

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

2007 Annual report

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Radio-tagged oystercatcher chick hides on a shelly flat on Cape Lookout National Seashore.

## Abstract

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 are: (1) understanding the factors affecting American Oystercatcher nesting success in North Carolina, (2) developing population models that incorporate human and natural influences on population trajectories, and (3) understanding migration and dispersal using mark-recapture methods.

Nest success 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. Nesting success was highly variable, but overall success (25.5%) was low. 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 they spent less time hiding in the dunes. Cats and ghost crabs were identified as the primary predators during the nestling stage. Major storm events are also a significant factor affecting reproductive success. Nesting success increased by 400% on some islands after Hurricane Isabel struck the Outer Banks in 2003. The storm improved nesting habitat and reduced mammalian predators on islands in the direct path of the storm. 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.

We developed a demographic model that used estimates of annual fecundity, mark-recapture data from our research in North Carolina, and parameter estimates from the literature to project the effects of periodic hurricanes on Oystercatcher populations over time. The majority of our model projections indicate a declining population. 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.

We have banded 309 individually color-marked American Oystercatchers in North Carolina since 1999. Resight studies have estimated annual adult survival of 92% and an age of first breeding estimate 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. We are currently analyzing our mark-recapture database to understand the migration and dispersal strategies of birds in different age classes.

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## **Introduction**

In 1995 a study of breeding American Oystercatchers was initiated on Cape Lookout National Seashore to examine factors affecting nesting success. 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 research to date on Cape Hatteras and Cape Lookout, as well as data from islands in the Cape Fear area managed by North Carolina Audubon.

During the 2007 summer field season we monitored all nesting pairs on both Seashores and continued a long term band-resight study designed to estimate return rates of breeding adults and document natal fidelity and age of first breeding of subadult oystercatchers. We concluded a multi-year radio telemetry and behavioral study designed to identify the factors affecting survival of chicks prior to fledging.

American Oystercatchers 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. 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.

The human population density increases along the Atlantic seaboard, and the rate of growth is expected to increase substantially, particularly in the southeastern states (Crossett et al. 2004). At the same time, recreational use of the coastal zone is on the rise. Many visitors to the

coast seek out undeveloped beaches. As coastal islands and beaches are developed, more visitors are concentrated onto the remaining undeveloped areas. Coastal development, recreational activity, and altered predator communities have seriously reduced the amount of suitable nesting habitat for American Oystercatchers in North Carolina. Shoreline development affects the availability of foraging habitat as well. Oystercatchers nest at higher densities and fledge more chicks when they have direct access to foraging areas (Nol 1989; Ens et al. 1992). Roads and artificial dunes along nesting beaches can limit access to sound-side marshes and flats that are important foraging habitats for 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.

American Oystercatchers are listed in both Georgia and Florida as “threatened”, and proposed as a “species of special concern” in North Carolina (J. Gerwin, pers. comm.). A recent 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).

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 Benedict 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 U. S. (Davis 1999, Mawhinney and Benedict 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.

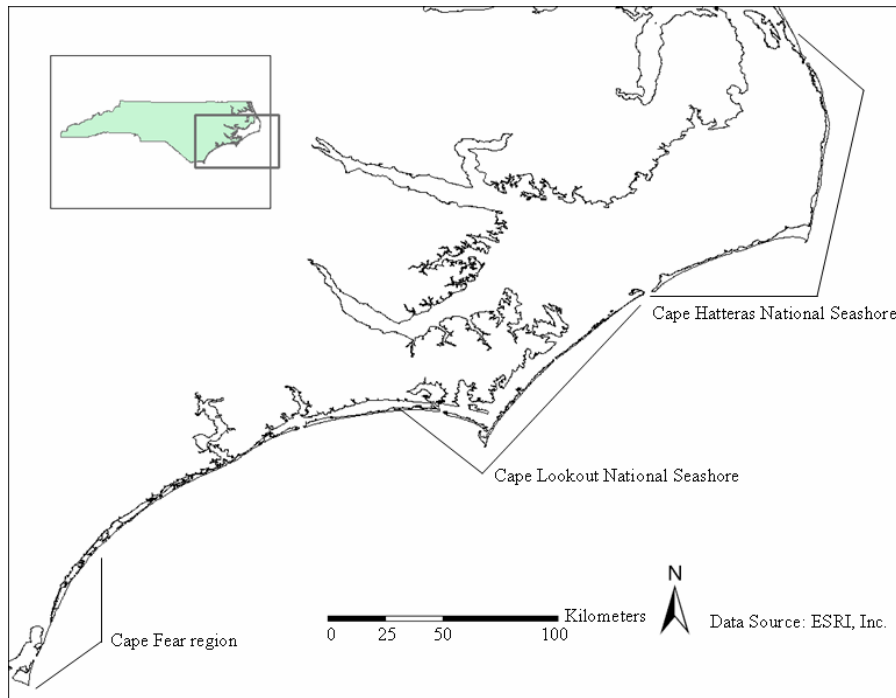
The objectives of our research are:

- 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 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 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 herodias*). 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 1.** American Oystercatcher study sites in North Carolina.

## **Nesting success**

### *Introduction*

A study of oystercatcher nesting success was initiated on South Core Banks, Cape Lookout National Seashore in 1995, and on North Core Banks in 1998. Nest monitoring began at Cape Hatteras National Seashore in 1997. The scope of oystercatcher nest monitoring in the state expanded 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 in 1997 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 have supported the conclusion that mammals are the primary nest predator, but they also suggested an interaction between human disturbance and nest predation rates (McGowan 2004, McGowan and Simons 2006).

### *Methods*

#### *Nest Monitoring*

Surveys of breeding Oystercatchers on the Outer Banks begin in early April. Nests are located by walking or slowly driving along the barrier beach and back-road system. When an adult Oystercatcher is located, observers watch for behavioral cues that indicate the bird has 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 is observed, scrapes are found by

following the tracks of the adult birds, or by systematic searches. Once located, nests are 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 is recorded with a handheld GPS. Nests are checked every 1-4 days until hatching or failure. We make 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 is considered active and it is only checked to determine if chicks have hatched. We avoid walking directly to sites, and spend a minimal amount of time in the vicinity of the nest to minimize cues for predators. If a nest fails, we attempt 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 is not always possible to determine the causes of nest failure.

### *Data Analysis*

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 hatch (Nol and Humphrey 1994). To obtain nest survival probabilities we raised estimates of daily survival rates (DSR) to the 27<sup>th</sup> 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 1487 nests monitored from 1995-2007. We used 1255 nests in the Program Mark analysis because data for some nests were not collected in a manner consistent with the Program Mark format.

### *Results*

Overall observed hatching success from the beginning of egg laying through hatching for all years was 0.299 (S.E. 0.012), and ranged among sites and years from 0.0 to 1.00 (Appendix 1). In other words, 29.9% of the nests we monitored 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 0.950 (95% CI = 0.947, 0.953). The probability of a nest surviving to hatching was  $0.950^{27} = 0.251$  (95% CI = 0.228, 0.274), which means that an estimated 25.1% 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.

Hatching success was highly variable among years and locations. Model results showed

that daily 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 daily survival rate confidence intervals for the three sites did not overlap, indicating significant differences in daily survival among the three major sites (Table 1). 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.** Daily survival rates for nests at three study sites in North Carolina.

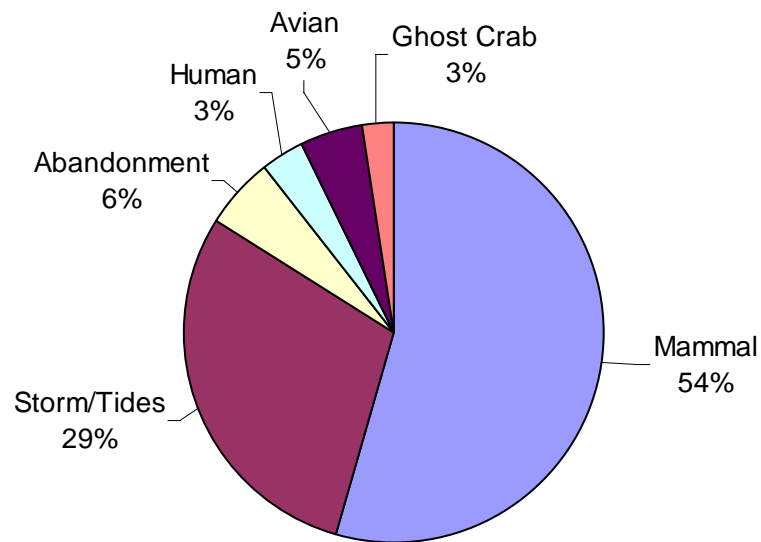
Site	Daily Survival Rate	Standard Error	95% CI	Nests
Cape Lookout (1997-2007)	0.940445	0.002363	0.935642-0.944910	800
Cape Hatteras (1999-2007)	0.959205	0.002821	0.953717-0.964118	371
Cape Fear (2002-2003)	0.971861	0.003588	0.963907-0.978102	113

#### *Sources of nest failure*

Mammalian depredation was the major identifiable cause of nest failure at our study sites from 1995-2007, accounting for approximately 54% of identifiable causes of nest failure (Figure 2). 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 2). We could not identify the causes of failure for 52% of failed nests because 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 water erased any clues of the causes of failure.

Raccoons are the primary mammalian predator on our study sites, and the presence or

absence of raccoons has a dramatic effect on daily nest survival rates. Nests on islands with raccoons had a 0.946 (S.E. 0.0019) daily survival rate (38.8% overall survival), while nests on islands without raccoons had a 0.966 (S.E. 0.0030) daily survival rate (22.3% overall survival). The confidence intervals for the two groups did not overlap, indicating that the daily survival rate for nests on islands without raccoons was significantly greater than on islands with raccoons.

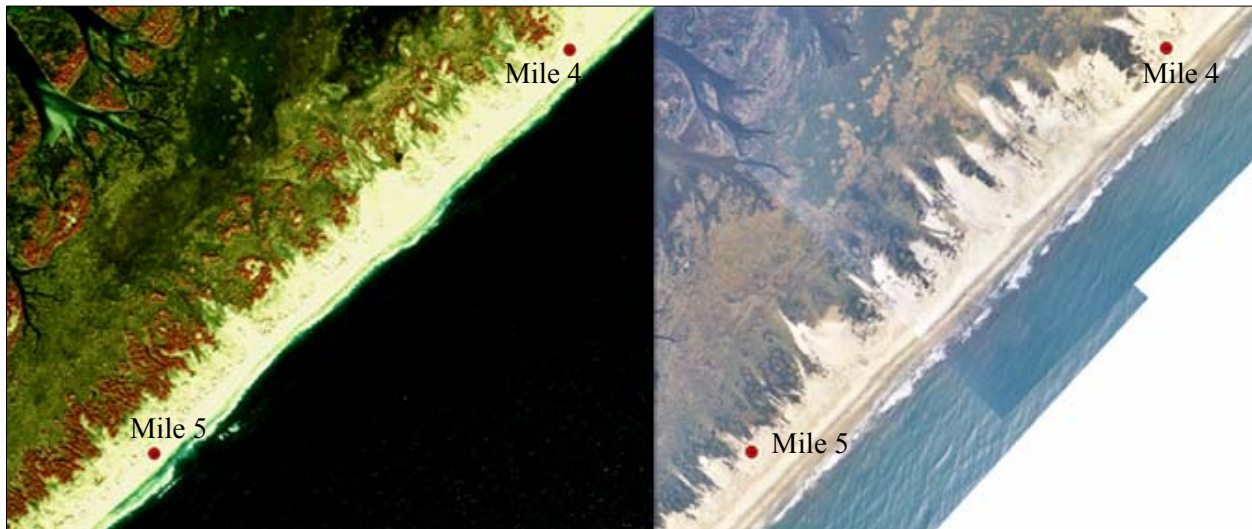


**Figure 2.** Causes of American Oystercatcher nest failure on the Outer Banks (1995-2007) and the Cape Fear River estuary (2002-2003) in North Carolina where cause of failure could be determined (N=478). Cause of failure could not be determined for 52% of nest failures (N=518).

Foxes were also an important nest predator on Cape Hatteras National Seashore. The daily nest survival rate on Hatteras Island fell from 0.952 (26.5% survival) in the period 1999–2001 to 0.878 (3.0% survival) in 2002, after foxes colonized the island. The daily survival rate increased again to 0.975 (51.0% survival) from 2003-2007 after control measures were initiated and Hurricane Isabel altered habitats on the Outer Banks.

### *Modeling Hurricane Effects*

On September 18<sup>th</sup> 2003, Hurricane Isabel struck the Outer Banks of North Carolina as a category two hurricane with winds of 156-166 kph and an eight foot storm surge (Bevin and Cobb 2004). This hurricane substantially altered the physical structure of parts of the barrier island chain, flattening dunes and opening wide overwash flats (Figure 3). Dune breaks and overwash flats are used by many beach nesting bird species, including American Oystercatchers.



**Figure 3.** A section of Cape Lookout National Seashore in 1998 (left) and 2004 (right) showing the overwash and dune loss caused by Hurricane Isabel in 2003. NPS mile markers are shown as reference points.

Demographic modeling based on mark-recapture and nest survival data in North Carolina projects a high risk of population decline over the next two decades in the absence of immigration or periodic “bonanza” years with increased fecundity (Schulte et al. in prep). Following Hurricane Isabel oystercatcher nest survival on North Core Banks, Cape Lookout National Seashore increased in 2004 to 450% of the average rate before the storm. We developed a set of hypotheses to explain the change in nest survival and monitored nesting on the island through 2007 to track productivity in the years following the initial habitat change.

Hypothesis 1 (Null hypothesis): Changes in nest survival were a result of normal inter-

annual variation and there was no specific hurricane effect.

Hypothesis 2: Oystercatcher pairs shifted territories to take advantage of the expansion and creation of new sand flats, resulting in increased nest survival.

Hypothesis 3: Hurricane Isabel reduced predator populations, resulting in increased survival of oystercatcher nests.

We modeled nest survival for each year to identify temporal and spatial variation across the study area. We compared five alternative models in Program Mark (White and Burnham 1999) to test for the presence of four proposed hurricane effects:

- 1) A single year burst of productivity, followed by a return to the pre-hurricane level.
- 2) A sustained increase in nest survival following the hurricane.
- 3) A single year burst of productivity followed by a one-year carryover effect (intermediate survival) before nest survival returned to pre-hurricane levels.
- 4) A single year burst of productivity followed by a two-year carryover effect (intermediate survival) before nest survival returned to pre-hurricane levels.
- 5) A year-effects model with separate parameters for each year.

The effects of the hurricane were not uniform across the study area. South Core Banks did not show a strong effect of the hurricane on nesting success. Approximately 84% of the model weight supported model five, the year effects model, suggesting that changes in nest survival were explained best by normal inter-annual variation. On North Core Banks the best model (86% of model weight) supported model four which included a hurricane effect and a separate parameter to allow for a two year carryover effect on nesting success after the initial impact. This result supports a strong hurricane effect on North Core Banks.

On Ocracoke Island of Cape Hatteras National Seashore there was some support for all

four hurricane models, with most of the support (46% of model weight) for model one, the single year impact model. On Hatteras Island the results were directly opposite. There was strong support for the year effects model (86% of model weight) and very little for any of the hurricane models.

At North Core Banks, the site with the hurricane effects, nest survival increased in all habitats following the hurricane, but the largest increase was in the dune habitat. The survival probability for nests in dunes increased from 0.121 prior to Hurricane Isabel, to 1.00 in 2004 (Table 2). Oystercatcher pairs also shifted habitats in 2004 following the hurricane. Pairs moved away from beach nesting sites and onto large and small flats. The percentage of birds nesting on small flats, the most productive habitat type, doubled in 2004 to 31% (Table 3).

**Table 2.** Nest survival by habitat type on North Core Banks, Cape Lookout National Seashore.

Year	Beach	Large Flat	Small Flat	Dunes
1999-2003	0.178	0.156	0.233	0.121
2004	NA	0.888	0.441	1.00
2005	0.208	0.316	0.822	0.272
2006	0.409	0.556	0.502	0.033
2007	0.010	0.174	0.340	0.335

**Table 3.** Percentage of nests in each habitat on North Core Banks, Cape Lookout National Seashore.

Year	Beach	Large Flat	Small Flat	Dunes
1999-2003	23%	31%	16%	30%
2004	0%	42%	31%	27%
2005	7%	7%	41%	45%
2006	19%	15%	48%	19%
2007	9%	12%	37%	42%

## *Discussion*

Hatching success is highly variable, but generally very low for American Oystercatchers in North Carolina. Our data show binomial models overestimate hatching success because some nests fail and are never found. Mammalian depredation is the primary source of American Oystercatcher nest failure. Raccoons accounted for most nest failures at Cape Lookout, while foxes, feral cats, and raccoons were important predators at Cape Hatteras. Daily nest survival rates over the course of the study were significantly greater on islands without raccoons.

Models of the effects of Hurricane Isabel reveal some very interesting patterns. Hurricane Isabel came ashore at Ocracoke Inlet, NC. Although significant hurricane damage was evident from New Drum Inlet, Cape Lookout, to Cape Point, Cape Hatteras, not all American Oystercatcher populations were affected in the same way. Ocracoke Island, which was directly northeast of the center of the hurricane only showed a mild, single year hurricane effect. This is likely because Ocracoke was already free of raccoons (*Procyon lotor*). This island typically had the highest success rate of any on the Outer Banks even before the hurricane, so the new habitat opened up by Isabel was less important to birds nesting on this island. In addition, much of the new habitat was quickly eliminated as the main road was cleared and the artificial dunes rebuilt over the course of the summer of 2004. This may explain why there was only a single year increase in productivity on this island.

North Core Banks, just to the south of the eye of the hurricane, showed the strongest hurricane effect. The best model was a three parameter model that allowed for a partial decline in nest survival following a year of high productivity directly after the storm. Much of North Core was overwashed during the hurricane. Several large flats and numerous small flats were opened up, and the dunes were flattened in many areas (Figure 3). Oystercatchers apparently

shifted their nest sites to take advantage of these new habitats. In the year after the hurricane the percentage of nests on large and small flats (the most productive habitat types) jumped from 47% to 73%. This habitat shift alone does not explain the high success. Nesting success was up in all habitats after the storm, but most notably in the dunes. From 1999-2003 very few dune nests survived. We often observed raccoon tracks following the dune line where nests were typically arrayed in a line and easy to find. In 2004 this habitat showed the same high success rate as the other types, and then started to drop again in 2005 and 2006. These results suggest a substantial decline in predator abundance following the hurricane. If predator populations were unaffected by the storm we should have only seen a modest increase in nesting success as birds experienced the benefits of nesting in the flats. The fact that nests in dunes also survived suggests that there were very few predators patrolling the beaches. Although we do not have reliable estimates of predator abundance for any year of the study, raccoon and feral cat (*Felis catus*) tracks were seen daily on North Core Banks through 2003, while they were very rare in 2004 and still uncommon in 2005. By the 2007 field season cat and raccoon tracks and sightings were commonplace again, and there was a corresponding increase in nest predation.

South Core Banks was relatively unaffected by Hurricane Isabel, particularly toward the south end of island. South Core Banks was not in the direct path of the storm, and the island is wider and higher at the south end, and a maritime forest that could have served as a refuge for predators during a hurricane. Some flats were opened up near the north end of South Core, but not to the extent that occurred on North Core Banks. Thus, it seems likely that the bulk of the predator population survived on South Core Banks.

Our model results did not show a hurricane effect for Hatteras Island. Hatteras hit hard by Hurricane Isabel, and the storm broke through the island near the town of Hatteras Village.

However, this habitat alteration had very little effect on nesting birds, because the inlet was filled in and dunes rebuilt before the start of the 2004 nesting season. In addition, nesting success was extremely variable, even before the storm. The Park Service initiated a predator control program in the spring of 2003, which continued through 2007. This program is apparently benefiting oystercatchers, because nest survival averaged 51% from 2003 through 2007, up from 3% in 2002 when foxes initially colonized the island.

The number of nests on Bodie Island was too small to draw any meaningful conclusions, but this area is heavily populated with raccoons and foxes during the breeding season, and it also receives very high numbers of visitors. These factors substantially limit oystercatcher productivity on this island in most years.

It appears that periodic hurricanes can benefit oystercatcher nesting success by creating new habitats and reducing predator populations. Following hurricanes periodic "bonanza" years may be very important to long term oystercatcher population dynamics. Our demographic models suggests that periodic reproductive bonanzas can offset or reverse population declines caused by chronic predation and limited breeding habitat. Human activity can depress or enhance the effects of the hurricane. On parts of Ocracoke Island and Hatteras Island, much of the new habitat created by the storm was quickly removed as new artificial dunes were created to protect the main road. This negated the benefits of the storm for oystercatchers in these areas. Conversely, predator removal efforts following a hurricane may extend the period of high oystercatcher productivity for several additional years. A study of the raccoon population on South Core Banks, Cape Lookout is currently underway (see Simons and Waldstein 2008) and should be very helpful in understanding how predators and predator removal affect oystercatcher productivity on the barrier islands.

## **Oystercatcher Chick Survival**

### *Introduction*

The sources and timing of mortality are very difficult to determine for precocial shorebird chicks. Chicks often leave the nest within a few hours of hatching, after which they are cryptic and highly mobile. If a chick is 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 2005, 2006 and 2007 we used radio telemetry to monitor chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore to understand the factors affecting chick mortality.

### *Methods*

Chicks were radio marked 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 4). 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 5).



**Figure 4.** Recently hatched American Oystercatcher chicks. Lower chick is wearing a radio transmitter.



**Figure 5.** 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. Photo by Pat Leary.

We monitored chick survival at Cape Hatteras and Cape Lookout with the same protocols used in previous years. When a nest hatched, the young were checked every 2-4 days until fledging, or until all the chicks died or disappeared. With careful monitoring it was possible to determine annual fecundity, or the number of chicks fledged per pair, although not 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 different alarm calls. It was usually 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 if necessary a portable blind. On the rare occasion that a non-radio-tagged chick was found dead, we attempted to determine the cause of death. We calculated overall fecundity by dividing the number of chicks that survived to fledging by the number of breeding pairs for each year for each location.

### *Results*

We estimated fecundity from 1487 nesting attempts monitored over 13 years. Fecundity was highly variable among years and among locations (Appendix 1). A total of 310 chicks fledged from all study sites between 1995 and 2007. On average, 0.32 chicks fledged for every nesting pair and 0.21 chicks for every nesting attempt. Within 24 hours of hatching, adults begin bringing their chicks to the waterline to forage. Broods ranged up and down the beach from their nest site, often moving 500 meters or more each day. This pattern continued throughout the chick-rearing stage. At night, chicks were always located at the waterline or on the open beach. During the day chicks spent most of their time hiding in the dunes, particularly in areas open to vehicles.

Prior to this 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 vehicle tracks. From 1995 to 2007, 18 chicks were found killed by vehicles (9 on Cape Hatteras and 9 on Cape Lookout. This number is only a fraction of the total number of chicks killed by vehicles during this time, as dead chicks were located by chance in most cases and many chicks died and were never found. 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 6).

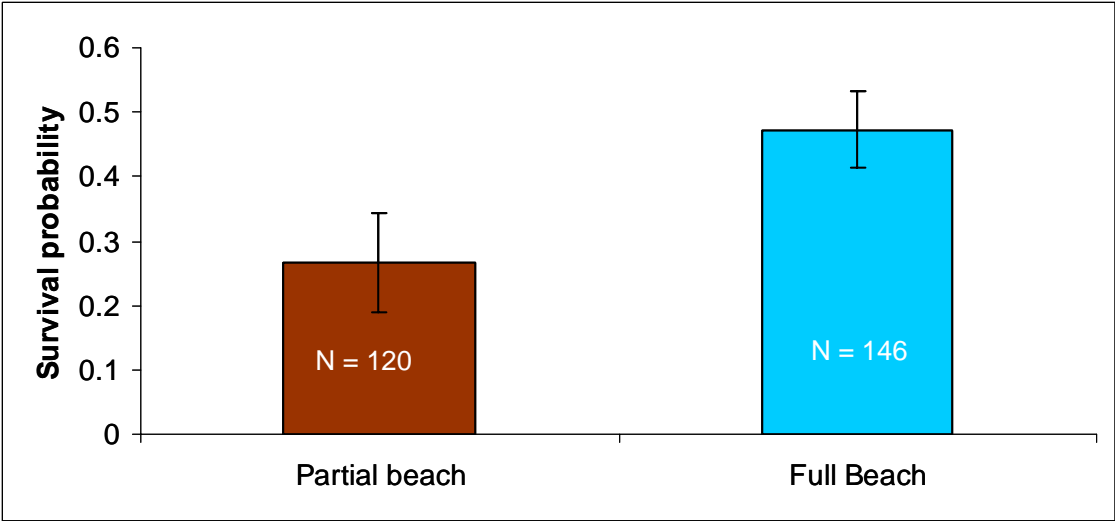


**Figure 6.** Radio-marked oystercatcher chicks crushed by a vehicle June 16 2005, Cape Lookout National Seashore.

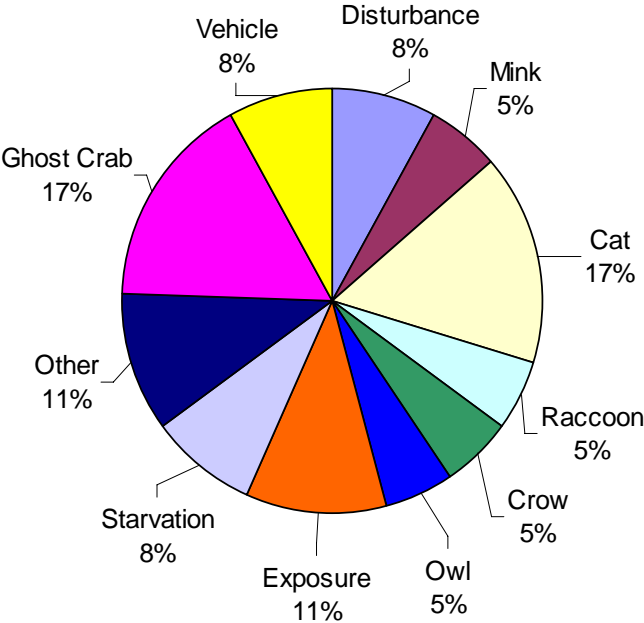
On 23 May 2006 two three-day old chicks near Hatteras inlet on Cape Hatteras National Seashore died of exposure and depredation after their parents were disturbed by vehicle traffic after dark. The parents brought the chicks down to the tideline at sunset and were subsequently disoriented and frightened 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 while the

parents were gone. 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 all highlight how vulnerable shorebird chicks are to vehicle traffic.

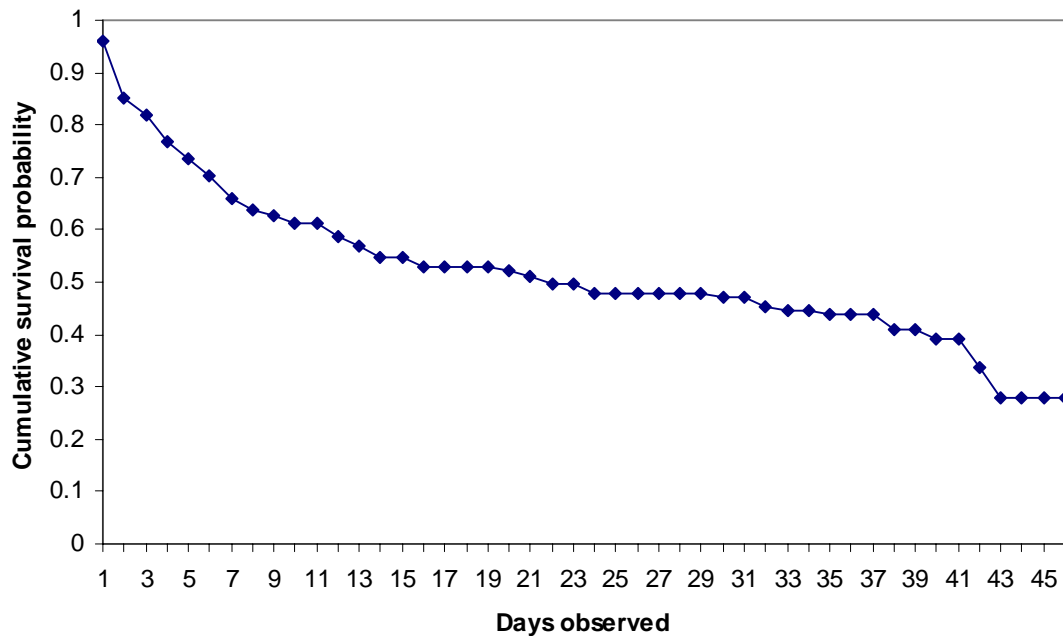
Since 1999, 47% of chicks in full beach closures on Cape Hatteras survived to fledging, while 27% survived when the beach had an open lane for vehicles and pedestrians (Figure 6). By radio tracking oystercatcher chicks on North Core Banks and Hatteras Island, we were successful in determining sources of mortality for many chicks that did not survive to fledging (Figure 7). 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*). Human activity (vehicle collisions and disturbance) was 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 8). Even with the radio tags we were unable to determine the cause of mortality for 51% of the chicks that died. Typically when this occurred both the chick and transmitter disappeared.



**Figure 7.** Chick survival by closure type on Cape Hatteras National Seashore from 1999-2007



**Figure 8.** Identified causes of pre-fledging American Oystercatcher chick mortality at Cape Hatteras and Cape Lookout National Seashores (N=37). Source of mortality could not be determined for 51% of chick deaths (N=39 chicks).



**Figure 9.** 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.

Despite high hatching success for the Cape Fear River nests (Appendix 1), the number of chicks that survived to fledging in 2002 and 2003 was very low. Overall, only 13 chicks of the 68 chicks that hatched on the Cape Fear River islands survived to fledging. Lea and Hutaff Island had very high hatching and fledging success in 2003. Data for nests on the Cape Fear River and Lea and Hutaff islands were not available for 2004, and 2005, 2006, and 2007 data are still pending from North Carolina Audubon.

## *Discussion*

Our estimates of fecundity generally tracked our estimates of nesting success. In 2004, North Core Banks had the highest fledging success of any site or year previously recorded in North Carolina (1.4 chicks/pair Appendix 1). Oystercatcher fledging success rates this high have only been recorded on a few predator free islands off the Virginia coast (Wilke and Watts 2004).

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 sources of mortality. 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 are most vulnerable during the first week after hatching when they are susceptible to exposure and ghost crab depredation (Figure 8).

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.

Chick survival and behavior was influenced by management policies. Overall chick

survival was almost twice as high in full beach closures on Cape Hatteras as in areas open to vehicle traffic. 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. No additional deaths from vehicle traffic have been documented on Cape Lookout since this policy went into effect. 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. 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. One chick was killed by a Park Service vehicle surveying for turtle nests, but overall fledging success was fairly high at 0.5 chicks/pair for the park.

## **Oystercatcher Chick Behavior**

### *Introduction*

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. Previous 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 vs. partial beach closures).

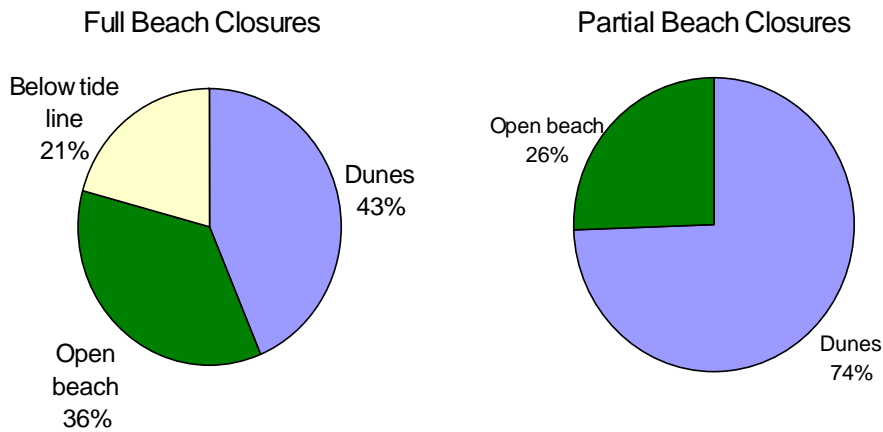
## *Methods*

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 tell which habitat they were in. 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 and at all times of the day and 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.

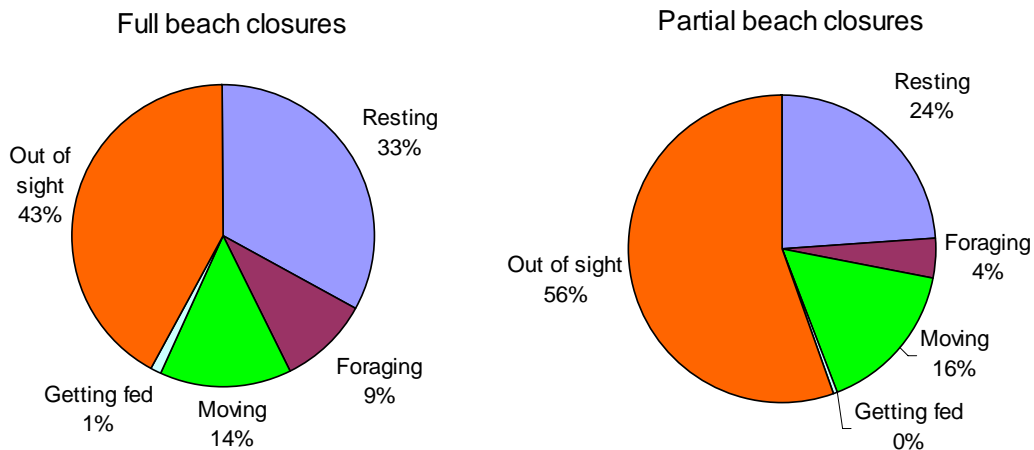
## *Results*

We conducted 160 hours of observation of chicks on Cape Hatteras National Seashore over four years. Over 90% of the observations were of chicks in full-beach closures because most of the locations where chicks hatched were subsequently closed off per 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 10). Chicks with only 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 11). 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 dogs on the beach than to humans alone. We did not document any dog-related mortality, but dogs were observed chasing adult oystercatchers on several occasions.



**Figure 10.** 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 11.** 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

Night observations of Chicks on Hatteras and Lookout invariably found the broods on the open beach or below the tide line on both open and closed sections of beach. Parents always brought their chicks to the beach around sunset. Oystercatchers of all ages become disoriented by bright lights and will walk, run or fly toward the light source at night. We observed adult oystercatchers on open sections of the beach become disoriented by headlights and leave the chicks until the vehicles had passed. In most cases the adults returned to the chicks, but in at least one case the adults were kept away by multiple vehicles passing, which resulted in the deaths of the young chicks.

### *Discussion*

These data indicate that human and vehicle disturbance of oystercatcher broods produces measurable differences in chick behavior, habitat use, and 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.

## **American Oystercatcher Demography and Annual Movement Patterns**

### *Introduction*

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).

### *Model development*

We developed a demographic population model for American Oystercatchers to assess the status of the species in North Carolina. Our goals were to

- 1) Examine the dynamics of the American Oystercatcher population in the state and assess the impacts of hurricane events
- 2) Identify the most critical data needs
- 3) Calculate the relative effect of different vital rates on population growth and identify where management actions could be most effective.

We constructed a three-stage matrix model with juvenile (post-fledging), subadult (non-breeding), and adult (breeding) stages. The model used five demographic parameters; fecundity ( $F$ ), adult survival ( $S_a$ ), subadult survival without transition ( $S_s$ ), subadult transition to adult ( $T_{sa}$ ), and juvenile survival ( $S_j$ ).

After developing a baseline model, we used alternate parameter sets to evaluate the effects of periodic fecundity bonanza years at different occurrence frequencies. We compared the outcomes from each model using the finite rate of population increase, or lambda ( $\lambda$ ) and projected the population trajectory over 50 years as an average of 1000 model runs.

To simulate the bonanza effect of a hurricane year, we created a new stochastic matrix with elevated mean fecundity corresponding with the observed increase after the changes made by Hurricane Isabel in 2003 (Schulte et al. in prep). 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 generally 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).

The initial population size for the model was set using the most recent estimate of breeding adults in North Carolina. A 2007 statewide survey found 677 breeding adults (Cameron and Allen 2007). Based on a stable age distribution in which adults comprise 70.2% of the total population, the initial population size was set at 963 individuals ( $676/0.702$ ).

### *Results*

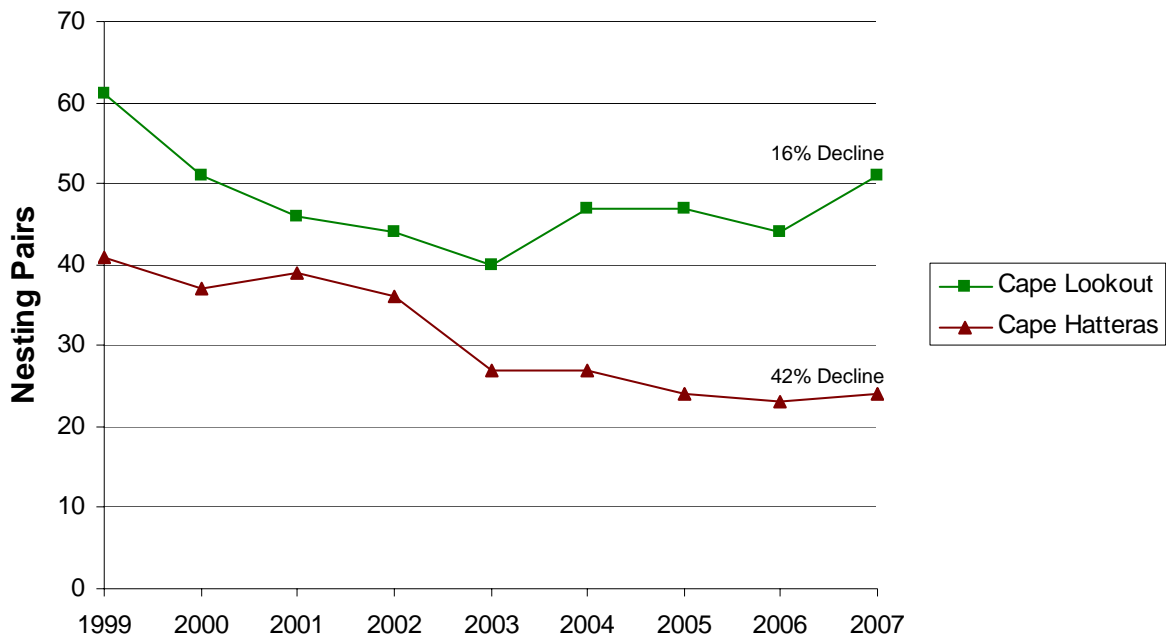
The baseline population model indicates a rapidly declining population. The finite rate of population increase ( $\lambda$ ) for the baseline model was 0.988, which indicates a 45% population decline over 50 years. An average hurricane effect frequency of 15 years, increased  $\lambda$  to 0.999 and led to only a 2% population decline, or a roughly stable population. With a hurricane frequency of 10 years,  $\lambda$  increased to 1.0048 and resulted in a 27% increase in the population over 50 years.

As expected for a long lived species with a low reproductive rate,  $\lambda$  was much more

sensitive to adult survival than any other parameter. After adult survival,  $\lambda$  was also sensitive to changes in fecundity, and to a lesser extent, subadult survival and transition. Changes in juvenile survival had relatively little effect on  $\lambda$ .

### *Discussion*

Under the baseline model, the American Oystercatcher population in North Carolina declined rapidly. Without periodic years of high productivity, the population could not sustain itself. We ran the models over 50 years, or approximately two oystercatcher life spans (Safriel et al. 1984). Only the most optimistic model (10 year hurricane events) projected a population increase. Nevertheless, hurricanes clearly could play an important role in sustaining populations. American Oystercatchers may have a life history strategy of maintaining a minimal annual fecundity and then taking advantage of periodic bonanza years when predator numbers are low and habitat and food resources are optimal. Our projections from the baseline model are consistent with the overall decline in breeding pairs observed on Cape Hatteras and Cape Lookout National Seashores. Oystercatcher pairs on Cape Lookout have declined 16% since 1999 and have declined by 42% over the same period on Cape Hatteras (Figure 12). Although this area was struck by a hurricane during the study period, oystercatcher populations on the outer banks continued to decline. Our models assumed an equal effect over the entire study area, but the effects of Hurricane Isabel were limited to about 40km of coastline out of 160 for the entire study area.



**Figure 12.** American Oystercatcher nesting pairs on Cape Lookout and Cape Hatteras National Seashores from 1999 to 2007.

Human actions can alter the effects of hurricane years. Our models assumed that a hurricane strike would result in the fecundity bonanza equal to the one we observed on Cape Lookout in 2004 (Schulte et al. in prep). The increased productivity is actually a result of reduced predators and improved or expanded habitat, so any actions that mitigate these changes would also reduce or eliminate the positive effect of the storm. In 2004, much of the new habitat created by Hurricane Isabel was quickly altered or eliminated as roads and artificial dunes were rebuilt. Oystercatcher fecundity and total nesting pairs in these areas the following year was much lower than similar areas on Cape Lookout where the natural sand movement was unaltered. 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.

Resource management actions can affect fecundity and to a lesser extent, subadult to

adult transition rates. Fecundity is reduced by nest predation, disturbance, and storm overwash during the breeding season (Nol and Humphrey 1994, Davis et al. 2001, McGowan et al. 2005a Wilke et al. 2005). Increases in fecundity can be obtained through predator population management, while public education and protection of nesting areas will alleviate the effects of human disturbance. Increasing available habitat to would open new potential breeding sites and increase recruitment rates. This is somewhat more difficult than managing fecundity, but still feasible. Protecting current nesting habitats and the creation of new habitats through dredge deposition or natural processes will foster population growth.

Our population model is also useful for estimating the probability that a population will decline, go extinct, or increase over time given assumptions about population size and vital rates (Akçakaya et al. 1999, Mace et al. 2001, Lande 2002). Additionally the model can be used to test the sensitivity of the population to each demographic parameter (Akçakaya et al. 1999, Mace et al. 2001, Lande 2002). These analyses provide a useful framework for assessing the relative costs and benefits of various management options for American Oystercatchers on the Outer Banks of North Carolina. Results indicate that American Oystercatcher populations are most sensitive to changes in adult survival and high variability in annual fecundity.

### **Cooperative Research**

Interest in American Oystercatcher research is increasing. In addition to the work in North Carolina, there are color-banding projects in Massachusetts, New Jersey, Virginia, South Carolina, and Georgia. All researchers working with American Oystercatchers have agreed on a uniform banding and reporting scheme. In 2004 a large scale coordinated resighting effort was initiated to expand and standardize previous which were largely ad hoc and opportunistic. A central database of all banded oystercatchers and resightings is now maintained at North

Carolina State University. The database includes 1243 marked oystercatchers and close to 5000 individual resights. We are currently using data from this coordinated resighting effort to estimate key demographic parameters, including survival and transition rates for each age class. Using these estimates we hope to generate much more accurate population models than are currently available. Better population models are important for assessing the effects of management actions and projecting future population trends.

Communication among scientists, and managers involved in American Oystercatcher research is facilitated by a website maintained at NCSU (<http://www.ncsu.edu/project/simonslab/AMOY/Research.htm>). The site contains information on current American Oystercatcher research and monitoring efforts in North America. Sightings of banded birds are reported through this site and added to the central database. The site has proven to be an excellent tool for public education and involvement.

### *Banding and Resighting*

Adult birds are captured using a decoy and noose carpet method developed at NCSU (McGowan and Simons 2005b). A remote-controlled decoy and song playback device is used to lure territorial breeding oystercatchers to a bal-chatri type noose carpet (Berger and Mueller 1959, Bub 1991). We mount the decoy on a wooden box containing two radio-controlled servomotors. The motors and controller were adapted from a standard model airplane remote control kit available at many hobby shops. One servomotor turns the decoy from side to side. The second servomotor activates a mercury tip switch that controls an amplified speaker and mp3 player with oystercatcher territorial calls. The device allows us to move the decoy and play calls at will. The noose carpets are made out of four-foot by one-foot panels of one-inch by one-inch welded wire fencing. Each panel is covered with hundreds of slipknot “nooses” tied from

50 lb. test clear fishing line. The panels are staked down and covered with one to two inches of sand so that the nooses protrude out of the sand. We place several panels around the oystercatcher decoy in the middle of an active oystercatcher territory (Figure 13). Placing the decoy in an active breeding territory stimulates the resident pair to display to and attack the decoy as if it were a real intruder. The birds tangle their feet in the slip-knot nooses as they approach the decoy.



**Figure 13.** Our mechanical decoy and noose carpets.

We now use a cast resin oystercatcher decoy made by Mad River Decoy (Figure 14). This decoy is much more durable than previous foam and light wood versions and holds up to the rigors of the field season. We are most successful trapping birds just prior to egg laying when they are courting and making nest scrapes, although the method works well throughout the nesting season.



**Figure 14.** American Oystercatcher attacks the cast resin decoy.

We successfully trapped 105 breeding adults from 2002 through 2007 using this 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. Chicks are captured by hand shortly before fledging. A total of 309 individual oystercatchers have been banded in North Carolina since the banding project began in 1999 (112 adults, 197 chicks Appendix 2).

Captured adults and chicks were originally marked with steel USFWS bands and combinations of Darvic color bands (Figure 15). 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 15). 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 15.** American Oystercatchers banded with old (left) and new (right) banding schemes. Photos by Diana Churchill (left) and Pat Leary (right).

Eighty-five individual birds banded in North Carolina have been resighted on their wintering habitats from Virginia to the Gulf Coast of Florida (Figure 16). Many reports are from Cape Romain National Wildlife Refuge, SC where up to 20% of the oystercatcher population in North America winters. We conduct systematic wintering surveys for banded birds and coordinate with other banders and observers up and down the east coast to build the comprehensive banding database. This project has generated a lot of interest in the birding community. A chick banded near Buxton Village in 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 Fort 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. At least six other Oystercatchers that hatched in 2001 and 2002 returned to the Outer Banks in the summer of 2004. None of these birds nested,

but several were observed exhibiting territorial behavior and fighting with resident adults (McGowan et al. 2005c). 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 banded American Oystercatcher chick returning and successfully nesting. Since then, four other chicks have returned to nest on Cape Hatteras and Cape Lookout. Overall, 38% of banded chicks returned to nest on Cape Hatteras and Cape Lookout. Overall, 38% of banded chicks returned to the breeding grounds by their second or third year. This is very likely an underestimate of the total survival of banded chicks because many may remain on the wintering grounds for several years or disperse to other sites (Goss-Custard et al. 1982).



**Figure 16.** Winter resightings of American Oystercatchers banded in North Carolina.

The color banding 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. Observations of returning subadults led to a preliminary estimate of the age of first breeding at 3.89 years (S.E. 1.05). 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).

Partnerships and coordination among researchers and land managers are critical to filling the gaps in our current knowledge of oystercatcher populations. Continuing cooperative large-scale banding efforts will be important in developing and refining estimates of survival, dispersal, and migratory patterns in oystercatchers necessary for ongoing effective management.

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## Appendices

### Appendix 1: American Oystercatcher productivity in North Carolina from 1995-2007

Year and Location	# of breeding pairs	# of clutches	# of nests hatched	Nest survival observed (SE)	Nest survival Mark (SE)	No. of chicks fledged	Fecundity (Chicks fledged/ breeding pair)
<b>CAPE LOOKOUT</b>							
<b>North Core Banks</b>							
1998	32	72	5	0.069	NA	4	0.13
1999	33	61	11	0.180	0.170	5	0.15
2000	29	36	7	0.194	0.248	1	0.03
2001	22	52	11	0.212	0.173	2	0.09
2002	22	46	5	0.109	0.089	5	0.23
2003	19	37	7	0.189	0.157	2	0.11
2004	22	25	20	0.800	0.736	33	1.50
2005	16	20	11	0.550	0.453	6	0.38
2006	15	18	8	0.444	0.399	5	0.33
2007	17	32	8	0.250	0.191	14	0.82
Island	227	399	93	0.233 (0.021)	0.227 (0.022)	77	0.34
<b>Middle Core Banks</b>							
2004	5	5	4	0.800	NA	7	1.40
2005	7	9	5	0.556	0.511	9	1.29
2006	8	9	6	0.667	0.745	8	1.00
2007	11	11	7	0.636	0.570	10	0.91
Island	31	34	22	0.647 (0.082)	0.604 (0.093)	34	1.10
<b>Ophelia Banks</b>							
2007	2	3	2	0.667	NA	3	1.50
<b>South Core Banks</b>							
1995	20	36	12	0.333	NA	7	0.35
1997	22	34	4	0.118	0.036	2	0.09
1998	28	26	7	0.269	0.135	2	0.07
1999	28	52	5	0.096	0.115	1	0.04
2000	22	39	18	0.462	0.303	8	0.36
2001	24	57	8	0.140	0.158	1	0.04
2002	22	44	5	0.114	0.061	1	0.05
2003	21	59	9	0.153	0.121	6	0.29
2004	20	31	13	0.419	0.279	6	0.30
2005	24	27	9	0.333	0.317	4	0.17
2006	19	31	6	0.194	0.203	10	0.53
2007	21	41	4	0.098	0.073	4	0.19
Island	271	477	100	0.21 (0.019)	0.144 (0.015)	52	0.19
<b>Shackleford Banks</b>							
2004	6	7	0	0.000	NA	1	0.17
2005	9	10	1	0.100	NA	0	0.00

2006	9	11	1	0.091	NA	0	0.00
2007	10	12	0	0.000	NA	0	0.00
Island	34	40	2	0.05 (0.034)	NA	1	0.03

### CAPE HATTERAS

Ocracoke Island							
1996	12	12	8	0.667	NA	8	0.67
1999	15	17	7	0.412	0.321	2	0.13
2000	12	17	6	0.353	0.270	7	0.58
2001	13	15	11	0.733	0.624	17	1.31
2002	12	18	6	0.333	0.266	3	0.25
2003	8	12	4	0.333	0.255	1	0.13
2004	9	11	7	0.636	0.566	8	0.89
2005	5	10	3	0.300	0.295	1	0.20
2006	5	8	5	0.625	0.492	2	0.40
2007	5	12	3	0.250	0.102	1	0.20
Island	96	132	60	0.455 (0.043)	0.341 (0.042)	50	0.52
Hatteras Island							
1997	22	26	13	0.500	NA	8	0.36
1999	24	31	7	0.226	0.287	3	0.13
2000	23	29	10	0.345	0.251	2	0.09
2001	24	28	10	0.357	0.259	6	0.25
2002	21	25	3	0.120	0.030	4	0.19
2003	14	21	8	0.381	0.372	4	0.29
2004	15	18	14	0.778	0.706	9	0.60
2005	17	25	13	0.520	0.501	10	0.59
2006	14	19	11	0.579	0.525	5	0.36
2007	15	23	10	0.435	0.481	9	0.60
Island	189	245	99	0.404 (0.031)	0.349 (0.032)	60	0.32
Bodie Island							
1996	2	2	1	0.500	NA	2	1.00
1999	2	2	0	0.000	NA	0	0.00
2000	2	3	0	0.000	NA	0	0.00
2001	2	3	1	0.333	NA	1	0.50
2002	3	5	1	0.200	NA	2	0.67
2003	5	5	1	0.200	NA	0	0.00
2004	3	7	0	0.000	NA	0	0.00
2005	2	3	1	0.333	NA	0	0.00
2006	2	2	1	0.500	NA	0	0.00
2007	2	2	1	0.500	NA	0	0.00
Island	25	34	7	0.206	0.172 (0.051)	5	0.20

(0.069)

Green Island							
2004	2	3	2	0.667	NA	2	1.00
2005	2	3	2	0.667	NA	0	0.00
2006	2	2	2	1.000	NA	2	1.00
2007	2	2	1	0.500	NA	2	1.00
Island	8	10	7	0.7 (0.145)	NA	6	0.75
CAPE FEAR REGION							
Cape Fear River Islands							
2002	32	48	27	0.563	0.534	6	0.19
2003	34	49	15	0.306	0.367	7	0.21
Island	66	97	42	0.433 (0.050)	0.443 (0.047)	13	0.20
Lea and Hutaff Islands							
2003	16	16	11	0.688	0.617 (0.126)	9	0.56
<b>Total/Mean</b>	<b>965</b>	<b>1487</b>	<b>445</b>	<b>0.299 (0.012)</b>	<b>0.251 (0.011)</b>	<b>310</b>	<b>0.32</b>

## 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	RD;GF/S	DB;OR/DG	Chick

Buxton					
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);-	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	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 (Rocky Island)	DG(M5)	DG(M5);S	Chick
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

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.