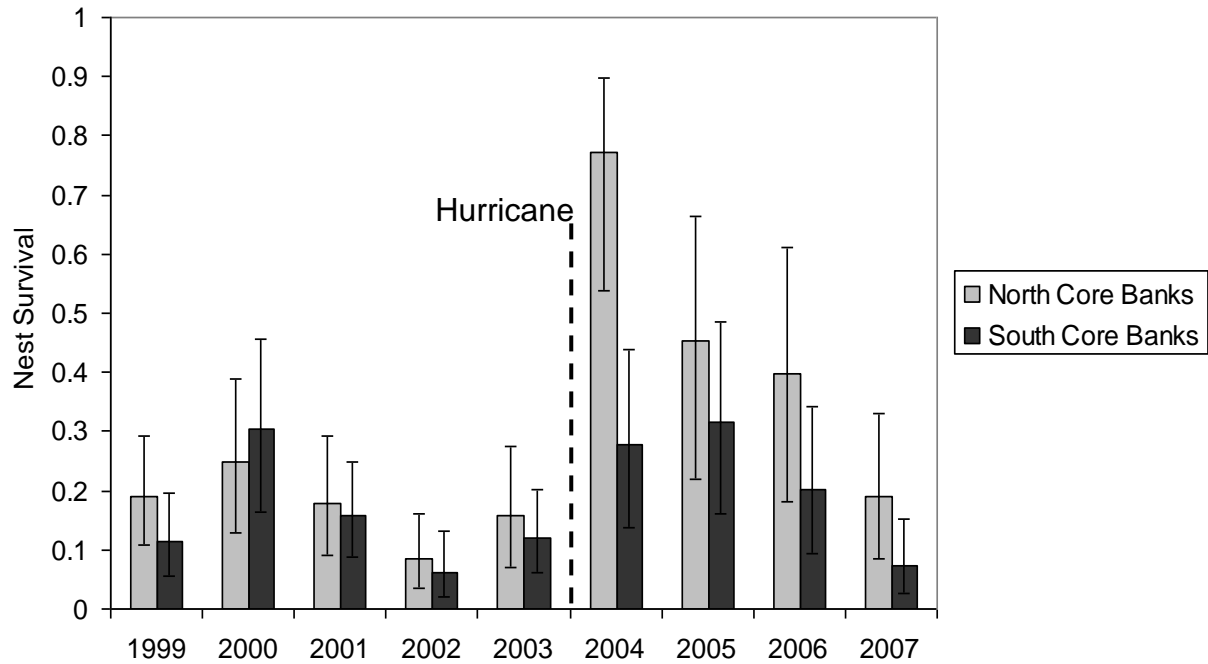
Figure 3.1. American Oystercatcher nest survival on two islands of Cape Lookout National Seashore before and after Hurricane Isabel. Error bars represent 95% confidence intervals for the survival estimates.

Both islands experienced extensive habitat change from overwash and wind (Figure 3.2). Delineation of habitat type on ortho-rectified aerial photos from before and after the hurricane revealed that the total area of sand flats on North Core Banks increased by 31% from 382 to 501 hectares. The amount of open sand flat habitat increased by 100-200% over much of this island, but there was significant erosion of a large flat at the north end of the island which reduced the total area of open flats. On South Core Banks, the area of open sand flat habitat increased by 110% from 52 to 209 hectares.

Oystercatcher pairs shifted nesting locations after the hurricane. On North Core Banks the average distance of a nest from the high tide line increased from 92.7 meters (SE 5.14) before the hurricane to 150.2 meters (SE 21.6) after the storm, as Oystercatcher pairs moved away from the beach and onto overwash flats. On South

Core Banks, the mean distance from nest to high tide line increased from 49.3 to 71.1 meters in the year after the hurricane. There was no apparent shift in the proportion of birds nesting on dunes versus flats for either island (Figure 3.3).
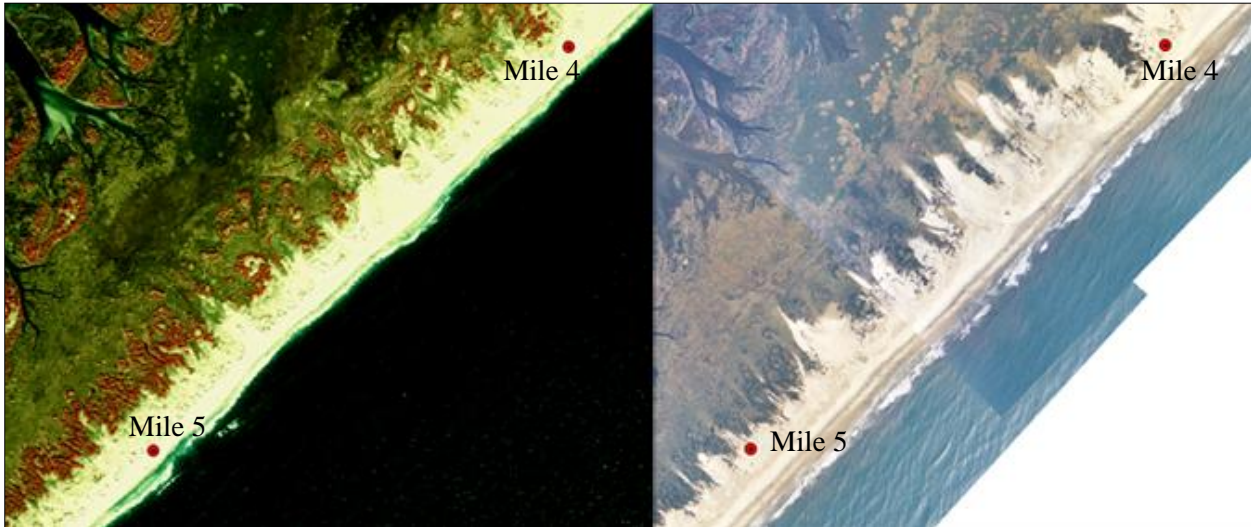
Figure 3.2. A section of North Core Banks in 1998 (left) and 2004 (right) showing overwash and dune breakup caused by Hurricane Isabel in 2003. NPS mile markers are used as reference points.

The variability in the spatial arrangement of nests increased on both islands after the hurricane. The mean residual distance from the mean distance of nests to the high tide line increased from 53.1 meters (SE 3.56) to 82.8 meters (SE 13.5) on North Core Banks, and from 28.8 (SE 1.91) to 51.6 (SE 8.67) on South Core Banks.

We compared habitat specific survival estimates to determine if habitat type affected nest survival at different levels of overall nest survival. In years where overall nest survival was low (< 0.34), we found no difference in nest survival on open flats (0.161, SE 0.020) and in the dunes (0.160, SE 0.017). The confidence intervals for each habitat fully overlapped the mean survival rate for the other habitat (Figure 3.4). When overall nest survival was high (>0.66), there was still no difference between habitats, with open flat nest survival at 0.859 (SE 0.162) and dune nest survival at 0.731

(SE 0.116) (Figure 3.3). Nest survival did vary between dune and flat habitats at intermediate levels (0.33 < S < 0.67) of overall nest survival. The survival rate for nests on open sand flats was 0.600 (SE 0.112), while the survival rate for nests in the dunes was 0.243 (SE 0.094). The confidence interval for nest survival in each habitat did not encompass the mean survival rate for nests in the other habitat (Figure 3.3).
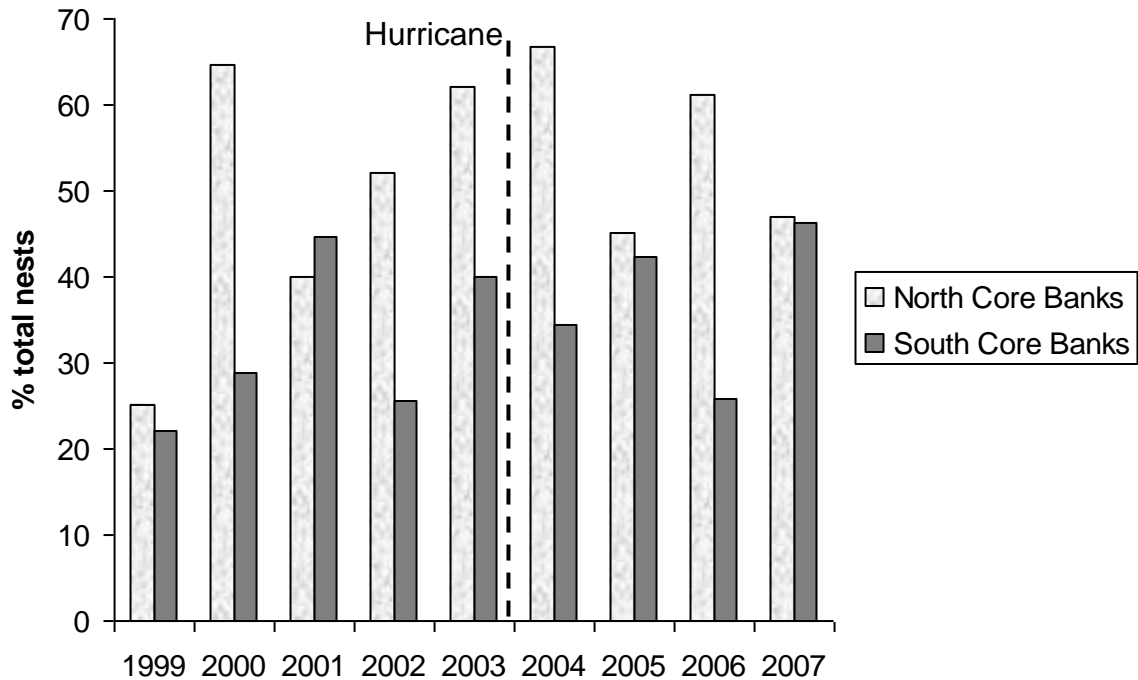
Figure 3.3. Percentage of nests on open sand flats on two islands of Cape Lookout National Seashore
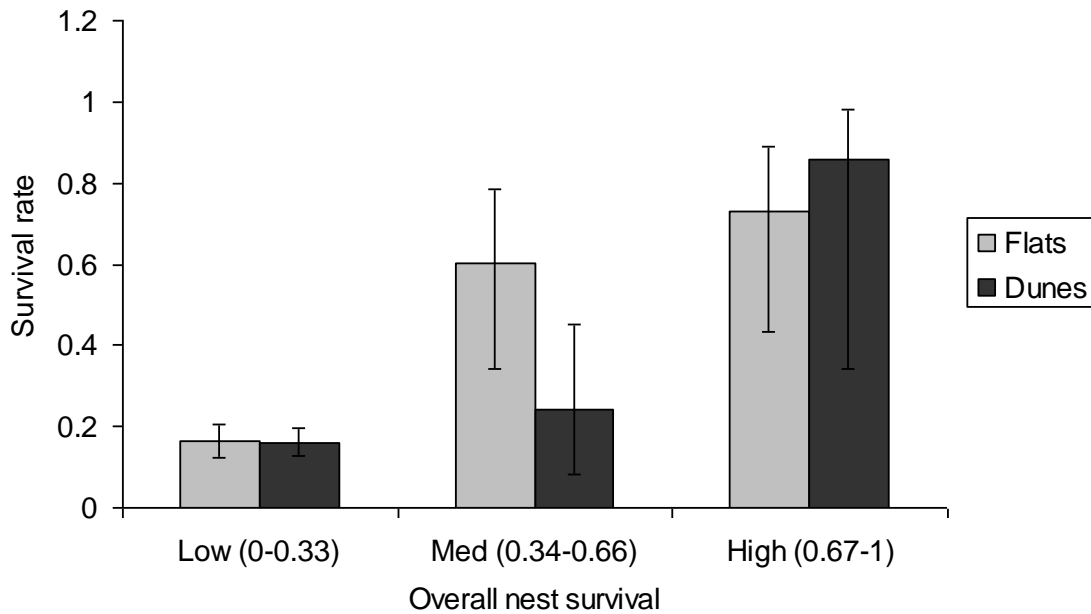
Figure 3.4. Habitat-specific survival for nests in two habitats (sand flats and dunes) at three levels of overall nest survival at Cape Lookout National Seashore

Mammalian depredation accounted for 57% (SE 1.9%) of all nest fates, and 74% (SE 1.9%) of all nest failures after unidentified losses were allocated. Storm overwash was responsible for an additional 12%,(SE 1.4%) of nest failures, while the remaining nests losses were attributable to avian predators, ghost crabs, and human activity. The source of failure could not be identified for 50% (SE 2%) of all nest failures. The proportion of nests lost to mammalian depredation varied across years and between the islands (Figure 3.5 and 3.6). On North Core Banks during non-hurricane years 58% (SE 3%) of all nests laid were lost to mammalian depredation. In the first year after Hurricane Isabel this number dropped to 20% (SE 8%). Over the next two nesting seasons mammalian depredation remained low at 15% (SE 5.8%). On South Core Banks mammalian depredation accounted for 62% (SE 2.4%) of all nests laid over the study period. There was no evidence for a reduction in mammalian depredation on South Core Banks after Hurricane Isabel.
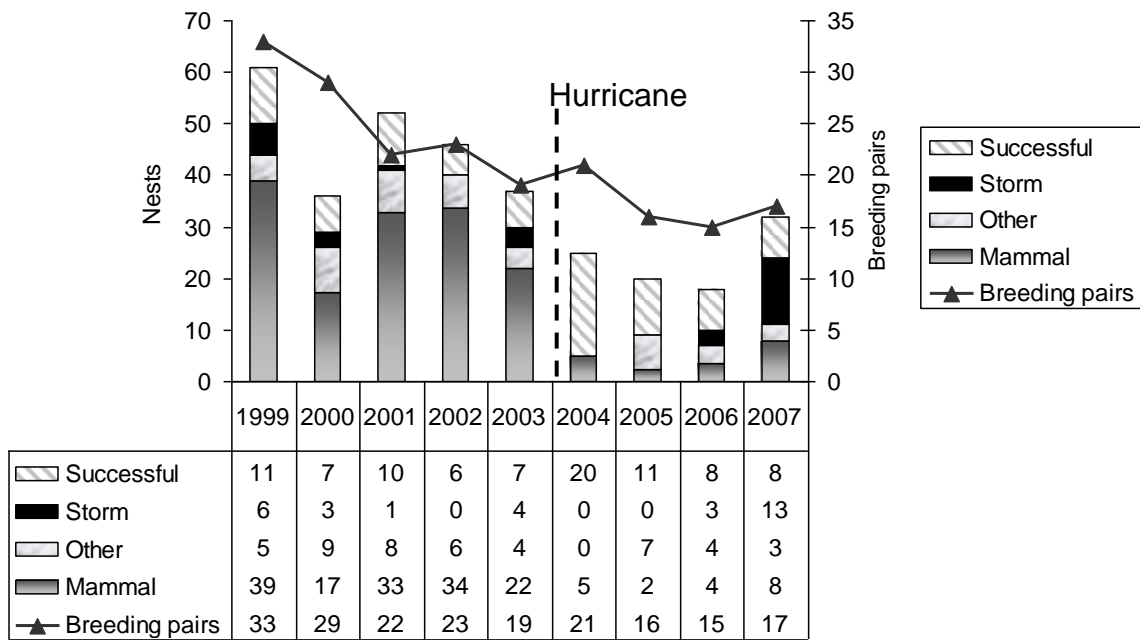
Figure 3.5. Nest fates for Oystercatcher nests on North Core Banks, Cape Lookout National Seashore from 1999 - 2007
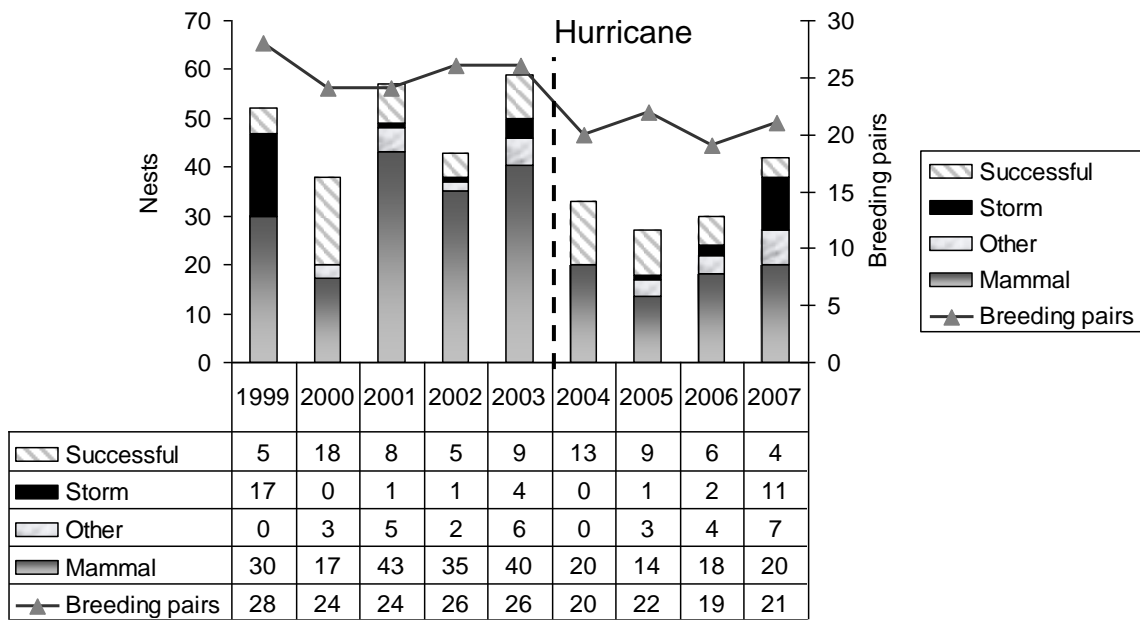
Figure 3.6. Nest fates for Oystercatcher nests on South Core Banks, Cape Lookout National Seashore from 1999 - 2007

General observations of predator activity corresponded to observed rates of nest

depredation. Mammalian predator sign was frequently observed on North Core Banks

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from 1999 to 2003 with tracks and sightings over the entire island throughout the nesting season. In 2004 we did not observe any predator sign until the second week in May, four weeks into the nesting season. Raccoon (*Procyon lotor*) and Feral Cat (*Felis catus*) tracks were observed occasionally during the second half of the season, but only near a group of rental cabins, the main center of human activity on the island. In 2005 and 2006, the frequency of predator tracks and sightings increased on North Core Banks. Tracks were common in every month of the nesting season near the cabins, as well as locally at several other sites comprising approximately 25% of the island. By the 2007 nesting season, predator activity on North Core Banks was back to the pre-hurricane level with tracks observed over the entire length of the island throughout the nesting season. On South Core Banks Raccoon tracks were observed during the entire nesting season from April to August over the length of the island in all years. Raccoon sightings were common, particularly near centers of human activity.

DISCUSSION

The wind and wave action from Hurricane Isabel had a strong effect on the physical characteristics of the islands of Cape Lookout National Seashore, resetting succession and altering dune lines. Effects on wildlife populations on Cape Lookout were somewhat more complex. Despite similar physical changes to both of our study islands, North Core and South Core Banks, the change in the survival rate of American Oystercatcher nests was quite different between the two islands.

Nesting success on North Core Banks was affected by changes from Hurricane Isabel. Our best model of the temporal effects of the hurricane on nest survival included three parameters for North Core Banks: A parameter for constant survival for non-

hurricane years (1999 to 2003 and 2007), A parameter for a single-year increase in survival after the hurricane (2004), and a parameter for two years of intermediate nest survival before returning to the baseline level. This model included separate parameters for each year for the island of South Core Banks, indicating that changes in nest survival on this island were within the range of annual variation.

Our first explanatory hypothesis for the observed changes in nest survival stated that increased availability of open flat habitat would lead to increased nest survival. This hypothesis reflected our expectation that nests on open sand flats were harder for predators to find. Incubating Oystercatchers leave the nest as soon as they detect a nest predator, relying on the cryptic coloration of the eggs for protection. On extensive open flats, nest predators such as Raccoons and Cats must search the entire flat as opposed to the relatively narrow dune line and upper beach habitats where Oystercatchers also nest.

The hurricane increased the amount of open flat nesting habitat on both islands, and mean distance of nests from the high tide line increased, suggesting that Oystercatchers shifted away from the beach and onto newly created sand flats. The proportion of nests in each habitat did not change, however, which may indicate that the resident territory holders expanded their territories into the newly created sand flats. Pairs without prior access to sand flats remained in the dune habitat, and sand flat nesters moved closer to sound-side foraging areas, and away from human disturbance on the beach. Nevertheless we found little support for our first hypothesis. We found no difference in survival between dune and beach nests before the hurricane where overall nest survival was low, or after the storm where overall nest survival was high.

Habitat specific nest survival differed only at an intermediate level of overall nest survival. After the initial increase following the hurricane, nest survival on North Core Banks declined steadily to the baseline rate. Nest survival in the dune habitat immediately dropped to pre-hurricane levels, but survival of nests on the flats remained high for three years after the storm. If habitat quality were driving the overall increase in nest survival we should have observed a habitat specific difference in survival immediately after the storm. Furthermore, although both islands experienced substantial habitat change, nest survival only increased on North Core Banks.

We also found little support in our data for our second hypothesis, greater variability in the spatial arrangement of Oystercatcher nests might have contributed to lower predation rates. We predicted that an increase in habitat complexity would benefit nesting Oystercatchers by reducing the ability of predators predict nest locations. Prior to the hurricane most Oystercatcher nests were arranged in a linear pattern along the dune line. Raccoons were often seen traveling along the dunes and apparently had little difficulty finding Oystercatcher nests. Variability in nest placement was represented by the mean deviation from the mean distance from the high tide line. High tide lines were mapped each year, so we used this metric as a consistent way to compare overall variability in nest placement among years. Variability in nest placement increased on both islands after the hurricane, but nest survival only increased on North Core Banks. Clearly habitat changes and spatial arrangement were not the primary factors affecting changes in nest survival.

Our third explanatory hypothesis proposed that a reduction in mammalian predators was the primary factor responsible for differences in nest survival before and

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after the hurricane. Although we have no quantitative estimates of predator abundance during our study, we did document the proportion of nests taken by mammalian predators, and observations of predator sign noted during nest monitoring to evaluate the relative change in predator activity before and after the hurricane. Our observations of predator activity on both islands corresponded to documented changes in the proportion of nests taken by mammalian predators. On South Core Banks we found no significant difference in the proportion of nests taken by mammals before and after the hurricane. Predator activity remained high on South Core Banks throughout the study. Signs of predators, including tracks and sightings disappeared almost entirely on North Core Banks the year after the hurricane, and the proportion of nests lost to mammals dropped from 58% to 20%. Without quantitative estimates of predator abundance we cannot definitively say that Hurricane Isabel reduced predator populations on North Core Banks, but there was clearly less predator sign, fewer nests taken by mammals, and higher overall nest survival following the hurricane

The difference in apparent predator abundance on North Core and South Core Banks after the hurricane may be explained by a difference in the physical character of the islands and the trajectory of the hurricane. The eye of the hurricane passed over the south end of the North Core Banks, and the highest storm surge occurred north and east of the eye. North Core Banks is very low lying and much of the island was completely overwashed during the hurricane. Many of the Raccoons and Feral Cats on North Core Banks may have drowned during the storm. South Core Banks is wider at the south end, and has more upland habitat where raccoons and other mammalian predators could take refuge.

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We believe that the interaction between habitat type and nest survival can be explained by mammalian nest predator abundance. When predator populations are very high or very low there we predict there should be no difference in nest survival between habitats. If enough predators are searching, nests are very likely to fail even in optimal habitat. When predators are absent, nest survival increases in all habitats. Nest survival should vary by habitat only when predator abundance is intermediate. We found some support for this hypothesis on North Core Banks in 2005 and 2006 when predator activity began to increase after the initial decline in 2004. Survival of dune nests dropped rapidly, but nests on open flats maintained a high survival rate for several years after the storm.

These findings have implications for developing conservation strategies for other beach-nesting birds, especially when humans intervene to restore beach habitats to their pre-hurricane condition. On developed barrier islands, new overwash habitat created by storms is often quickly removed as roads are re-built and artificial dunes are created to protect roads and structures. These activities often negate the beneficial effects of storms for beach nesting birds. Introduced predators such as feral cats, and artificially abundant populations of native predators like raccoons are increasingly common in the coastal zone, even on remote sites like Cape Lookout. Management efforts to control predator populations may be particularly effective if they follow major storms which can improve habitat conditions and reduce predator populations. Well-designed studies of barrier island predator communities would significantly improve our understanding of predator-prey interactions in these systems.

Major storms clearly have the potential to affect Oystercatcher nest survival by

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creating new nesting habitat and reducing predator populations. High reproductive success subsequent to major storms may be important to the long term growth and stability of Oystercatcher populations. Demographic modeling suggests that periodic years with high reproductive success can offset or reverse population declines depending on the baseline reproductive rate and the frequency of the high production years. Thus, although sea level rise associated with global warming may reduce habitat for coastal birds in some areas, our findings suggest that increased habitat disturbance from more frequent hurricanes may benefit species associated with these dynamic environments.

SECTION 4 – A DEMOGRAPHIC MODEL FOR AMERICAN OYSTERCATCHERS

We studied American Oystercatchers on the Outer Banks of North Carolina from 1995 through 2008, and found that a variety of factors affect Oystercatcher reproductive success including nest predators, weather patterns, flooding events, proximity to food sources, and human activity. Exceptionally high reproductive success following a hurricane suggested that disturbance from hurricanes may periodically provide the conditions necessary for elevated nesting success (Section 3, Schulte and Simons in revision). Specifically, hurricane overwash creates optimal nesting habitat, opens access to foraging areas, and reduces populations of mammalian nest predators. American Oystercatchers evolved in an environment shaped by severe storms and appear to have several adaptations that allow them to take advantage of periodic hurricane disturbance. Sub-adult Oystercatchers can use new nesting areas created by storms to establish a territory and join the breeding population. Breeding Oystercatchers produce more chicks than they can successfully fledge in most years,

which allows for an immediate increase in productivity in a post-hurricane environment with better foraging opportunities and fewer predators.

In this section we present a demographic model for American Oystercatchers to assess the relationship between hurricane disturbance and American Oystercatcher population growth rates. Prior to this study, many basic demographic parameters were unknown for American Oystercatchers. Estimates of juvenile survival, subadult survival, and recruitment are still preliminary, but they allow comparisons to published estimates for the similar and intensively studied Eurasian Oystercatcher (*Haematopus ostralegus*). Reproductive success of American Oystercatchers has been better documented (Nol 1989, Davis et al 2001, McGowan et al 2005, Sabine et al 2006, Traut et al 2006, Schulte and Simons in prep), and in recent years, coordinated, widespread banding and re-sighting efforts along the Atlantic coast have provided insights into connections between breeding and wintering sites, return rates, and apparent adult survival rates. We used six years of mark-recapture data from the Outer Banks of North Carolina to estimate apparent adult survival and age of first breeding.

Estimating the status and viability of American Oystercatcher populations is problematic because unlike the European Oystercatcher (*Haematopus ostralegus*) some basic demographic parameters are unknown. In recent years, coordinated, widespread banding and re-sighting efforts along the Atlantic coast have revealed connections between breeding and wintering sites, and a tantalizing glimpse into the complexity of patterns of movement and dispersal (American Oystercatcher Working Group 2006). Five years of color banding adult and juvenile birds in North Carolina have provided the basis for estimating apparent adult survival, but estimates of juvenile

survival, subadult survival, and recruitment are still preliminary. Estimates of

reproductive success are now available for populations from Massachusetts to Florida

(Nol 1989, Schulte and Brown 2003, McGowan et al 2005a, Wilke et al 2005).

METHODS

We constructed a four-stage matrix model with juvenile (post-fledging), subadult

1 (second year), subadult 2, and adult (breeding) stages (Figure 4.1). The model

includes six demographic parameters: fecundity (F), juvenile survival (S_j), subadult$_1$

survival (S_1), subadult$_2$ survival without transition (S_2), subadult$_2$ survival with transition

to adult (T_{s2}), and adult survival (S_a) (Figure 4.1).
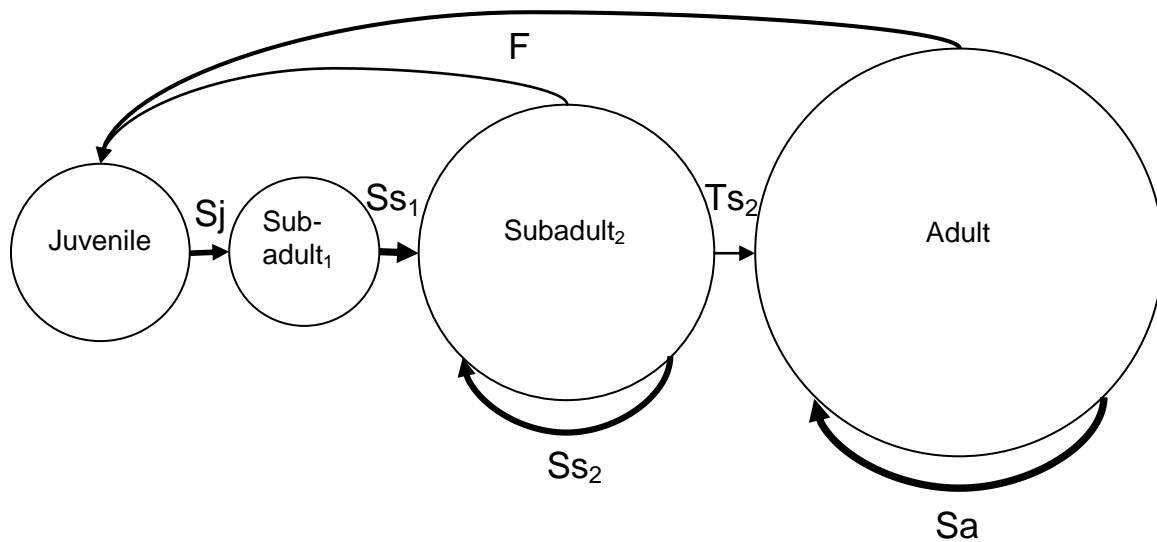
Figure 4.1. A conceptual stage-based model diagram of an American Oystercatcher
population. The size of each node represents the proportion of the population in that
stage. Arrow width corresponds to parameter values.

We used Program Matlab (Mathworks 2005) to create a basic deterministic

matrix model to find the stable stage distribution, and the sensitivity of lambda to each

of the matrix elements. We then simulated annual stochasticity by using the variance of

each parameter estimate to draw a value for each year of the simulation from an

appropriate distribution. The initial population size (678 breeding adults) was set using the most recent estimate of breeding adults in North Carolina (Cameron and Allen 2007). The initial population size was set at 1255 individuals based on a stable age distribution with adults comprising 54% of the total population.

Baseline and alternate input parameters were derived from both published and unpublished sources for the American Oystercatcher, as well as published literature on the closely related European Oystercatcher. Adult survival was calculated from from six years of mark-resight data on the Outer Banks using the Cormack-Jolly-Seber (recaptures only) model in Program Mark (White and Burnham 1999). We examined four separate models where survival (φ) and capture probability (ρ) were either time-dependent or constant ($\varphi_t\rho_t$, $\varphi_t\rho$, $\varphi\rho_t$, $\varphi\rho$). We used the weighted average of the estimable survival values to account for variations in standard error each time period. The resulting estimate of apparent adult survival was 0.89 (SE 0.013). This survival rate does not account for emigration from the study area. Although Oystercatchers have high site fidelity, they can be driven off their territory by other Oystercatchers, or abandon the site if the habitat becomes poor. Survival studies for the similar European Oystercatcher suggest that apparent survival may be biased low by 3-10% (Goss-Custard et al 1982). Therefore, we used 0.92 as our estimate of adult survival for American Oystercatchers.

Estimates of subadult survival, subadult transition to adult, and juvenile survival were based on published studies of the European Oystercatcher. Subadults that survive each year either remain as non-breeders or they transition to breeding adults; thus, overall subadult survivorship is composed of two separate transition probabilities.

Ens et al (1995), Heg et al (2000a), and van de Pol et al (2007) discuss in detail the processes and decisions involved when nonbreeding Oystercatchers attempt to acquire a breeding territory. The age of first breeding for Eurasian Oystercatchers was quite variable, ranging from 3-11 years. After an Oystercatcher reached age two, the probability of surviving and becoming a breeder was 19%, while the probability of surviving and remaining a nonbreeder was 72% (Ens et al 1995). Safriel et al (1984) reported recruitment to a breeding population over a 15-year period; mean levels (the same for males and females) were between 11% and 13% while yearly estimates varied from a low of 2% to a high of 35%. Both the survivorship and transition probability reported by Ens et al (1995) are likely too high for the entire population of subadults because younger subadults often do not show up on the breeding grounds (Goss-Custard et al 1982). Therefore, we set subadult survivorship at 0.90 in the baseline model (slightly lower than the Ens et al (1995) estimate, and between the two values Durell and Goss-Custard (1996) used for younger and older subadult survivorship in their model). We used a transition probability from subadult to adult of 0.15 (Table 4.1) which is between the estimates given by Safriel et al (1984) and Ens et al (1995).

Estimates of juvenile survival in European Oystercatchers are quite variable. Goss-Custard et al (1982) found that about 88% of juveniles survive their first fall and winter. Other studies, however, have estimated juvenile survival at 64% (Boyd 1962) and 60% (Harris 1967). Kersten and Brenninkmeijer (1995) estimated average juvenile survival at only 40% based on return rates to natal breeding sites; return rates for cohorts varied from 10% to 68% depending on the severity of their first winter. Without the one extreme winter where only 10% of the cohort returned, the average return rate

Table 4.1. Input parameters for baseline and alternate models. Parameter stimates are reported as mean values with standard errors in parentheses. Initial Population = 679 adults; 447 subadults; 129 juveniles in all models.

Model	Fecundity (F)	Juvenile survival (S_j)	Second year survival (S_{s1})	Subadult survival w/o transition (S_{s2})	Subadult transition to adult (T_{s2a})	Adult survival (S_a)
Baseline	0.146 (0.019)[1]	0.70 (0.025)[2]	0.90 (0.025)[3]	0.77 (0.025)[3]	0.15 (0.025)[3]	0.92 (0.013)[4]
Post – Hurricane	0.553 (0.12)[1]	0.70 (0.025)	0.90 (0.025)	0.77 (0.025)	0.15 (0.025)	0.92 (0.013)
Post Hurricane +1 year	0.35 (0.12)[1]	0.70 (0.025)	0.90 (0.025)	0.77 (0.025)	0.15 (0.025)	0.92 (0.013)
Post Hurricane +2 years	0.25 (0.12)[1]	0.70 (0.025)	0.90 (0.025)	0.77 (0.025)	0.15 (0.025)	0.92 (0.013)

Parameter data sources:

1: Breeding success data from Cape Lookout and Cape Hatteras National Seashore.1998-2007.
2: Literature sources on juvenile survival rates of the Eurasian Oystercatcher (Haematopus ostralegus). Goss-Custard et al (1982), Kersten and Brenninkmeijer (1995), Boyd (1962), Harris (1967).
3: Literature sources on subadult survival and transition rates of the Eurasian Oystercatcher (Haematopus ostralegus). Ens et al (1995), Heg et al (2000), van de Pol et al (2007), Safriel et al (1984), Goss-Custard et al (1982), and Durell and Goss-Custard (1996).
4: Mark-recapture data from Cape Lookout and Cape Hatteras National Seashore.2001-2007.

was 50% (Kersten and Brenninkmeijer 1995). For the baseline model we used an

estimate of 0.70 average juvenile survival (midpoint of the high and low estimates

described above). The largest concentrations of wintering American Oystercatchers are

in areas of relatively mild winter weather (South Carolina, Virginia, and Florida) (Nol et

al 2000, Brown et al 2005) and, thus, may not be subject to the extremes described for

the European Oystercatcher.

Fecundity was defined as the number of female chicks per female per year, or

one half of the number of chicks produced per pair per year, assuming an even sex ratio

in the chicks. The sex ratio of American Oystercatcher hatchlings is unknown, but Eurasian Oystercatchers produce equal numbers of males and females, so this assumption is probably reasonable (Heg et al 2000b). Baseline fecundity was calculated from 912 breeding pairs monitored in North Carolina between 1995 and 2007. We assumed an even sex ratio in fledged chicks (N=266), so the mean rate of female chicks fledged per female adult per year was 0.146 (S.E. 0.019).

After developing a baseline model, we created a set of alternative population matrices with elevated mean fecundity to simulate the effect of hurricane events. Hurricanes can have a powerful effect on Oystercatcher reproductive success through predator reduction and habitat creation. Nest survival increased by as much as 400% in the year after a hurricane on Cape Lookout National Seashore, but returned to the pre-hurricane baseline rate within three years (Schulte and Simons in revision). From 1886-2004 the North Carolina coast was struck by an average of 0.28 hurricanes per year (State Climate Office of North Carolina 2006). A given hurricane will not affect all areas of the coast equally, so the probability of any single location experiencing a hurricane will be lower than the cumulative probability for the state. Jagger et al (2001) used a maximum likelihood estimator to model hurricane strike probabilities for coastal counties in the southeastern United States. Strike probabilities for North Carolina counties ranged from 0.248 (portions of Dare county) to 0.044 (Onslow county). The hurricane matrix for our simulations was selected based on a set probability of either 0.1 (10 year hurricane event) or 0.0667 (15 year hurricane event). Initial post-hurricane fecundity was set at 0.553 (SE 0.12) based on data from Cape Lookout National Seashore following Hurricane Isabel (Schulte and Simons, in revision). We simulated the return to

pre-hurricane fecundity by using 0.35 (SE 0.012) and 0.25 (SE 0.012) for two years

after the initial increase. For each year of the model simulation, the set of hurricane

matrices was selected with a probability of 0.1 to simulate a 1 in 10 chance of a

hurricane impact or 0.0667 to simulate a 1 in 15 chance of a hurricane impact.

We compared the outcomes from each parameter set using the population

growth rate (λ) and the projected population change over time. Each model set

(baseline, 10 year hurricanes, 15 year hurricanes) was projected 10000 times over 50

years, twice the average Oystercatcher lifespan (Safriel et al 1984). Because of the

uncertainty in population projections when stochasticity is included in parameter

estimates (Akçakaya et al 1999), we also used probabilistic results (risk of decline) to

compare the models. We modeled the probability of a 50% decline during the 50 year

simulation. A 50% decline is a benchmark often used in conservation planning to

identify high priority species or populations (Akçakaya and Sjögren-Gulve 2000).

<p align="center">RESULTS</p>

The Oystercatcher population declined under the baseline model (Table 4.2).

The finite rate of population growth (λ) for the baseline model was 0.984 (SD 0.017) with

a mean population decline of 681 individuals (SD 575.7, 54% decline) over 50 years. In

78.5% of the simulations the population decreased by at least 50% during the 50 year

period (Table 4.2). When we increased the hurricane probability to 0.0667, or a 1 in 15

chance of a hurricane strike, λ increased to 0.999 (SD 0.018) with a mean population

decline of 59 individuals (SD 1271.3, 4.6% decline). The population declined by at least

50% in 56.6% of the simulations. When hurricane frequency increased to 1 in 10 years,

λ increased to 1.006 (SD 0.019) with a mean population growth of 399 individuals (SD

<p align="center">58</p>

1889.4, 31.7% increase) over 50 years. The population declined by at least 50% in

47.1% of the simulations.

Table 4.2. Results of American Oystercatcher population models. Risk of decline is defined as the probability of the population declining by at least 50% during the 50 years simulation to fewer than 628 individuals.

Model	Risk of 50% decline	λ, finite rate of increase	Population change over 50 years
Baseline	0.785	0.9846	-681 (SD 575.7, -54.0%)
15 year hurricane event	0.390	0.9990	-59 (SD 1271.3, -4.6%)
10 year hurricane event	0.471	1.0055	+399 (SD 1889.4, +31.7%)

Table 4.3. Elasticity values for each element of the population matrix. S_j: Juvenile survival. Ss_1: Subadult (2) survival without transition to adult. Ss_2: Subadult (2) survival without transition to adult. Ts_2: Subadult survival with transition to adult. Sa: Adult survival. F: Fecundity

0	0	$(F^*TS_2) = 0.0128$	$(F^*Sa) = 0.07525$
$(Sj) = 0.088129$	0	0	0
0	$(Ss_1) = 0.088129$	$(Ss_2) = 0.220707$	0
0	0	$(TS_2) = 0.075249$	$(Sa) = 0.439657$

In the absence of a hurricane effect or a change in adult survival, an increase in average annual fecundity could prevent population decline. Our model projects a stable population ($\lambda = 1.000$) when baseline fecundity increased from our empirical estimate of 0.146 to 0.195 female chicks per female (0.39 chicks/pair).

As expected for a long lived species with a low reproductive rate, the proportional sensitivity of λ to adult survival was much higher than to any other parameter (Table 4.3). Small changes in adult survival can have large effects on the trajectory of a population.

DISCUSSION

Barrier island systems are in a constant state of low-level change. Wind and currents build and erode beaches while pioneering grasses colonize sandflats and are washed out by tides and storms. Hurricanes are a powerful force in the coastal zone and have the capacity to reshape barrier island ecosystems overnight. A strong hurricane can fully over-wash a low lying barrier island chain, reset succession, flatten dunes, and alter or eliminate meso-fauna communities.

Hurricane frequency and intensity is expected to increase in coming decades as ocean temperatures rise as a result of multi-decadal oscillations in the North Atlantic and increased atmospheric greenhouse gases (Goldenberg et al 2001, Emanuel 2005 Webster et al 2006). The frequency of hurricanes and associated high productivity years can have a large effect on the trajectory of Oystercatcher populations. In the absence of hurricane events our model projects a rapid decline for American Oystercatchers in North Carolina over 50 years. A hurricane probability of 0.067 or a 1 in 15 chance of hurricane strike each year was enough to prevent population decline, while a probability of 0.1 or a 1 in 10 chance led to an increasing population. These projections are not intended to be absolute predictors for the Oystercatcher population in North Carolina. Estimates of transition rates and true survival are problematic because mortality is confounded with emigration unless the study area encompasses

the entire range of the marked individuals. Rather, if we accept that model parameters are close to their true values, our projections illustrate the relative effects of variable hurricane frequencies on American Oystercatcher populations. Population modeling is a useful endeavor if it provides a better understanding of the likely response of a population to changing parameters, and helps set priorities for future data collection efforts (Boyce 1992; Groom and Pascual 1997).

American Oystercatchers appear to have evolved a life history strategy shaped by periodic disturbance of their nesting habitats. Adaptations to some types of disturbance are well understood. Fire is a common source of regular disturbance through much of North America. A wide array of plant species are adapted to or even dependant on fire disturbance and these adaptations influence other parts of the ecosystem. Kirtland's Warblers, for example, nest exclusively in young jack pines, a fire dependant species (Mayfield 1992). Hurricanes are generally less predictable and frequent than fires, but Oystercatchers are a long lived species and may experience the effects of a hurricane several times over their lifespan. Oystercatchers appear to exploit hurricane disturbance through increased recruitment of subadults into the breeding population and elevated nesting success for established breeders. Oystercatchers are delayed breeders, so there is typically a pool of non-breeders waiting for nesting territories (Nol and Humphrey 1994, van de Pol 2006, this study). When a strong storm creates new habitat non-breeders are poised to move in and begin nesting. Established nesting pairs will shift their nest location within a territory to take advantage of better habitat.

In addition to creating new nesting habitat, hurricane overwash fans create

provide access to foraging sites in marshes and mudflats on the back side of barrier islands. Oystercatchers are unusual among shorebirds in that their chicks are semi-precocial and require feeding throughout the fledging period. Eurasian Oystercatchers fledge more chicks when they can bring their chicks directly to feeding sites and do not have to make foraging flights to and from the nesting area (Heg and van der Velde 2001). We observed a similar relationship on Cape Lookout where broods with direct access to soundside foraging areas experienced higher fledging rates (Schulte and Simons, in revision). Oystercatchers lay 2-3 eggs per clutch, but often only fledge one chick or fail completely. In most years the extra reproductive potential goes unrealized, but this strategy allows American Oystercatchers to take advantage of post-hurricane years with fewer predators, improved nesting habitat, and increased access to foraging areas (Schulte and Simons in revision). Long-lived seabird species like the black-legged kittiwake (*Rissa tridactyla*) employ a similar strategy. Kittiwakes lay 2-3 eggs, but typically only one chick survives to fledging (Gill et al 2002). Thus, in most years the extra eggs are not useful, but they position the birds to double or triple their reproductive output in years of high food abundance.

Human actions can alter the effects of hurricanes on American Oystercatcher productivity. In our models we assumed that a hurricane strike resulted in higher survival of nests and chicks in subsequent years, similar to the phenomenon observed on Cape Lookout National Seashore from 2004 to 2006 (Schulte and Simons in prep). This increase resulted from reduced predator populations and improved or expanded habitat. Habitat management that mitigates these changes will also reduce or eliminate the positive effects of the storm. In 2004, new habitat created by Hurricane Isabel on

Cape Hatteras National Seashore was quickly altered or eliminated as roads and artificial dunes were rebuilt. Oystercatcher fecundity in these areas the following year was much lower than that of birds nesting in similar areas on Cape Lookout where the natural sand movement was unaltered and the island was heavily overwashed. Truly natural barrier islands with unaltered sand movement and inlet dynamics are increasingly rare. In North Carolina they are limited to the islands of Cape Lookout National Seashore and several islands managed by NC Audubon in the southeastern portion of the state. As traditional barrier island nesting habitat is lost to development, the habitat quality on remaining sites becomes more important. In the face of this habitat compression, more frequent hurricanes or management practices that simulate hurricane disturbance may be critical to maintaining viable populations of American Oystercatchers in the Southeastern United States. Oystercatcher pairs on Cape Lookout have declined 16% since 1999 and have declined by 42% over the same period on Cape Hatteras. Although the Outer Banks were struck by a strong hurricane during the study period, the positive effects of the storm were limited to about 40km of coastline out of 160 for the entire study area.

Actions that affect adult survival will have the greatest influence on population trends, but this is generally the least tractable parameter to manage. American Oystercatchers winter in flocks along the Atlantic and Gulf coasts, which places them at risk from local catastrophic events such as oil spills or loss of roost sites. Habitat protection and reducing pollution of food sources may prevent declines in adult survival. Fecundity, and to a lesser extent, subadult to adult transition rates are more amenable to management actions. Fecundity is reduced by nest predation, disturbance, and

spring storms (Nol and Humphrey 1994, Davis et al 2001, McGowan et al 2005, Sabine et al 2006). It may be possible to mimic or extend the effect of hurricanes by managing populations of nest predators, particularly non-native and artificially abundant mammalian mesocarnivores.

Predictions about the ecological effects of climate change usually focus on large scale patterns of atmospheric change, or negative impacts on a species or ecosystem. Estimates of global temperature increases over the next century range from 1.8 to 4.0 degrees centigrade (IPCC 2007), and the warming trend is already affecting many species. The loss of arctic sea ice threatens polar bear (*Ursus maritimus*) populations (Derocher et al 2004). Amphibian populations worldwide have declined severely as a result of the chytrid fungus (*Batrachochytrium dendrobatidis*) which is more virulent at higher temperatures (Bosch et al 2007). This focus is important in the context of promoting human welfare and conserving biodiversity. At the same time, it is important to recognize that climate change will produce both winners and losers at the species, community, and ecosystem levels. American Oystercatchers appear to have a life history adapted to take advantage of periodic severe disturbance events caused by hurricanes. An increase in the frequency and intensity of tropical cyclones should benefit American Oystercatchers and other barrier island nesters because storm overwash improves habitat and reduces predator populations. The long-term future of the American Oystercatcher is by no means certain because some climate change effects such as sea level rise may result in a net loss of suitable habitat. Nevertheless, the relationship between hurricane disturbance and Oystercatcher population growth provides evidence for at least one positive effect of climate change on this species of

conservation concern.

SECTION 5 – MIGRATION AND DISPERSAL

Understanding patterns of connectivity in migratory birds can help predict effects from habitat loss, environmental damage, or conservation actions (Rubenstein and Hobson 2004, Webster and Marra, 2005). If a breeding population has a strong connection to a wintering area it means that a large proportion of the population winters in that location. Anything that affects that wintering area will have a large effect on the associated breeding population(s). Conversely, breeding populations with weak or dispersed connectivity to wintering areas may spread across a wide wintering range and are less affected by events at any single location (Webster et al 2002, Kelly et al 2002). By its very nature, migratory connectivity is often difficult to study because of the challenges involved in following individual birds throughout the year. In recent years, new techniques and technologies, such as isotope analysis, smaller satellite transmitters, and geolocators are advancing our understanding of migration strategies, pathways and connectivity for an array of bird species (Marra et al 1998, Hobson 2005, Croxall et al 2005, Stuchbury et al 2009, Shaffer et al 2005). In this study we use a more traditional approach, individual color-marking, to investigate questions about movement and connectivity in American Oystercatchers (*Haematopus palliatus*). Oystercatchers lend themselves to such a study because they are large, conspicuous, long-lived, and breed and overwinter in coastal regions of the United States. Still, this opportunity to investigate movement patterns across the range of the species was only possible through active cooperation between of members of the American Oystercatcher Working Group, an association of researchers, students, resource

managers, and interested members of the public representing over 20 different State, Federal, and private organizations.

Our objectives for this research are to:

1) Understand migration strategies and patterns of connectivity for breeding and wintering populations of American Oystercatchers on the Atlantic and Gulf coasts of North America.

2) Estimate recruitment and dispersal of sub-adults

METHODS

Resighting records of individually banded birds are the primary tool we used to explore Oystercatcher migration and dispersal patterns. Individual-specific banding efforts are ongoing at study sites in Massachusetts, New Jersey, Virginia, North Carolina, South Carolina, and Georgia.

Resight records are a mix of coordinated resight efforts by researchers, state and federal agencies, and private organizations, as well as reports by interested members of the public. Sightings of banded birds by members of the public are reported through the American Oystercatcher Working Group website (AMOY Working Group 2009). Banding and resighting records for all projects are maintained in a central database, which consists of 1424 individually marked birds and 6127 resight records.

Adult Oystercatchers on the breeding grounds are captured using a variety of methods, including a decoy and nose carpet (McGowan and Simons 2005, Figure 5.1 Berger and Mueller 1959, Bub 1991), box traps, and "whoosh" nets. Pre-fledging chicks are captured by hand or with light hand nets.

Figure 5.1. Mechanical decoy and noose carpets.

We successfully trapped 116 breeding adults from 2002 through 2008 using the noose carpet method, and we found that it is an effective way to trap breeding adult birds with minimal disturbance to the nest site. No injuries, aside from minor skin abrasions on the tibiotarsus, have resulted from our trapping efforts. A total of 366 individual Oystercatchers have been banded in North Carolina since the mark-resight study began in 1999 (136 adults, 230 chicks, Appendix 2). In 2009 we will begin using "whoosh" nets (miniature versions of canon nets that use an elastic cord to deploy the net) which have proven to be highly effective and efficient at trapping American Oystercatchers at other study sites. We hope that the new method will reduce overall trapping time and permit simultaneous captures of breeding pairs.

Captured adults and chicks were originally marked with steel USFWS bands and combinations of Darvic color bands (Figure 5.2). Under a new cooperative banding

scheme, adopted by all researchers in the American Oystercatcher working group and approved by the Bird Banding Lab, birds are now marked with two identical bands engraved with a unique two-digit code as well as a metal USFWS band (Figure 5.2). North Carolina bands are green with white lettering. Other states are using yellow with black lettering (Massachusetts), orange with black lettering (New Jersey), black with white lettering (Virginia), blue with white lettering (South Carolina), and red with white lettering (Georgia).

Figure 5.2. American Oystercatchers banded with old (left) and new (right) banding schemes. Photos by Diana Churchill (left) and Pat Leary (right).

We described connectivity between breeding sites on the Outer Banks and wintering areas throughout the Southeast by estimating the proportion of banded birds wintering in each of seven wintering regions. Wintering regions were primarily defined by state boundaries because of differences in timing, scope, and effort of resight surveys in each state. Wintering regions identified include coastal areas of New Jersey, Virginia, North Carolina, South Carolina, Georgia, and Northeast, Northwest, and Southwest Florida.

RESULTS

Eighty-five individual birds banded in North Carolina were resighted on winter roosts from Virginia to the Gulf Coast of Florida (Figure 5.3). Thirty-two percent were resighted in North Carolina, which contains only 5% of the total wintering population (Figure 5.4). Twenty percent were resighted in South Carolina, and 18 percent in Northwest Florida, which respectively contain 39% and 10% of the total winter population.

Figure 5.3. Winter resightings of American Oystercatchers banded in North Carolina.
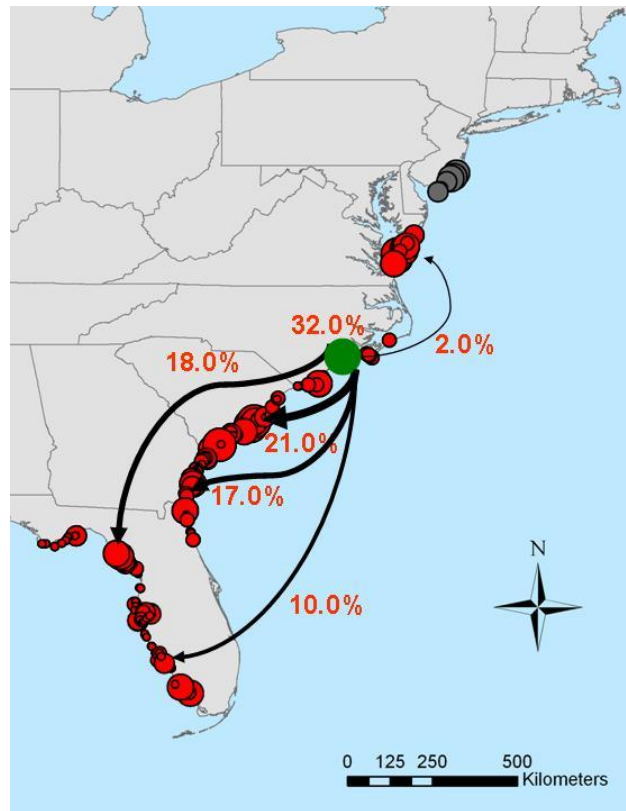
Figure 5.4. Proportion of banded American Oystercatchers observed in six wintering areas in the Southeast United States.

Oystercatchers banded as fledglings spent the first one to two years of life on the wintering grounds. Subadults began to return to their natal area during their second or third year. Twenty-two percent of all banded fledglings were resighted on the breeding grounds during their second year and 33% during their third year. The majority of these birds did not nest, though most were paired by their third year. In 2005 a bird banded as a chick on North Core Banks in 2002 returned to the island, paired successfully, and fledged a chick. This was the first record of a known-age American Oystercatcher chick returning and successfully nesting. Since 2005, 21 banded Oystercatcher chicks have returned to nest. Average age of first breeding is 3.52 years (SE 0.15). Dispersal distance was defined as the distance between an individual's natal site and location of first nest. Dispersal distance averaged 35.5km (SE 7.3) and ranged from 3-120 km.

DISCUSSION

American Oystercatchers from North Carolina migrated to wintering areas throughout the Southeast coast. The strongest connection was to local wintering sites in North Carolina, but adults and juveniles dispersed across the Southeast, with a few birds even moving north to overwinter in Virginia. Interestingly, a relatively high percentage (18%) of North Carolina Oystercatchers were resighted in Northwest Florida, even though this area only contains 10% of the total wintering Oystercatcher population. Similarly, North Carolina Oystercatchers were under-represented in South Carolina compared to the overall population. A similar "Leapfrog" migration pattern has been documented in European Oystercatchers. Northern migrants bypass central wintering areas to spend the winter farther south (Hulscher et al 1996). This behavior is thought to arise because of the competitive advantage enjoyed by year-round residents in the central part of the range. Northern birds apparently trade off the risks of a longer migration against reduced competition for winter food resources. American Oystercatchers breeding in North Carolina may face the same choices. South Carolina has a large population of resident Oystercatchers with whom migrant birds have to compete for winter feeding territories. The Cedar Key region in Northwest Florida is rich in food resources, but has relatively little habitat suitable for nesting, which minimizes competition from local residents. Additional research is needed to determine if the observed migration patterns for American Oystercatchers are real or if they result from differences in survey methods and detection probabilities.

This project has generated a great deal of interest in the birding community. In addition to designed resight surveys, many of our resighting reports come from

interested birders who can report banded Oystercatchers through a website maintained at NCSU (http://www.ncsu.edu/project/simonslab/AMOY/Research.htm). A chick banded near Buxton Village on Cape Hatteras National Seashore was reported by three different people in Fort Myers Beach Florida in the winter and spring of 2003. This bird was seen again in Forth Myers in the winter of 2003-2004 and in June of 2004 it returned within a few miles of where it hatched on Cape Hatteras. This bird returned to Hatteras again in 2005, 2006, and 2007. In 2007 it paired up and nested successfully on Cape Hatteras about 15 miles from where it hatched in 2002. Combined efforts like this allow us to connect different periods in an individual bird's life history in a way that was previously impossible.

Our estimates of the rates of return for different age classes very likely underestimate true survival because many individuals may remain on the wintering grounds for several years or disperse to other breeding sites (Goss-Custard et al 1982). Similarly, our current estimate of the age of first breeding is likely biased low because some birds may not start breeding until they are much older and our data set is not long enough to capture those individuals yet. Additional observations will allow us to refine this estimate over the next few years. Age of first breeding is an important metric, because it affects how quickly the population can grow and it can indicate density dependence. Delayed breeding, a result of older experienced birds excluding younger birds from nesting areas, is typical of populations experiencing density dependence (Ens et al 1995).

The mark-resight effort has already allowed us to estimate adult survival (92%), and start to understand migration and dispersal in different age classes. We now know

that members of family groups do not necessarily migrate together and that they

disperse throughout the winter range of the species. Partnerships and coordination

among researchers and land managers are critical to filling the gaps in our current

knowledge of Oystercatcher populations. Improving and standardizing cooperative

large-scale banding efforts will be critical to ongoing efforts to estimate survival,

dispersal, and migratory patterns in Oystercatchers. These estimates are necessary to

understand the effects of natural events and management actions.

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Appendices

Appendix 1: American Oystercatcher productivity in North Carolina from 1995-2008

Year and Location	Breeding pairs	Nests	Nests hatched	Nest survival observed (SE)	Nest survival adjusted (SE)	Chicks fledged	Chick Survival (SE)	Chicks fledged/pair (SE)
CAPE LOOKOUT								
North Core Banks								
1998	38	72	5	0.069 (0.030)	NA	4	NA	0.105 (0.062)
1999	39	62	11	0.177 (0.049)	0.170 (0.042)	5	0.208 (0.083)	0.128 (0.061)
2000	29	36	7	0.194 (0.066)	0.248 (0.068)	1	0.059 (0.057)	0.034 (0.034)
2001	29	53	12	0.226 (0.057)	0.173 (0.049)	1	0.091 (0.061)	0.034 (0.034)
2002	23	46	4	0.087 (0.042)	0.084 (0.033)	5	0.455 (0.150)	0.217 (0.125)
2003	20	36	7	0.194 (0.066)	0.157 (0.053)	2	0.118 (0.078)	0.100 (0.069)
2004	21	25	20	0.800 (0.080)	0.772 (0.089)	31	0.608 (0.068)	1.476 (0.255)
2005	16	20	11	0.550 (0.111)	0.453 (0.120)	6	0.286 (0.099)	0.375 (0.155)
2006	14	18	8	0.444 (0.117)	0.399 (0.116)	5	0.263 (0.101)	0.357 (0.133)
2007	17	32	8	0.250 (0.077)	0.191 (0.065)	14	0.778 (0.098)	0.824 (0.261)
2008	14	22	4	0.182 (0.082)	0.248 (0.084)	3	0.429 (0.187)	0.214 (0.114)
Island	260	422	97	0.230 (0.020)	0.228 (0.021)	77	0.376 (0.035)	0.296 (0.043)
Middle Core Banks								
2004	5	5	4	0.800 (0.179	NA	7	0.875 (0.117)	1.400 (0.510)
2005	7	9	5	0.556 (0.166)	0.511 (0.172)	9	0.643 (0.128)	1.286 (0.474)
2006	8	9	7	0.778 (0.139	0.745 (0.155)	8	0.500 (0.125)	1.000 (0.267)
2007	11	11	7	0.636 (0.145)	0.570 (0.160)	10	0.833 (0.108)	0.909 (0.315)
2008	6	6	4	0.667 (0.192)	NA	7	0.875 (0.117)	1.167 (0.477)
Island	37	40	27	0.675 (0.074)	0.604 (0.096)	41	0.707 (0.060)	1.108 (0.168)
Ophelia Banks								
2007	2	3	2	0.667 (0.272)	NA	3	0.750 (0.217)	1.500 (0.500)
2008	2	2	1	0.500 (0.354)	NA	0	0.000 (0.000)	0.000 (0.000)
Island	4	5	3	0.600 (0.219)	NA	3	0.500 (0.204)	0.750 (0.479)
South Core Banks								
1995	20	36	12	0.333 (0.079)	NA	7	NA	0.350 (0.131)

1997	23	34	4	0.118 (0.055)	0.036 (0.022)	2	0.286 (0.171)	0.087 (0.060)
1998	20	26	7	0.269 (0.087)	0.135 (0.062)	3	0.214 (0.110)	0.150 (0.082)
1999	28	52	5	0.096 (0.041)	0.115 (0.036)	1	0.125 (0.117)	0.036 (0.036)
2000	25	38	18	0.474 (0.081)	0.303 (0.077)	6	0.120 (0.046)	0.240 (0.087)
2001	27	56	8	0.143 (0.047)	0.158 (0.042)	1	0.050 (0.049)	0.037 (0.036)
2002	23	43	4	0.093 (0.044)	0.061 (0.028)	1	0.143 (0.132)	0.043 (0.043)
2003	27	59	9	0.153 (0.047)	0.121 (0.036)	6	0.273 (0.095)	0.222 (0.096)
2004	20	33	13	0.394 (0.085)	0.279 (0.080)	6	0.231 (0.083)	0.300 (0.147)
2005	22	27	9	0.333 (0.091)	0.317 (0.086)	3	0.188 (0.098)	0.136 (0.068)
2006	19	31	6	0.194 (0.071)	0.203 (0.065)	10	0.769 (0.117)	0.526 (0.246)
2007	21	41	4	0.098 (0.046)	0.073 (0.032)	4	0.571 (0.187)	0.190 (0.131)
2008	24	44	5	0.114 (0.048)	0.087 (0.034)	5	0.625 (0.171)	0.208 (0.120)
Island	299	520	104	0.200 (0.018)	0.139 (0.014)	55	0.242 (0.030)	0.184 (0.027)
Shackleford Banks								
2003	7	10	1	0.100 (0.095)	NA	0	0.000 (0.000)	0.000 (0.000)
2004	6	8	1	0.125 (0.117)	NA	1	1.000 (0.000)	0.167 (0.408)
2005	9	10	1	0.100 (0.095)	NA	0	0.000 (0.000)	0.000 (0.000)
2006	9	11	1	0.091 (0.087)	0.071 (0.061)	1	1.000 (0.000)	0.111 (0.011)
2007	10	12	0	0.000 (0.000)	0.110 (0.088)	0	0.000 (0.000)	0.000 (0.000)
2008	11	17	3	0.176 (0.092)	0.059 (0.046)	0	0.000 (0.000)	0.000 (0.000)
Island	52	68	7	0.103 (0.037)	0.075 (0.035)	2	0.167 (0.108)	0.038 (0.027)
CAPE HATTERAS								
Ocracoke Island								
1999	15	17	7	0.412 (0.119)	0.321 (0.105)	2	0.182 (0.116)	0.133 (0.091)
2000	12	17	6	0.353 (0.116)	0.270 (0.107)	7	0.778 (0.139)	0.583 (0.260)
2001	13	15	11	0.733 (0.114)	0.624 (0.132)	12	0.600 (0.110)	0.923 (0.265)
2002	12	18	6	0.333 (0.111)	0.266 (0.102)	3	0.250 (0.125)	0.250 (0.131)
2003	8	12	4	0.333 (0.136)	0.255 (0.117)	1	0.250 (0.217)	0.125 (0.125)
2004	9	11	6	0.545 (0.150)	0.566 (0.144)	8	0.727 (0.134)	0.889 (0.309)
2005	5	10	3	0.300 (0.145)	0.295 (0.136)	1	0.167 (0.152)	0.200 (0.200)
2006	5	8	4	0.500 (0.177)	0.492 (0.202)	2	0.182 (0.116)	0.400 (0.400)
2007	5	12	3	0.250 (0.125)	0.102 (0.078)	1	0.250 (0.217)	0.200 (0.200)

2008	3	3	1	0.333 (0.272)	0.347 (0.260)	2	1.000 (0.000)	0.667 (0.667)
Island	87	135	51	0.415 (0.044)	0.341 (0.042)	39	0.433 (0.052)	0.448 (0.080)
Hatteras Island								
1999	24	31	7	0.226 (0.075)	0.287 (0.087)	3	0.273 (0.134)	0.125 (0.069)
2000	23	29	10	0.345 (0.088)	0.270 (0.081)	2	0.087 (0.059)	0.087 (0.060)
2001	24	28	10	0.357 (0.091)	0.259 (0.083)	7	0.389 (0.115)	0.292 (0.112)
2002	17	25	3	0.120 (0.065)	0.030 (0.023)	4	0.800 (0.179)	0.235 (0.136)
2003	16	23	10	0.435 (0.103)	0.372 (0.106)	6	0.286 (0.099)	0.375 (0.155)
2004	15	18	13	0.722 (0.106)	0.706 (0.110)	9	0.360 (0.096)	0.600 (0.235)
2005	17	25	16	0.640 (0.096)	0.501 (0.110)	10	0.417 (0.101)	0.588 (0.196)
2006	14	19	11	0.579 (0.113)	0.525 (0.120)	6	0.316 (0.107)	0.429 (0.202)
2007	15	21	10	0.476 (0.109)	0.477 (0.102)	9	0.450 (0.111)	0.600 (0.235)
2008	15	20	9	0.450 (0.111)	0.565 (0.102)	11	0.611 (0.115)	0.733 (0.267)
Island	180	239	99	0.414 (0.032)	0.373 (0.032)	67	0.364 (0.035)	0.372 (0.052)
Bodie Island								
1999	2	3	0	0.000 (0.030)	0.030 (0.035)	0	0.000 (0.000)	0.000 (0.000)
2000	2	3	0	0.000 (0.081)	0.081 (081)	0	0.000 (0.000)	0.000 (0.000)
2001	2	3	1	0.333 (0.272)	0.285 (0.253)	1	0.500 (0.354)	0.500 (0.500)
2002	2	5	1	0.200 (0.179)	0.138 (0.137)	2	1.000 (0.000)	1.000 (1.000)
2003	5	5	1	0.200 (0.179)	0.311 (0.182)	0	0.000 (0.000)	0.000 (0.000)
2004	3	6	0	0.000 (0.000)	0.091 (0.089)	0	0.000 (0.000)	0.000 (0.000)
2005	2	3	1	0.333 (0.272)	0.390 (0.260)	0	0.000 (0.000)	0.000 (0.000)
2006	2	2	1	0.500 (0.354)	0.400 (0.367)	0	0.000 (0.000)	0.000 (0.000)
2007	2	2	1	0.500 (0.354)	0.545 (0.331)	0	0.000 (0.000)	0.000 (0.000)
2008	3	5	2	0.400 (0.219)	0.361 (0.212)	2	0.100 (0.000)	0.667 (0.333)
Island	25	37	8	0.216 (0.068)	0.191 (0.053)	5	0.417 (0.142)	0.200 (0.100)
Green Island								
2004	2	3	2	0.667 (0.272)	NA	2	0.500 (0.250)	1.000 (1.000)
2005	2	3	2	0.667 (0.272)	NA	0	0.000 (0.000)	0.000 (0.000)

2006	2	2	2	1.000 (0.000)	NA	2	1.000 (0.000)	1.000 (0.000)
2007	2	2	1	0.500 (0.354)	NA	2	0.667 (0.272)	1.000 (1.000)
2008	2	4	1	0.150 (0.217)	NA	2	1.000 (0.000)	1.000 (1.000)
Island	10	14	8	0.571 (0.132)	NA	8	0.571 (0.132)	0.800 (0.293)
CAPE FEAR REGION								
Cape Fear River Islands								
2002	32	47	26	0.553 (0.073)	0.534 (0.073)	7	0.149 (0.052)	0.219 (0.074)
2003	34	50	15	0.300 (0.065)	0.367 (0.064)	7	0.333 (0.103)	0.206 (0.066)
Island	66	97	41	0.423 (0.050)	0.443 (0.049)	14	0.206 (0.049)	0.212 (0.049)
Lea and Hutaff Islands								
2003	16	16	11	0.688 (0.116)	0.617 (0.133)	9	0.391 (0.102)	0.563 (0.204)
Total/mean	**1036**	**1581**	**456**	**0.288 (0.011)**	**0.246 (0.011)**	**320**	**0.360 (0.016)**	**0.309 (0.020)**

Appendix 2. American Oystercatchers banded in North Carolina.

USFWS #	Date	Banding Location	Left Leg	Right Leg	Age
805-60021	5/10/99	CALO - NCB	-;DB(1)/S	-;-	Adult
805-60022	5/11/99	CALO - NCB	-;DG(1)/S	-;-	Adult
805-60024	5/12/99	CALO - NCB Mile 21.3	-;GF/S	-;RD/WH	Adult
805-60026	5/12/99	CALO – NCB	WH;GF/S	WH;DB/RD	Adult
805-60027	5/13/99	CALO – NCB	WH;DG(B)/S	WH;-	Adult
805-60028	5/9/99	CALO - NCB	-;DB(3)/S	-;RD(6)	Chick
805-60029	5/9/99	CALO - NCB	-;DB(3)/S	-;DG(2)	Chick
805-60030	5/9/99	CALO - NCB	-;-	-;YE(3)/S	Chick
805-60034	6/22/99	CALO - NCB	-;-	-;DG(3)/S	Chick
805-60035	6/27/99	CALO - NCB	-;-	-;RD(3)/S	Chick
805-60036	6/28/99	CALO - NCB	-;YE(4)/S	-;RD(4)	Chick
805-60037	6/28/99	CALO - NCB	-;DB(5)/S	-;DG(4)	Chick
805-60038	5/12/00	CALO – NCB	-;S	-;DB(7)/DG(5)	Adult
805-60039	5/16/00	CALO – NCB	-;S	-;DG(6)/RD(5)	Adult
805-60040	5/16/00	CALO – NCB	-;S	-;RD(6)/DB(8)	Adult
805-60041	5/17/00	CALO – NCB	-;S	-;YE(9)/DG(7)	Adult

805-60042	5/19/00	CALO – NCB	-;S	-;DG(8)/RD(7)	Adult
875-98376	5/19/00	CALO - NCB - Mile 4.3	DG(37);-	DG(37);S	Adult
805-60044	6/12/00	CALO – NCB	-;S	-;YE(8)/DB(10)	Adult
805-60049	6/28/00	CALO – NCB	-;S	-;RD(8)/DG(10)	Adult
805-60050	7/5/00	CALO - NCB	-;S	-;DG(14)/YE(10)	Adult
805-60045	6/22/00	CALO - NCB Mile 18.5	-;DG(9)/S	-;-	Chick
805-60046	6/17/00	CALO – SCB	-;DG(11)/S	-;-	Chick
805-60047	6/8/00	CALO – SCB	DB;GF/S	YE;DG/RD	Chick
805-60048	6/8/00	CALO – SCB	-;DG(13)/S	-;-	Chick
805-60051	5/25/01	CALO - NCB Mile 3.7	-;DG/S	-;DB	Adult
805-60052	5/25/01	CALO - NCB Mile 3.5	-;DG/S	-;RD	Adult
805-60053	5/26/01	CALO - NCB Mile 4.7	-;DG/S	-;YE	Adult
805-60054	5/31/01	CALO – NCB Mile 9.6	-;DG/S	-;DG	Chick
805-60055	5/31/01	CALO - NCB Mile 6.6	DG(B);DG/S	-;WH	Adult
805-60056	6/3/01	CALO - NCB Mile 16.3	-;GF/S	-;DB/OR	Adult
805-60057	6/5/01	CALO – NCB Mile 10.3	-;GF/S	-;OR	Chick
805-60058	6/12/01	CALO - NCB Mile 5.9	-;GF/S	-;YE/DG	Adult
805-60059	7/1/01	CALO – NCB Mile 0.0	-;GF/S	-;OR/YE	Chick
805-60060	6/17/01	CALO - NCB Mile 8.4	-;S	-;WH/OR	Adult
805-60061	6/18/01	CALO - NCB Mile 11.7	-;S	-;WH/DB	Adult
805-60062	6/18/01	CALO - NCB Mile 11.7	-;S	RD;DG/RD	Adult
805-60063	6/19/01	CALO – SCB Mile 38	-;DG/S	-;RD/DB	Chick
805-60064	6/19/01	CALO - SCB Mile 38	-;S	-;RD/OR	Adult
805-60065	7/12/01	CALO – NCB Mile 0.2	-;GF/S	-;RD/YE	Chick
805-60066	7/13/01	CALO – NCB Mile 8.9	-;GF/S	-;WH/WH	Chick
805-60067	7/13/01	CALO - NCB Mile 8.9	-;S	-;OR/OR	Adult
805-60068	3/28/02	CALO - NCB Mile 13.8	YE;S	YE;OR/RD	Adult
805-60069	4/1/02	Battery Is.	OR;GF/S	OR;YE/RD	Adult
805-60070	4/1/02	Battery Is.	WH;DG/S	DB;-	Adult
805-60071	5/13/02	Battery Island	-;GF/S	-;WH/RD	Chick
805-60072	5/13/02	Battery Island	-;GF/S	-;OR/DB	Chick
805-60073	5/13/02	Battery Is.	-;GF/S	-;DB/WH	Chick
805-60074	5/17/02	CALO - NCB Mile 0.0	WH;GF/S	WH;RD/RD	Adult

875-98366	5/21/02	CAHA - Hatteras Island Mile 28	DG(28);-	DG(28);S	Adult
805-60076	5/21/02	CAHA - Hatteras Island South Beach	WH;S	WH;DG/DG	Adult
805-60077	5/22/02	CAHA – Ocracoke Island	-;DG/S	-;YE/DB	Chick
805-60078	5/22/02	CAHA - Ocracoke Island	WH;GF/S	WH;DB/DB	Adult
805-60079	5/25/02	CALO – NCB Mile 9.55	WH;DG/S	-;YE/DB	Chick
805-60080	5/27/02	CALO - SCB Mile 38	OR;S	OR;WH/WH	Adult
805-60081	5/28/02	CALO – SCB The Spit	-;GF/S	-;YE/WH	Chick
805-60082	5/28/02	CALO - SCB The Spit	OR;GF/S	OR;OR/OR	Adult
875-98375	5/31/02	CALO - NCB Mile 6.15	OR;DG/S	OR;DB/DB	Adult
805-60084	6/1/02	CALO - NCB Mile 8.4	DB;S	WH;DB/WH	Adult
805-60085	6/1/02	CALO – NCB Mile 5.9	-;GF/S	WH;RD/WH	Chick
805-60086	6/9/02	CAHA - Hatteras Island Buxton	RD;GF/S	DB;RD/RD	Adult
805-60087	6/11/02	CAHA – Hatteras Island Buxton	-;GF/S	-;OR/DG	Chick
805-60088	6/11/02	CAHA – Hatteras Island Buxton	RD;GF/S	DB;OR/DG	Chick
805-60089	6/11/02	CAHA – Hatteras Island Buxton	YE;GF/S	YE;YE/YE	Chick
875-98362	6/13/02	CAHA - Hatteras Island Buxton	DG(24);-	DG(24);S	Adult
805-60091	6/14/02	CAHA – Ocracoke Island	YE;-	-;GF/S	Chick
805-60092	6/14/02	CAHA – Ocracoke Island	RD;GF/S	-;-	Chick
805-60093	6/16/02	CALO – NCB Mile 9.55	-;DG	RD;S	Chick
805-60094	6/17/02	Battery Is.	-;GF/S	RD;OR/WH	Adult
805-60095	6/17/02	South Pelican Is.	WH;GF/S	-;RD/RD	Chick
805-60096	6/17/02	South Pelican Is.	YE;GF/S	DB;OR	Chick
805-60097	6/18/02	Battery Is.	DG;GF/S	-;WH/DG	Adult
805-60098	6/18/02	Battery Is.	-;GF/S	-;RD/RD	Chick
805-60099	6/18/02	South Pelican Is.	YE;GF/S	RD;DB/YE	Adult
805-60100	6/29/02	CALO – NCB Mile 9.55	DB;-	RD;S	Chick
975-85201	7/1/02	CALO – NCB Mile 2.3	-;GF/S	-;DG/YE	Chick
975-85202	7/1/02	CALO – NCB Mile 2.3	RD;S	-;YE	Chick
975-85203	5/27/03	Battery Is.	WH;DG(A)/S	YE;-	Chick
975-85204	5/27/03	South Pelican Is.	RD;DG(A)/S	OR;-	Chick
975-85205	6/1/03	CAHA – Hatteras Island	-;DG(A)/S	-;DB/DB	Chick
975-85206	6/2/03	CAHA – Ocracoke Island	OR;DG(B)/S	OR;-	Adult
975-85207	6/5/03	CALO – SCB mile 24.1	YE;DG(B)/S	WH;-	Adult

975-85208	6/6/03	CALO – SCB mile 39.75	RD;DG(B)/S	YE;-	Adult
875-98335	6/6/03	CALO – SCB, Cape point	DG(16);-	DG(16);S	Adult
975-85291	6/18/03	CALO – NCB mile 3.2	S;-/DG(A)	WH;OR/OR	Chick
975-85210	6/18/03	CALO – NCB mile 3.2	DG(H);-/DG(A)	WH;OR/S	Chick
975-85293	6/23/03	CALO – NCB mile 10.4	S;-/DG(A)	-;DG/WH	Chick
975-85211	6/25/03	CALO – SCB mile 40.55	-;-/DG(A)	RD;RD/RD/S	Chick
875-98321	4/17/04	CAHA – Hatteras Island South Beach	DG(01);-	DG(01);S	Adult
875-98322	4/17/04	CAHA – Hatteras Island Hatteras Inlet	DG(02);-	DG(02);S	Adult
875-98323	5/4/04	CALO – NCB mile 3.0	DG(03);-	DG(03);S	Adult
875-98324	5/6/04	CALO – NCB mile 9.5	DG(04);-	DG(04);S	Adult
875-98325	5/15/04	CAHA – Hatteras Island – North of Buxton	DG(05);-	DG(05);S	Adult
875-98326	5/15/04	CAHA – Hatteras Island – North of Buxton	DG(06);-	DG(06);S	Adult
875-98327	5/16/04	CAHA – Hatteras Island, Cape Point	DG(07);-	DG(07);S	Adult
875-98328	5/17/04	CALO – NCB Mile 0.0	DG(08);S	DG(08);-	Adult
875-98329	5/18/04	CALO - NCB Mile 0.0	DG(09);-	DG(09);S	Adult
875-98330	5/24/04	CAHA - Green Island	DG(10);-	DG(10);S	Adult
875-98331	5/24/04	CAHA - Green Island	DG(11);-	DG(11);S	Adult
875-98332	5/24/04	CAHA - Hatteras Island, South Beach	DG(12);-	DG(12);S	Adult
2406-00411	5/25/04	CAHA - Ocracoke, Pair O08	DG(13);-	DG(13);S	Adult
875-98333	5/25/04	CAHA - Ocracoke, Pair O07	DG(14);-	DG(14);S	Adult
875-98334	5/26/04	CALO – NCB Mile 6.15	DG(15);-	DG(15);S	Adult
875-98336	5/28/04	CALO - SCB Mile 37.3	DG(17);-	DG(17);S	Adult
2406-00412	5/29/04	CALO – NCB Mile 18.5	DG(18);-	DG(18);S	Adult
875-98338	5/31/04	CALO - NCB Mile 0.0	DG(19);-	DG(19);S	Chick
875-98339	5/31/04	CALO - NCB Mile 0.0	DG(20);-	DG(20);S	Chick
875-98340	6/1/04	CAHA - Ocracoke Inlet	DG(21);-	DG(21);S	Adult
875-98361	6/1/04	CAHA – Ocracoke	DG(22);-	DG(22);S	Adult
2406-00413	6/1/04	CAHA – Buxton Washout	DG(23);-	DG(23);S	Adult
875-98363	6/2/04	CAHA - Hatteras Inlet	DG(25);-	DG(25);S	Adult
875-98364	6/3/04	CAHA - 1 Mile North of Ramp 34	DG(26);-	DG(26);S	Adult

875-98365	6/3/04	CAHA - 1 Mile North of Ramp 34	DG(27);-	DG(27);S	Adult
875-98368	6/7/04	CALO - SCB Mile 39.7	DG(29);-	DG(29);S	Chick
875-98367	6/8/04	CALO - NCB Mile 10.3	DG(30);-	DG(30);S	Adult
875-98369	6/9/04	CALO - NCB Mile 0.0	DG(31);-	DG(31);S	Chick
875-98370	6/10/04	CALO - NCB Mile 18.5	DG(32);-	DG(32);S	Chick
875-98371	6/10/04	CALO - NCB Mile 18.5	DG(33);-	DG(33);S	Chick
875-98372	6/10/04	CALO - NCB Mile 6.9	DG(34);-	DG(34);S	Chick
875-98373	6/10/04	CALO - NCB Mile 6.9	DG(35);-	DG(35);S	Chick
875-98374	6/11/04	CALO - NCB Mile 8.9	DG(36);-	DG(36);S	Chick
875-98377	6/16/04	CALO – MCB - Mile 0.6	OR;DG/S	DB;DB	Chick
875-98378	6/16/04	CALO – MCB - Mile 0.6	DB;DG/S	DB;RD	Chick
875-98379	6/16/04	CALO – MCB - Mile 0.6	RD;DG/S	YE;WH	Chick
875-98380	6/17/04	CALO - NCB Mile 6.9	DG(38);-	DG(38);S	Chick
875-98381	6/18/04	CAHA - Ocracoke Inlet.	DB;DG/S	YE;WH	Chick
875-98382	6/18/04	CAHA - Ocracoke Inlet.	OR;DG/S	YE;DB	Chick
875-98383	6/18/04	CAHA - Hatteras Inlet	RD;DG/S	OR;WH	Chick
875-98384	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(56);-	DG(56);S	Chick
875-98385	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(57);-	DG(57);S	Chick
875-98386	6/19/04	CAHA - 1 mile S of Ramp 27	WH;DG/S	DG;WH	Chick
875-98387	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(58);-	DG(58);S	Chick
875-98388	6/22/04	CALO - NCB Mile 7.15	DG(39);S	DG(39);S	Adult
875-98389	6/22/04	CALO - NCB Mile 6.01	DG(40);-	DG(40);S	Adult
875-98390	6/23/04	CALO - Old Dump Island at Old Drum Inlet	DB;DG/S	RD;RD	Chick
875-98391	6/26/04	Sandbag Island.Pair S02	DG(41);-	DG(41);S	Chick
875-98392	6/26/04	Sandbag Island.Pair S02	DG(42);-	DG(42);S	Chick
875-98393	6/26/04	Sandbag Island.Pair S02	DG(43);-	DG(43);S	Chick
875-98394	6/27/04	CALO - NCB Mile 6.01	DG(44);-	DG(44);S	Chick
875-98395	6/27/04	CALO - NCB Mile 6.01	DG(45);-	DG(45);S	Chick
875-98396	6/27/04	CALO - NCB Mile 2.0	DG(46);-	DG(46);S	Chick
875-98397	6/27/04	CAHA – Ocracoke	DG(47);-	DG(47);S	Chick
875-98398	6/27/04	CAHA – Ocracoke	DG(48);-	DG(48);S	Chick
875-98399	6/27/04	CAHA – Ocracoke	DG(49);-	DG(49);S	Chick

875-98400	6/27/04	CAHA – Ocracoke	DG(50);-	DG(50);S	Chick
875-98421	6/27/04	CAHA – Ocracoke	DG(51);-	DG(51);S	Adult
875-98422	6/28/04	CAHA - Avon - 0.9 Miles North of Ramp 34.	DG(52);-	DG(52);S	Chick
875-98423	6/28/04	CAHA - Avon - 0.9 Miles North of Ramp 34.	DG(53);-	DG(53);S	Chick
875-98424	6/28/04	CAHA - 1.4 miles south of Ramp 27.	DG(54);-	DG(54);S	Chick
875-98425	6/28/04	CAHA - 1.4 miles south of Ramp 27.	DG(55);-	DG(55);S	Chick
875-98426	6/28/04	CAHA - 1.4 miles south of Ramp 27	DG(59);-	DG(59);S	Adult
875-98427	6/29/04	CALO - NCB Mile 6.01	DG(60);-	DG(60);S	Chick
875-98428	6/29/04	CALO - NCB Mile 7.15	DG(61);-	DG(61);S	Chick
875-98429	6/30/04	CALO - NCB Mile 6.3	DG(62);-	DG(62);S	Chick
875-98430	6/30/04	CALO - NCB Mile 9.5	DG(63);-	DG(63);S	Chick
875-98431	6/30/04	CALO - NCB Mile 7.15	DG(64);-	DG(64);S	Chick
875-98432	6/30/04	CALO - NCB Mile 7.15	DG(65);-	DG(65);S	Chick
875-98433	6/30/04	CALO - NCB Mile 10.3	DG(66);-	DG(66);S	Chick
875-98434	6/30/04	CALO - NCB Mile 10.3	DG(67);-	DG(67);S	Chick
875-98435	7/1/04	CALO - NCB Mile 3.9	DG(68);-	DG(68);S	Chick
875-98436	7/1/04	CALO - NCB Mile 3.9	DG(69);-	DG(69);S	Chick
875-98437	7/1/04	CALO - NCB Mile 3.9	DG(70);-	DG(70);S	Chick
875-98348	7/3/04	CALO - NCB Old Drum Inlet	DG(71);-	DG(71);S	Chick
875-98349	7/3/04	CALO - NCB Old Drum Inlet	DG(72);-	DG(72);S	Chick
875-98350	7/3/04	CALO - NCB Mile 9.5	DG(73);-	DG(73);S	Adult
875-98441	7/3/04	CALO - NCB Mile 6.3	DG(74);-	DG(74);S	Chick
875-98442	7/4/04	CALO - NCB Mile 3.4	DG(75);-	DG(75);S	Chick
875-98443	7/4/04	CALO - NCB Mile 3.4	DG(76);-	DG(76);S	Chick
875-98444	7/19/04	Cape Fear - Ferry Slip	DG(77);-	DG(77);S	Chick
875-98445	7/19/04	Cape Fear - Ferry Slip	DG(78);-	DG(78);S	Chick
875-98446	7/19/04	Cape Fear - South Pelican	DG(79);-	DG(79);S	Chick
875-98447	7/19/04	Cape Fear - South Pelican	DG(80);-	DG(80);S	Chick
875-98448	7/22/04	CALO - SCB mile 22.6	DG(81);-	DG(81);S	Chick
875-98449	7/22/04	CALO - SCB mile 22.6	DG(82);-	DG(82);S	Chick
875-98450	7/29/04	CAHA - Ocracoke Pair O03	DG(83);-	DG(83);S	Chick

875-98451	7/29/04	CAHA - Ocracoke Pair O03	DG(84);-	DG(84);S	Chick
875-98452	8/1/04	CALO – NCB Mile 6.15	DG(85);-	DG(85);S	Chick
875-98453	8/5/04	CALO - SCB Mile 23.5	DG(86);-	DG(86);S	Chick
875-98454	8/5/04	CALO - SCB Mile 23.5	DG(87);-	DG(87);S	Chick
875-98455	3/19/05	CAHA - Hatteras Is, Hatteras inlet	DG(88)	DG(88);S	Adult
875-98456	3/20/05	Ocracoke Inlet – Shellcastle/ Ballast rocks Is.	DG(89)	DG(89);S	Adult
875-98457	3/20/05	Ocracoke Inlet -Shellcastle/ Ballast rocks Is.	DG(90)	DG(90);S	Adult
875-98458	3/20/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(91)	DG(91);S	Adult
875-98459	3/21/05	CAHA -Hatteras Is, Hatteras spit, the breach	DG(92)	DG(92);S	Adult
875-98460	4/1/05	CAHA - Bodie Island spit.	DG(A1)	DG(A1);S	Adult
875-98461	4/2/05	CAHA - 1 mile N. of ramp 30	DG(A2)	DG(A2);S	Adult
875-98462	4/3/05	CAHA - 1.8 miles south of ramp 23	DG(A3)	DG(A3);S	Adult
875-98463	4/3/05	CAHA - 1.8 miles south of ramp 23	DG(A4)	DG(A4);S	Adult
875-98464	4/3/05	CAHA - Sandy Bay/Isabel Inlet - sound side	DG(A5)	DG(A5);S	Adult
875-98466	4/17/05	CAHA - Cape Point	DG(A7)	DG(A7);S	Adult
875-98468	4/18/05	CALO - SCB mile 38.5	DG(A9)	DG(A9);S	Adult
875-98469	5/7/05	CALO - NCB mile 9.9	DG(A0)	DG(A0);S	Adult
875-98471	5/7/05	CALO - NCB mile 4.5	DG(C2)	DG(C2);S	Adult
875-98472	5/7/05	CALO - NCB mile 4.5	DG(C3)	DG(C3);S	Adult
875-98473	5/8/05	CALO - NCB mile 10.4	DG(C4)	DG(C4);S	Adult
875-98474	5/9/05	Ocracoke inlet - Shellcastle Islands - with duck blind.	DG(C5)	DG(C5);S	Adult
875-98475	5/9/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(C6)	DG(C6);S	Adult
875-98476	5/9/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(C7)	DG(C7);S	Adult
875-98477	4/10/05	CAHA - Bodie Island spit. North side of bay.	DG(C9)	DG(C9);S	Adult

875-98478	4/10/05	CAHA 0.8 miles S. of ramp 27	DG(C8)	DG(C8);S	Adult
875-98479	5/11/05	Oregon inlet, East waterbird island (near bridge)	DG(C0)	DG(C0);S	Adult
875-98480	5/11/05	Oregon inlet - Island MN (north side)	DG(E1)	DG(E1);S	Adult
785-09571	5/11/05	Oregon inlet - Island MN (north side)	DG(E2)	DG(E2);S	Adult
875-98481	5/11/05	Oregon Inlet - Island L. NW side.	DG(E3)	DG(E3);S	Adult
875-98482	5/11/05	Oregon inlet - Island D (East side)	DG(E4)	DG(E4);S	Adult
875-98483	5/11/05	Oregon Inlet -Wells Island	DG(E5)	DG(E5);S	Adult
875-98484	5/11/05	Oregon Inlet - Wells Island	DG(E6)	DG(E6);S	Adult
875-98485	5/11/05	Oregon Inlet - Island G	DG(E7)	DG(E7);S	Adult
875-98486	5/13/05	CALO - Shackleford Banks - West end	DG(E8)	DG(E8);S	Adult
875-98487	5/13/05	CALO - Shackleford Banks - mile 49.9	DG(E9)	DG(E9);S	Adult
875-98488	5/17/05	CALO - NCB - Mile 15.5	DG(E0)	DG(E0);S	Adult
875-98489	5/17/05	CALO - NCB - Mile 3.8	DG(F1)	DG(F1);S	Adult
875-98492	5/26/05	CALO - NCB - Mile 12.2	DG(F4)	DG(F4);S	Adult
875-98493	5/26/05	CALO - NCB - Mile 6.8	DG(F5)	DG(F5);S	Adult
875-98494	5/26/05	CALO - NCB - Mile 0.2	DG(F6)	DG(F6);S	Adult
875-98495	6/1/05	CAHA - South Beach	DG(F7)	DG(F7);S	Adult
875-98497	6/13/05	Oregon Inlet - Island MN	DG(93)	DG(93);S	Chick
875-98498	6/13/05	Oregon inlet, bridge island	DG(94)	DG(94);S	Chick
875-98499	6/18/05	CAHA - South Beach	DG(H2)	DG(H2);S	Chick
875-98500	6/18/05	CAHA - South Beach	DG(H3)	DG(H3);S	Chick
875-98402	6/18/05	CAHA - North Beach	DG(H4)	DG(H4);S	Chick
875-98403	6/19/05	Ocracoke Island 3.3 miles north of ramp 67	DG(95)	DG(95);S	Chick
875-98404	6/19/05	CALO - SCB - mile 44.8	DG(F9)	DG(F9);S	Chick
875-98405	6/20/05	CALO – SCB - power squadron spit - sound side	DG(F0)	DG(F0);S	Chick
875-98406	6/22/05	CALO - MCB - north end	DG(K1)	DG(K1);S	Chick
875-98407	6/22/05	CALO - MCB - north end	DG(K2)	DG(K2);S	Chick
875-98408	6/25/05	CALO - NCB - Mile 10.5	DG(J1)	DG(J1);S	Chick

875-98409	7/9/05	CALO - NCB - Mile 15.5	DG(J2)	DG(J2);S	Chick
875-98410	7/9/05	CALO - NCB - Mile 15.5	DG(J3)	DG(J3);S	Chick
875-98411	7/10/05	CALO - NCB - Mile 10.8	DG(J5)	DG(J5);S	Chick
875-98413	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K3)	DG(K3);S	Chick
875-98414	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K4)	DG(K4);S	Chick
875-98415	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K5)	DG(K5);S	Chick
875-98416	7/14/05	CAHA - South Beach	DG(H6)	DG(H6);S	Chick
875-98417	7/14/05	CAHA - South Beach	DG(H7)	DG(H7);S	Chick
875-98418	7/15/05	CAHA - 0.6 Miles north of Ramp 30	DG(H8)	DG(H8);S	Chick
875-98419	7/20/05	CALO - MCB - NW corner at Old Drum inlet	DG(K6)	DG(K6);S	Chick
875-98420	7/20/05	CALO - MCB - NW corner at Old Drum inlet	DG(K7)	DG(K7);S	Chick
1055-04701	7/21/05	CALO - NCB - Mile 7.6	DG(J6)	DG(J6);S	Chick
1055-04702	8/1/05	CALO - NCB - Mile 6.01	DG(J7)	DG(J7);S	Chick
1055-04703	8/2/05	CAHA - Ocracoke, 1.6 miles north of ramp 70	DG(K8)	DG(K8);S	Chick
1055-04704	8/2/05	CAHA - Cape Point	DG(H9)	DG(H9);S	Chick
1055-04705	8/3/05	CALO - MCB - 1.2 miles south of Old Drum inlet	DG(K9)	DG(K9);S	Chick
1055-04706	8/3/05	CALO - MCB - 1.2 miles south of Old Drum inlet	DG(K0)	DG(K0);S	Chick
1055-04708	8/10/05	CAHA - North of Buxton	DG(H0)	DG(H0);S	Chick
1055-04710	4/12/06	CALO - SCB mile 35.2	DG(J0)	DG(J0);S	Adult
1055-04711	4/12/06	CALO - SCB mile 35.2	DG(M1)	DG(M1);S	Adult
1055-04712	4/13/06	CALO - SCB mile 28.3	DG(M2)	DG(M2);S	Adult
1055-04712	5/3/06	CALO - NCB mile 10.6	DG(M3)	DG(M3);S	Adult
1055-04714	6/9/06	Shellcastle Islands - Shellcastle West (Rocky Island)	DG(M4)	DG(M4);S	Chick
1055-04715	6/9/06	Shellcastle Islands - Shellcastle West	DG(M5)	DG(M5);S	Chick

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1055-04716	6/9/06	Shellcastle Islands - North Rock East	DG(M6)	DG(M6);S	Chick
1055-04717	6/9/06	Shellcastle Islands - North Rock East	DG(M7)	DG(M7);S	Chick
1055-04718	6/10/06	CALO - MCB. 0.5 miles south of Old Drum Inlet.	DG(M8)	DG(M8);S	Adult
1055-04719	6/11/06	Old Dump Island, Old Drum Inlet.	DG(M9)	DG(M9);S	Chick
1055-04720	6/17/06	CAHA - Buxton washout.	DG(P2)	DG(P2);S	Chick
1055-04721	6/17/06	CAHA - Buxton washout.	DG(P1)	DG(P1);S	Chick
1055-04722	6/18/06	CALO - MCB - Old Drum Inlet	DG(M0)	DG(M0);S	Chick
1055-04723	6/19/06	CALO - SCB Mile 38	DG(P3)	DG(P3);S	Chick
1055-04724	6/19/06	CALO - SCB Mile 38	DG(P4)	DG(P4);S	Chick
1055-04725	6/19/06	CALO - SCB Mile 38	DG(P5)	DG(P5);S	Chick
1055-04727	6/29/06	CAHA - South Beach	DG(N1)	DG(N1);S	Chick
1055-04728	6/29/06	CAHA - South Beach	DG(N3)	DG(N3);S	Chick
1055-04730	6/29/06	CALO - NCB - mile 3.6	DG(N6)	DG(N6);S	Chick
1055-04731	6/29/06	CALO - NCB - mile 9.3	DG(N7)	DG(N7);S	Chick
1055-04732	6/29/06	CALO - NCB - mile 10.3	DG(N8)	DG(N8);S	Chick
1055-04734	7/2/06	CALO - NCB - Mile 8.9	DG(T2)	DG(T2);S	Chick
1055-04735	7/7/06	CALO - MCB	DG(N0)	DG(N0);S	Chick
1055-04737	7/8/06	Bigfoot Island Slough	DG(U1)	DG(U1);S	Chick
1055-04738	7/8/06	CAHA - North Beach	DG(U2)	DG(U2);S	Chick
1055-04739	7/9/06	CALO - MCB	DG(U3)	DG(U3);S	Chick
1055-04740	7/9/06	CALO - MCB	DG(U4)	DG(U4);S	Chick
1055-04741	7/14/06	CALO - SCB	DG(U5)	DG(U5);S	Chick
1055-04742	7/14/06	CALO - SCB	DG(U6)	DG(U6);S	Chick
1055-04743	7/20/06	Ocracoke Inlet - Shellcastle Island	DG(U7)	DG(U7);S	Chick
1055-04744	7/20/06	Ocracoke Inlet - Shellcastle Island	DG(P7)	DG(P7);S	Chick
1055-04745	7/20/06	Ocracoke Inlet - Shellcastle Island central (with blind)	DG(U8)	DG(U8);S	Chick
1055-04746	7/20/06	Ocracoke Inlet - Shellcastle Island central (with blind)	DG(P8)	DG(P8);S	Chick
1055-04747	7/21/06	CALO - NCB	DG(U9)	DG(U9);S	Chick
1055-04748	7/21/06	CALO - MCB	DG(U0)	DG(U0);S	Chick

1055-04749	7/21/06	CALO - MCB	DG(P9)	DG(P9);S	Chick
1055-04750	7/27/06	CALO - MCB	DG(P0)	DG(P0);S	Chick
1055-04751	7/27/06	CALO - Ophelia Island - North End	DG(R1)	DG(R1);S	Chick
1055-04752	7/27/06	CALO - Ophelia Island - North End	DG(R2)	DG(R2);S	Chick
1055-04753	7/28/06	CALO - SCB	DG(N2)	DG(N2);S	Chick
1055-04754	7/28/06	CALO - SCB	DG(N4)	DG(N4);S	Chick
1055-04755	7/28/06	CALO - SCB	DG(R3)	DG(R3);S	Chick
1055-04756	5/12/07	CAHA - Buxton/Avon - Canadian Hole	DG(R5)	DG(R5);S	Adult
1055-04757	5/12/07	CAHA - Buxton/Avon - Canadian Hole	DG(R6)	DG(R6);S	Adult
1055-04758	5/16/07	CALO - SCB - Mile 46.7	DG(R7)	DG(R7);S	Adult
1055-04759	5/16/07	CALO - SCB - Mile 37.9	DG(R8)	DG(R8);S	Adult
1055-04760	5/20/07	CAHA - South Beach	DG(R9)	DG(R9);S	Adult
1055-04761	5/27/07	CAHA - South Beach, 0.1 miles east of ramp 45	DG(R0)	DG(R0);S	Adult
1055-04762	5/27/07	CAHA - North Beach, 0.8 m N R30	DG(T4)	DG(T4);S	Adult
1055-04763	6/16/07	CAHA	DG(T5)	DG(T5);S	Chick
1055-04764	6/16/07	CAHA	DG(T6)	DG(T6);S	Chick
1055-04765	6/17/07	CALO - NCB - Mile 9.1	DG(T7)	DG(T7);S	Chick
1055-04766	6/17/07	CALO - NCB - Mile 9.1	DG(T8)	DG(T8);S	Chick
1055-04767	6/17/07	CALO - NCB - Mile 9.1	DG(T9)	DG(T9);S	Chick
1055-04768	6/30/07	CALO - NCB - Mile 8.9	DG(TO)	DG(TO);S	Chick
1055-04769	7/14/07	CAHA - South Beach	DG(X1)	DG(X1);S	Chick
1055-04770	7/14/07	CAHA - South Beach	DG(X2)	DG(X2);S	Chick
1055-04771	7/14/07	CAHA - South Beach	DG(X3)	DG(X3);S	Chick
1055-04772	7/14/07	CAHA - North Beach	DG(X4)	DG(X4);S	Chick
1055-04773	7/15/07	CALO - NCB - Mile 0.0	DG(X5)	DG(X5);S	Chick
1055-04774	7/15/07	CALO - NCB - Mile 0.0	DG(X6)	DG(X6);S	Chick
1055-04775	7/15/07	CALO - NCB - Mile 3.6	DG(X7)	DG(X7);S	Chick
1055-04776	7/15/07	CALO - NCB - Mile 3.8	DG(X8)	DG(X8);S	Chick
1055-04777	7/15/07	CALO - NCB - Mile 3.8	DG(X9)	DG(X9);S	Chick
1055-04778	7/27/07	CAHA - North Beach	DG(Y1)	DG(Y1);S	Chick

1055-04779	7/27/07	CAHA - North Beach	DG(X0)	DG(X0);S	Chick
1055-04780	7/28/07	CALO - NCB - Mile 10.38	DG(Y2)	DG(Y2);S	Chick
1055-04781	7/28/07	CALO - NCB - Mile 3.8	DG(Y3)	DG(Y3);S	Chick
1055-04782	7/29/07	CALO - NCB - Mile 11.5	DG(Y4)	DG(Y4);S	Chick
1055-04783	8/3/07	CALO - MCB - Mile 19.66	DG(Y5)	DG(Y5);S	Chick
1055-04784	8/3/07	CALO - MCB - Mile 19.45	DG(Y6)	DG(Y6);S	Chick
1055-04785	8/3/07	Old Dump Island, Old Drum Inlet.	DG(Y7)	DG(Y7);S	Chick
1055-04786	8/3/07	Old Dump Island, Old Drum Inlet.	DG(Y8)	DG(Y8);S	Chick
1055-04787	8/4/07	CAHA - Ocracoke	DG(Y9)	DG(Y9);S	Chick
2406-00414	4/12/2008	CALO - SCB - Cape Point	DG(L1)	DG(L1);S	Adult
2406-00415	4/14/2008	CALO - SCB - Mile 38.83	DG(L2)	DG(L2);S	Adult
2406-00416	4/14/2008	CALO - SCB - Mile 38.83	DG(L3)	DG(L3);S	Adult
1055-04789	5/3/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(L4)	DG(L4);S	Adult
1055-04790	5/3/2008	CAHA - Hatteras Is. - North of Buxton	DG(L5)	DG(L5);S	Adult
2406-00417	5/3/2008	CAHA - Hatteras Is. - South Beach	DG(L6)	DG(L6);S	Adult
1055-04791	5/5/2008	CAHA - Ocracoke Is. - 1.0 miles south of Ramp 68	DG(L7)	DG(L7);S	Adult
2406-00418	6/10/2008	CAHA - Hatteras Is. - North of ramp 34	DG(L8)	DG(L8);S	Adult
2406-00419	6/10/2008	CAHA - Hatteras Is., 0.7 miles south of ramp 27	DG(L9)	DG(L9);S	Adult
1055-04792	6/22/2008	CAHA - Hatteras Is. - 1.1 miles north or ramp 30	DG(L0)	DG(L0);S	Chick
1055-04793	6/22/2008	CAHA - Hatteras Is. - North of Buxton	DG(W1)	DG(W1);S	Chick
1055-04794	6/22/2008	CAHA - Hatteras Is. - North of Buxton	DG(W2)	DG(W2);S	Chick
1055-04795	6/22/2008	CAHA - Hatteras Is. - Sandy Bay	DG(W3)	DG(W3);S	Chick
1055-04796	6/22/2008	CAHA - Hatteras Is. - Sandy Bay	DG(W4)	DG(W4);S	Chick
1055-04797	6/22/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(W5)	DG(W5);S	Chick
1055-04798	6/22/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(W6)	DG(W6);S	Chick
2406-00420	6/26/2008	Cape Fear River - Battery Is., South Point	DG(W7)	DG(W7);S	Adult
2406-00421	6/26/2008	Cape Fear River - Battery Is., South Point	DG(W8)	DG(W8);S	Adult

1055-04799	7/3/2008	CALO - NCB, Mile 9.0	DG(W9)	DG(W9);S	Chick
1055-04800	7/3/2008	CALO - NCB, Mile 6.6	DG(W0)	DG(W0);S	Chick
1055-04801	7/3/2008	CALO - MCB - Mile 19.66	DG(EA)	DG(EA);S	Chick
1055-04802	7/3/2008	CALO - MCB - Mile 19.66	DG(EC)	DG(EC);S	Chick
1055-04803	7/3/2008	CALO - MCB - Mile 19.66	DG(EE)	DG(EE);S	Chick
1055-04804	7/3/2008	CALO - MCB - Mile 19.86	DG(EF)	DG(EF);S	Chick
1055-04805	7/12/2008	CALO - SCB - Mile 25.16	DG(EH)	DG(EH);S	Chick
1055-04806	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EJ)	DG(EJ);S	Chick
1055-04807	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EK)	DG(EK);S	Chick
1055-04808	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EL)	DG(EL);S	Chick
1055-04809	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EM)	DG(EM);S	Chick
1055-04810	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EN)	DG(EN);S	Chick
1055-04811	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EP)	DG(EP);S	Chick
1055-04812	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(ER)	DG(ER);S	Chick
1055-04813	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(EU)	DG(EU);S	Chick
1055-04814	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(ET)	DG(ET);S	Chick
1055-04815	8/1/2008	Oregon Inlet - Green Is. - NE side	DG(EW)	DG(EW);S	Chick
1055-04816	8/1/2008	CAHA - Bodie Is. Spit, Northeast side	DG(EX)	DG(EX);S	Chick
1055-04817	8/1/2008	CAHA - Bodie Is. Spit, Southwest side	DG(EY)	DG(EY);S	Chick
1055-04818	8/7/2008	CALO - SCB - Mile 38.06	DG(AA)	DG(AA);S	Chick
1055-04819	8/7/2008	CALO - SCB - Mile 38.06	DG(AC)	DG(AC);S	Chick
1055-04820	8/7/2008	CALO - SCB - Mile 31.78	DG(AF)	DG(AF);S	Chick
1055-04821	8/7/2008	CALO - SCB - Mile 31.78	DG(AE)	DG(AE);S	Chick
1055-04822	8/8/2008	CALO - NCB - Mile 8.9	DG(AH)	DG(AH);S	Chick

Key. DG = Dark Green, LG = Light Green, GF = Green Flag, DB = Dark Blue, LB = Light Blue, RD = Red, OR = Orange, YE = Yellow, WH = White, BK = Black, S = USFWS band, - = No Band, ; = separator for upper and lower legs, / = separator for two bands on the same part of the leg, (##) = engraved code on a band.