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**Subject:** 2010 NCSU American Oystercatcher Research - Annual Reports
**Date:** 03/22/2011 05:06 PM
**Attachments:** NCSU NC AMOY Conservation Initiative 2010 Annual Report Final.pdf
NCSU Overflight Annual Report 2010 Final.pdf

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Hello everyone,

I have attached two recent annual reports summarizing findings from our American Oystercatcher research in 2010. The first summarizes work under the NC American Oystercatcher Conservation Initiative sponsored by the National Fish and Wildlife Foundation, and the second summarizes findings from a study of the effects of military overflights on American Oystercatchers at Cape Lookout National Seashore funded by the US Marine Corps. We would welcome your questions or comments.

Sincerely,

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# Effects of Military Jet Overflights on American Oystercatcher Breeding Behavior and Productivity at Cape Lookout National Seashore

**2010 Annual Report**

**to**

**The U.S. Marine Corps**
**Marine Corps Air Station, Cherry Point, NC**

**3 March 2011**

**by**

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# Summary

As human populations and associated development increase, human-wildlife conflicts are occurring with greater frequency. Anthropogenic noise is an often overlooked and poorly understood source of potential wildlife disturbance. In this study we seek to assess the effects of anthropogenic noise on American Oystercatchers (*Haematopus palliates*) nesting at Cape Lookout National Seashore. The species is listed as a “Species of High Concern” by the U.S. Shorebird Conservation Plan and a “Special Concern” species by the State of North Carolina. Human activities that may disturb nesting birds at Cape Lookout include aircraft overflights, vehicles, watercraft, and recreation. Our study is focused on the effects of various forms of anthropogenic activity on the behavior, physiology, reproductive success, and survival of American Oystercatchers at Cape Lookout. We employ a variety of technologies including; audio recorders to monitor sound levels, video cameras and recorders to monitor oystercatcher behavior and beach activity, and microphones to monitor the heart rates of incubating birds. We are applying new software tools to automate the analysis of both audio and video recordings. We are quantifying the incubating behavior, nest attendance, and heart rate of the incubating birds to assess the relative effects of different forms of human activity. We are also comparing measures of productivity, such as the number of nesting attempts, clutch size, nest survival, number of eggs hatched, chick survival, and chicks fledged per pair to assess the effects on reproductive success.

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# Introduction

Interactions between humans and wildlife are closely linked to human population growth and urbanization, particularly in the coastal zone (Crosset et al. 2004). Anthropogenic noise is a potentially serious form of wildlife disturbance. Management of noise is complex because it can travel great distances and it easily crosses management boundaries, such as those around natural areas like parks, and wildlife refuges. Fewer and fewer natural areas are without the intrusion of human-created noise (Berger et al. 2003).

Aircraft are a significant source of anthropogenic noise, particularly in military operations areas or MOAs (Pepper et al. 2003). A review of overflight effects on National Parks by the National Park Service (NPS) found wildlife behavioral responses such as alert posture; alarm and panic; escape tactics such as flushing, swimming, and diving; altered movement patterns; and abandonment of noise-disturbed habitat (National Park Service 1994). Decreased foraging success and decreased ability to respond to predators were further effects of overflights (National Park Service 1994). Stalmaster and Kaiser (1997) found military helicopter overflights caused increased flushing rates in Bald Eagles, and they recommended restricting these activities in eagle foraging areas. Similar recommendations were adopted for Spotted Owl nesting areas (Delaney et al. 1999). In contrast, low-level F-16 military overflights were found to have no effect on wading bird colony size, establishment, or reproductive success. Some birds showed higher frequencies of alert postures, but often they showed no response (Black et al. 1984). Similarly, nesting Osprey also did not respond to low-flying CF-18 jets (Trimper et al. 1998), and low levels of aircraft were not deemed as a detrimental to waterfowl in North Carolina (Conomy et al. 1998a).

Wildlife occasionally show an initial response to overflight noise, but then habituate to the disturbance. Red-tailed Hawks showed a stronger aversion to helicopter overflights in areas of recently introduced aircraft activity compared to areas where aircraft had been flying for decades (Andersen et al. 1989). Minimal response to jet overflights by Peregrine Falcons and Ospreys was also thought to have been conditioned by prior exposure to jets (Ellis et al. 1991, Trimper et al. 1998). Black Ducks habituated to military jet fly-overs in a few days to few weeks, but Wood Ducks did not, suggesting species-specific responses to overflight noise (Conomy et al. 1998b). Species-specific responses also occurred for Brant and Canada Geese. A greater percentage of Brant flocks (75%) reacted to overflights than Canada Geese flocks (8%) (Ward et al. 1999).

Ellis et al. (1991) noted that bird responses were correlated with the distance to the aircraft. This correlation (particularly lateral distance as opposed to altitude for which the correlation was less clear) was confirmed in studies of Spotted Owls (Delaney et al. 1999) and Brant and Canada Geese (Ward et al. 1999). Noise intensity management recommendations for Spotted Owls included buffer distances for helicopters (Delaney et al. 1999).

Military aircraft disturbance differs from other forms of anthropogenic wildlife disturbance because military activities may continue throughout the night (Bisson et al. 2009). Belanger and Bedard (1990) suggested that substantial energetic consequences associated with human disturbance of Snow Geese might be offset by night time foraging. If disturbance reduces foraging efficiency, we might expect long term consequences for avian productivity and survival (Verhulst et al. 2001). We are unaware of research into the relationship between nighttime disturbance and foraging.

Disturbance during the breeding season can be particularly harmful to birds. Disturbance combined with the high energy demands of reproduction may lead to cost-tradeoff tactics such as decreased clutch size and nest abandonment (Safina and Burger 1983, Tremblay and Ellison 1979, Wikelski and Ricklefs 2001). Behaviors such as flushing, decreased foraging, and nest abandonment, which might occur in response to overflight noise, have the potential for negative reproductive consequences (Verhulst et al. 2001). Flushing and decreased nest attendance can lead to higher incidents of predation, and decreased egg viability due to environmental exposure (Tremblay and Ellison

1979, Westemeier et al. 1998, Westmoreland and Best 1985). The effects of anthropogenic disturbance on breeding behavior and breeding success are particularly relevant for species of conservation concern, such as the American Oystercatcher. A study of the effects of human recreation on American Oystercatchers during incubation associated aircraft overflights with higher rates of birds leaving their nests (McGowan and Simons 2006).

Disturbance can produce a variety of physiological responses which reduce the fitness of individual birds by reducing fecundity and survival (Wingfield and Sapolsky 2003). For example, greater energetic demands during reproduction in Kestrels were found to increase the likelihood of death the following winter (Daan et al. 1996). Hormonal and other physiological changes in response to stress may also suppress reproduction directly (Wingfield and Sapolsky 2003).

Several studies (Pepper et al. 2003, Efroymson and Suter 2001) have concluded that further research is necessary to pinpoint and quantify the effects of aircraft noise on wildlife. We hope to contribute to a better understanding of these questions through this study. Our research will evaluate the effects of lowering the minimum altitude of U. S. Marine Corps air operations over Cape Lookout National Seashore on breeding American Oystercatchers. The U. S. Marine Corps has requested lowering the minimum altitude from 10,000 to 3,000 feet in the Core Banks Military Operations Area (Core MOA) (Figure 1). Our focal species, the American Oystercatcher, is a large conspicuous breeding shorebird that is listed as a “species of special concern” in North Carolina (North Carolina Wildlife Resources Commission 2008). Oystercatchers are considered a “bird of conservation concern”, as well as a management “focal species” by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2004). Researchers at NC State University have studied American Oystercatcher populations on the Outer Banks continuously for the past 15 years. This research has documented a variety of factors affecting the distribution, abundance, and demographics of oystercatcher populations in North Carolina. Recently, the National Fish and Wildlife Foundation (American Oystercatcher Working Group and

National Fish and Wildlife Foundation 2008) designated the American Oystercatcher as a "Coastal Keystone Species" because oystercatchers are sensitive to many factors affecting coastal environments. Our goal in this research is to integrate new information on the effects of USMC aircraft overflights with existing knowledge about factors affecting breeding populations in North Carolina.

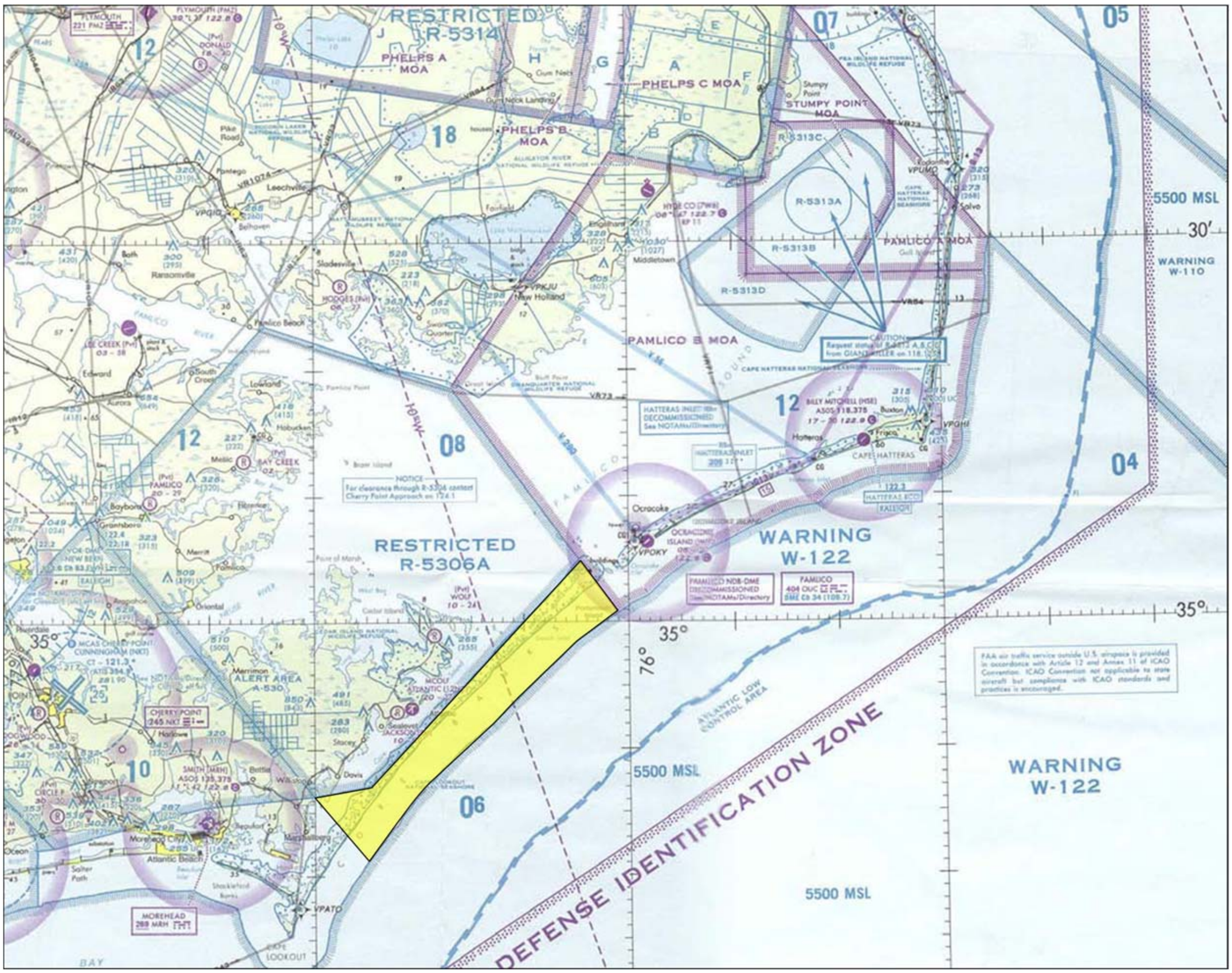



**Figure 1.** Military Core MOA over Cape Lookout National Seashore (in yellow) and adjacent operations areas.

# Research Objectives

(1) To assess if military overflights affect the behavior, physiology, reproductive success, and survival rates of breeding American Oystercatchers at Cape Lookout National Seashore.

(2) To compare the effects of military overflight events to other factors affecting breeding American Oystercatchers at Cape Lookout National Seashore.

# Methods

## Study Area

Our study site is located on North Core Banks within Cape Lookout National Seashore on the central coast of North Carolina (Figure 2). Cape Lookout National Seashore extends 56 miles from Beaufort to Ocracoke Inlets and consists of three barrier islands: North Core Banks, South Core Banks, and Shackleford Banks (Appendix 2). North Core Banks is almost entirely encompassed by the MOA. It is a typical Atlantic barrier island. Just under 23 miles in length, the narrow island is characterized by open beach habitats backed by dunes or sand "flats." These sand flats can extend across the width of the island from ocean to Core Sound or lie between open beach and the primary dunes. Grasses, shrub thickets, and occasional areas of low trees are found between the primary dunes and Core Sound. North Core Banks is accessed by a vehicular and pedestrian ferry near the southern end of the island and a pedestrian-only ferry at the northern tip of the island. Commercial ATV tours are offered at the historical village and beaches at the northern tip of the island. This produces heavier concentrations of vehicles on the southern portion of the island, and heavier pedestrian traffic on the northern tip. Most vehicle traffic is concentrated on the outer beach, but an unpaved road behind the primary dunes that extends from island mile 4 to island mile 6, and again from mile 7 to mile 18.5, provides vehicle access during periods of high tides.

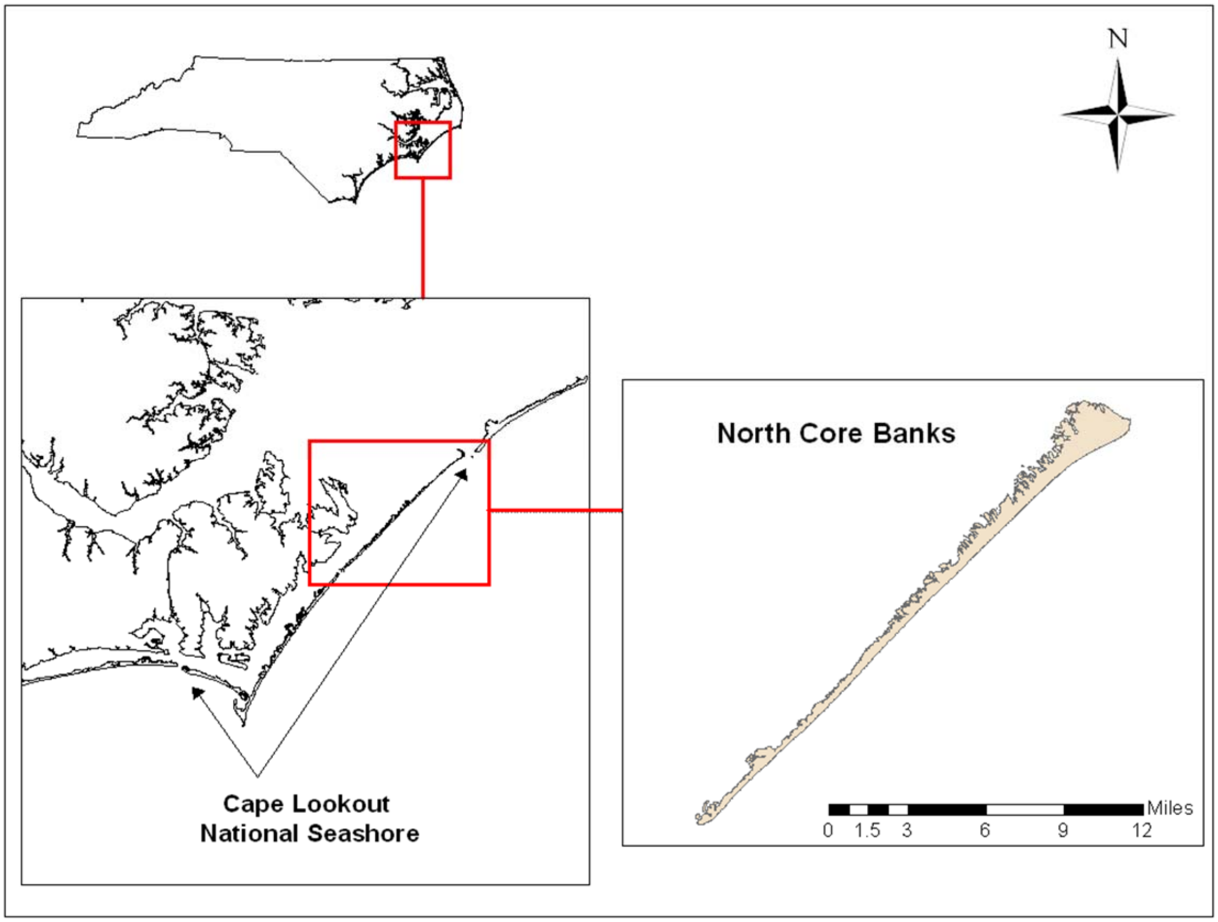



**Figure 2.** Location map of Cape Lookout National Seashore.

## Study Species

The American Oystercatcher (*Haematopus palliates*) is listed as a "Species of High Concern" by the U.S. Shorebird Conservation Plan. This designation is for species whose populations "are known or thought to be declining, and have some other known or potential threat" (Brown et al., 2001). In North

Carolina it is considered a "species of special concern", (North Carolina Wildlife Resources Commission 2008) and is listed as "threatened" in Georgia and Florida. Oystercatchers are considered a "bird of conservation concern", as well as a management "focal species" by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2004). The National Fish and Wildlife Foundation (American Oystercatcher Working Group and National Fish and Wildlife Foundation 2008) designated the American Oystercatcher as a "Coastal Keystone Species", and composed an initiative for their conservation, because they are sensitive to many factors affecting coastal environments. Although American Oystercatcher populations are expanding at the northern and southern portion of their range, populations in the center of the range, including the Outer Banks may be declining (Davis et al. 2001).

American Oystercatchers arrive at their breeding grounds, form pairs, and establish territories in early April. Breeding pairs often construct multiple nest scrapes before egg-laying as part of their courtship behavior. Most nests on the Outer Banks are found on the open beach or adjacent primary dunes, but birds also nest on over-wash flats, sound-side marshes, and dredge spoil islands. Clutches of one to three eggs are incubated by both adults for an average of 27 days. Pairs may attempt multiple clutches in a single breeding season if their nests are destroyed before the chicks hatch. Chicks are precocial and they leave the nest shortly after hatching, but they rely almost completely on parents for food and protection until they fledge about 35 days after hatching (Nol and Humphrey 1994). Chicks can remain on their natal territories with their parents for up to three months after they fledge.

## Population and Productivity Monitoring

### *Productivity Monitoring*

We conducted surveys of American Oystercatchers on North Core Banks from early April to mid-August 2010. Birds were located by driving the length of the island. We identified birds exhibiting breeding or territorial behaviors, and then located nests by observing the birds, following their tracks, or systematically searching areas of suspected breeding activity. We attempted to locate every oystercatcher nest on the island during the 2010 breeding season.

Nests in high traffic areas were posted with signs by National Park Service personnel to reduce human and vehicle activity in the vicinity of the nest. Nests on the open beach were provided additional protection in the form of a drive-through-only corridor that extended 300 feet on either side of the nest.

We monitored nests every 1-3 days to estimate the distribution, abundance, productivity and survival of oystercatchers during the2010 breeding season. Nest monitoring was conducted by direct observation and video recording (as described below) until the eggs hatched or the nest failed. If a nest failed, we determined cause of nest failure from evidence at the nest site or by reviewing the nest monitoring video. After hatching, we located and observed the family group daily to determine chick survival and fledging dates.

Just prior to hatching, the National Park Service established vehicle closures adjacent to nests and rerouted traffic along the back road behind the primary dunes. Areas lacking a back road were posted with signs to reduce the vehicle speed limit and warn vehicle operators of the presence of chicks.

### *Banding*

We attempted to capture and band both adult and nestling American Oystercatchers for future identification. All chicks were banded when their legs were large enough to accommodate a band (25 days old or older). We used both U.S. Fish and Wildlife Service metal bands and large alphanumeric color bands engraved with unique codes for each bird. Alphanumeric bands are readable with binoculars and spotting scopes at distances of up to 100 m. We resighted banded birds throughout the study to document movement patterns, habitat use, and survival. Adults were captured using an

Oystercatcher decoy, recorded vocalizations, and a “Whoosh Net” (Figure 3). We capture chicks by hand, or with light hand nets.

**Figure 3.** American Oystercatcher decoy and “Woosh Net” setup for capture of adult American Oystercatcher. The decoy and recorded oystercatcher vocalizations attract territorial oystercatchers. A hidden researcher deploys the net, which is propelled by taunt bungees, once target oystercatchers are within range.

## Anthropogenic Activity and Nest Monitoring

### *Sound Classification*

We installed Samson Zoom H2 digital audio recorders every two miles along the length of North Core Banks following protocols established by the Natural Sounds Program of the National Park Service

(Figure 4). Sound recordings were made over 5-7 day periods in May, June, and July to provide a baseline record of summer ambient noise levels on North Core Banks.


**Figure 4.** An audio recorder at mile marker nine on North Core Banks. The microphone and digital recorder are surrounded by a wind screen and suspended one meter above the ground. The white plastic bucket holds batteries that allow the recorder to run continuously for up to two weeks. An array of recorders distributed every two miles along the length of the island provided baseline ambient noise levels on the island.

### *Audio Monitoring at Nests*

We made audio recordings using similar equipment at selected American Oystercatcher nests throughout the breeding season. We were unable to monitor sound at all American Oystercatcher nests with recording equipment and therefore used a stratified sampling scheme in which we randomly selected nests for monitoring within strata based on location along the length of the island, location relative to the primary dunes, and vehicle closure status. Ambient sound was recorded continuously at these nests until the nest either failed or hatched. These recordings provided a record of the ambient noise, including natural sounds, overflights, off-road vehicles, and pedestrians in the immediate vicinity of nesting American Oystercatchers.

## *Video Monitoring at Nests*

We monitored behavior at selected American Oystercatcher nests with continuous digital video recording. We selected nests for monitoring in the manner described for audio monitoring above. In addition to recording Oystercatcher behavior during known Core MOA overflights, the video recordings also provided information about nest predation, incubation rates, interspecific interactions, and other forms of anthropogenic activity.

Our video recorders were comprised of an outdoor security camera with infrared-capability, a digital video recorder, 12V AGM sealed lead acid batteries, and a voltage regulator (Figure 5). This system allowed us to record activity at the nest 24 hours a day. All components were housed in a 5-gallon bucket with a waterproof lid for protection, weatherproofing, and transportability. We outfitted some of the cameras with 16mm zoom lenses so we could place them farther from the nests. The remainder of the cameras used their original 4 mm wide-angle lenses.

We built 35 video camera units, 20 with zoom lenses which were used for recording nests, and 15 with wide-angle lenses for recording activity on the beach. We maintained between 10 and 15 cameras on active nests throughout most of the breeding season. We replaced camera units in the field every seven days to download recorded video and replace batteries. We replaced cameras with a completely new system which allowed us to minimize the disturbance of nesting birds. Most camera exchanges were completed in less than 10 minutes.

**Figure 5.** Camera unit for video recording incubating American Oystercatchers at nests. The recording system consisted of a camera, digital video recorder, and batteries encased in a white 5-gallon plastic bucket (left). A camera unit in action recording an incubating oystercatcher (right).

Whenever possible, we positioned video cameras with the adjacent beach habitat in the field of view so that we could identify as many sources of human activity and potential disturbance (ORV's, pedestrians, pets, predators, etc.) as possible. If the location of the nest did not provide a clear view of the beach and the nest, we placed a second video recorder adjacent to the nest at a location where the beach was visible. We located adults and broods after hatching with binoculars and spotting scopes to assess chick survival.

### *Heart Rate Monitoring at Nests*

Weisenberger and others (1996) found that simulated aircraft noise caused heart rates to increase in desert ungulates. Heart rate monitoring is being used with greater frequency as a measure of disturbance (Bisson et al. 2009, Giese et al. 1999, Harms et al. 1997, Nimon et al. 1996, Weisenberger et al. 1996), but the methods and technology used to collect heart rate data are often quite invasive, requiring stressful captures and external mounting or internal implantation of monitoring devices (Bisson et al. 2009, Culik 1992, Harms et al. 1997).

To minimize disturbance, we recorded the heart rates of incubating oystercatchers using miniature microphones implanted in artificial eggs. This design has been previously used with terns and gulls (Arnold et al. in press). We constructed our heart rate sensors by drilling a hole in a plastic egg and mounting a small microphone flush with surface of the shell. A wire lead attached to the microphone allowed us to connect the sensor to an external digital audio recorder. The plastic eggs and microphones were then covered with either a balloon or parafilm to protect and conceal the microphone. The covering was painted to resemble an American Oystercatcher egg (Figure 6). We adapted the same Zoom H2 digital audio recorders used for ambient noise monitoring to record heart rates. We placed the recorder and battery in a protective bucket that was buried approximately 30 feet from the nest. We also buried the wire connecting the artificial egg to the recorder. We buried the cord about six inches below the artificial egg to tether the egg in place. This helped maintain the proper orientation of the microphone beneath the incubating bird while allowing some manipulation of the egg. On occasion the artificial egg became separated from the rest of the clutch due to the activity of the incubating adults. We hope to improve the design next year to minimize this problem.

Although we were initially concerned that the artificial eggs might disturb incubating birds we found little evidence of this problem. Indeed, on several occasions following destruction of the clutch by a nest predator the adults returned to the nest and incubated the remaining artificial egg.

**Figure 6.** A plastic egg with an embedded microphone (left). Once covered and painted to resemble real American Oystercatcher eggs, the sensors were added to an active nest and used to record the heart rate of incubating American Oystercatchers (right). The red arrow indicates the artificial egg in the nest.

## Data Processing and Analysis

The accumulated data from continuous sound, video, and heart rate monitoring are extensive. Reviewing these data in real-time using human observers is extremely time-consuming and arduous. We have therefore used various software programs to expedite these analyses.

We are using motion detection software developed by a collaborating engineering Ph.D. student, Syed Hussain, to detect activity at oystercatcher nests. The software processes the original video recordings and marks frames in which birds depart, exchange incubation duties, or arrive at the nest. This greatly increases the speed at which we can review the video.

We process the audio data using two software programs, Acoustic Monitoring Toolbox (AMT) (v1.3877) and Audio2NVSPL, developed and provided by the Natural Sounds Program of the National Park Service.

We used Adobe Audition to review video, audio, and heart rate files simultaneously. Concurrent viewing and listening allowed us to align the three recordings with a high degree of temporal accuracy, not achievable by the timestamp on the recordings alone. Although video data could be imported directly into Audition with no preparation, we had to split audio and heart rate files into two hour increments for importing them into Audition. However, we deemed using Adobe Audition to view all files types simultaneously an inefficient process, and use it only as necessary to resolve ambiguous information. Adobe Audition is now only used for analyzing heart rate recordings.

## Collaboration

This research involves collaboration among researchers at North Carolina State University, National Park Service staff, researchers at Virginia Tech, and US Marine Corps personnel. The NPS assists with logistics, data collection, and monitoring of American Oystercatchers. The US Marine Corps provides detailed flight information and scheduling of all military flights through the Core MOA. The researchers at NCSU and VT are sharing methodologies and data, responsibilities in the field, and findings, in an effort to maximize the knowledge gained from this research. Although this study is focused on American Oystercatchers, our Virginia Tech collaborators are simultaneously assessing the responses of Wilson's Plovers (*Charadrius wilsonia*), Black Skimmers (*Rynchops niger*), Least Terns (*Sternula antillarum*), Gull-billed Terns (*Gelochelidon nilotica*), and Common Terns (*Sterna hirundo*) to overflights and other forms of anthropogenic activity.

# Results

## Population and Productivity Monitoring

### *Productivity Monitoring*

We observed 68 adult American Oystercatchers on North Core Banks (approximately three oystercatchers/mile) during the 2010 breeding season. Of these, 31 pairs made 58 nesting attempts (Table 1). The first nest was found on 21 April and the last nest failed on the 31 July. Nests were distributed across the length of the island in open beach, inter-dunal, and sand flat habitats (Figure 7). Thirty chicks hatched from 15 nests, and 14 of those chicks survived to fledging. Nest survival was higher in 2010 on North Core Banks (0.259) than the previous year (0.175). However, chick survival on North Core Banks was lower in 2010 (0.467) than in 2009 (0.533). Chicks fledged per breeding pair was higher in 2010 than in 2009, 0.451 and 0.276, respectively (Table 1, Appendix 1). Nest survival, chick survival, and productivity in 2010 were comparable to overall levels in North Carolina from 1995 (Table 1, Appendix 1).

**Table 1.** Reproductive Data for North Core Banks.

| | **Breeding Pairs** | **Nests** | **Average Clutch Size** | **Average Nesting Attempt/Pair** | **Nests Hatched** | **Eggs (Chicks) Hatched** | **Nest Survival** (Nests Hatched/Total Nests) | **Chicks Fledged** | **Chick Survival** (Chicks Fledged/Chicks Hatched) | **Productivity** (Chicks Fledged/Pair) |
|---|---|---|---|---|---|---|---|---|---|---|
| **NCB 2010** | **31** | **58** | **2.38** | **1.87** | **15** | **30** | **0.259** | **14** | **0.467** | **0.451** |
| NCB 2009 | 29 | 40 | | | 7 | | 0.175 | 8 | 0.533 | 0.276 |
| NC Summary (1995-2009) | 1221 | 1812 | | | 550 | | 0.304 | 391 | 0.379 | 0.320 |


**Figure 7.** North Core Banks and locations of all 58 American Oystercatcher nests monitored in 2010.

## *Banding*

We banded three adult oystercatchers and 15 chicks in 2010. Banding is ongoing on North Core Banks, so we did not put extensive effort into banding adults as many were banded previously. However, we attempted to band every chick.

## Anthropogenic Activity and Nest Monitoring

The US Marine Corps reported 250 MOA flights over North Core Banks from 7 March - 12 August 2010. Of these, 109 MOA overflights occurred during the nesting period of American Oystercatchers (21 April 2010 – 31 July 2010). Only 24 of the 109 flights were under an altitude of 10,000 feet.

### *Sound Classification*

We recorded ambient sound along the length of the island from 20-25 May 2010, 17-24 June 2010, and 11-15 July 2010. Recordings totaled 3,924 hours. 1,327 hours were recorded in May; 1,506 hours in June; and 1,092 hours in July.

### *Audio Monitoring at Nests*

We monitored 32 nests (55% of 58 total nests found) with audio recording equipment. Based on our analysis of video recordings we estimate that we collected over 11,000 hours of digital audio recordings (see "Video Monitoring" section below).

We processed all audio data collected from one monitored nest (Nest 43) to provide an example of the full data extraction process and potential results. Nest 43 was located on the front beach approximately midway between the primary dunes and the average high tide line. The nest was monitored with audio and video recorders, and with a heart rate monitoring artificial egg. Monitoring equipment was installed early in the incubation period and the nest survived to hatching. Therefore it provides a full record for each type of data and a good pilot data set for analysis.

Anthropogenic events detected on the audio recordings included aircraft such as fixed wing airplanes, helicopters, MOA flights (jets which corresponded with reported military flights), jets (jets which did not correspond with reported military flights) and aircraft whose type we could not determine. Off-road vehicles (ORVs) heard on the audio recordings included all-terrain vehicles (ATVs) and vehicles (defined as 4-wheel drive trucks, sport-utility vehicles, RVs, etc.). We heard no pedestrians at Nest 43. Aircraft were heard slightly more frequently than ORVs and had a higher average Sound Exposure Level (SEL) than the ORVs (Figure 8). Sound Exposure Levels represent the total noise energy produced from a single event. They take into account A-weighted sound pressure levels measured at multiple frequencies over the duration of the event. The most common events were “Combined Jets” (a combination of MOA flights and other jets, as these were indistinguishable on the audio recordings) and ATVs (Figure 9). Helicopters had the highest Sound Exposure Level and all aircraft types had higher Sound Exposure Levels than either ATVs or vehicles (Figure 9). We identified events when American Oystercatchers were flushed off their nests in association with MOA flights, single-engine aircraft, ATVs, and vehicles by watching the video corresponding to the time an event was heard on the audio. ATVs were attributed to 88.5% of the flushings at Nest 43. Vehicles were responsible for 4.9% of the flushings, single-engine aircraft for 1.6%, and MOA flights for 1.6% (Figure 10). During all 32 MOA flights recorded at Nest 43, oystercatchers flushed from the nest only once (3.1%). Neither of the two MOA flights under an altitude of 10,000 feet were associated with oystercatchers flushing from their nests.

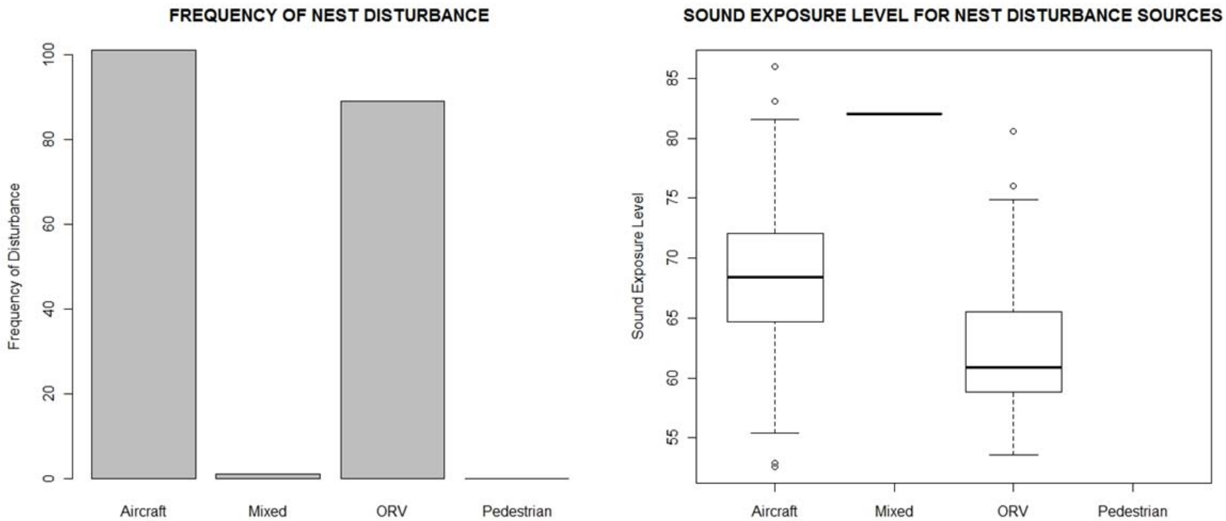
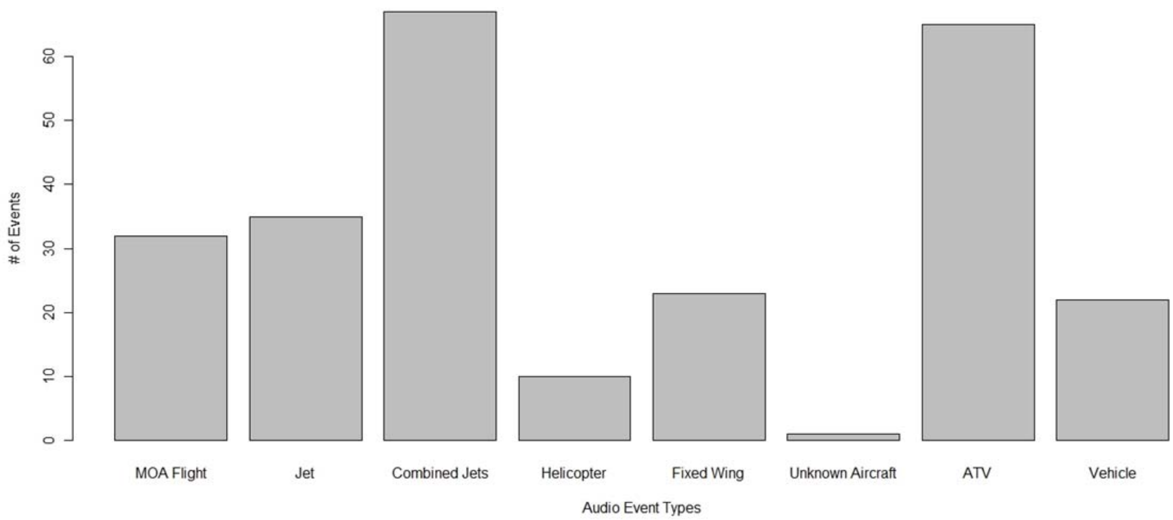



**Figure 8.** The number of events, classified into general categories, identified on audio recordings at Nest 43 (left panel). The Sound Exposure Levels (dBA) recorded for each event (right panel). Sound Exposure Levels represent the total noise energy produced from a single event. They take into account A-weighted sound pressure levels measured at multiple frequencies over the duration of the event. The "Mixed" classification refers to instances when more than one event type occurred at the same time, such as a vehicle driving by at the same time a jet flies over.



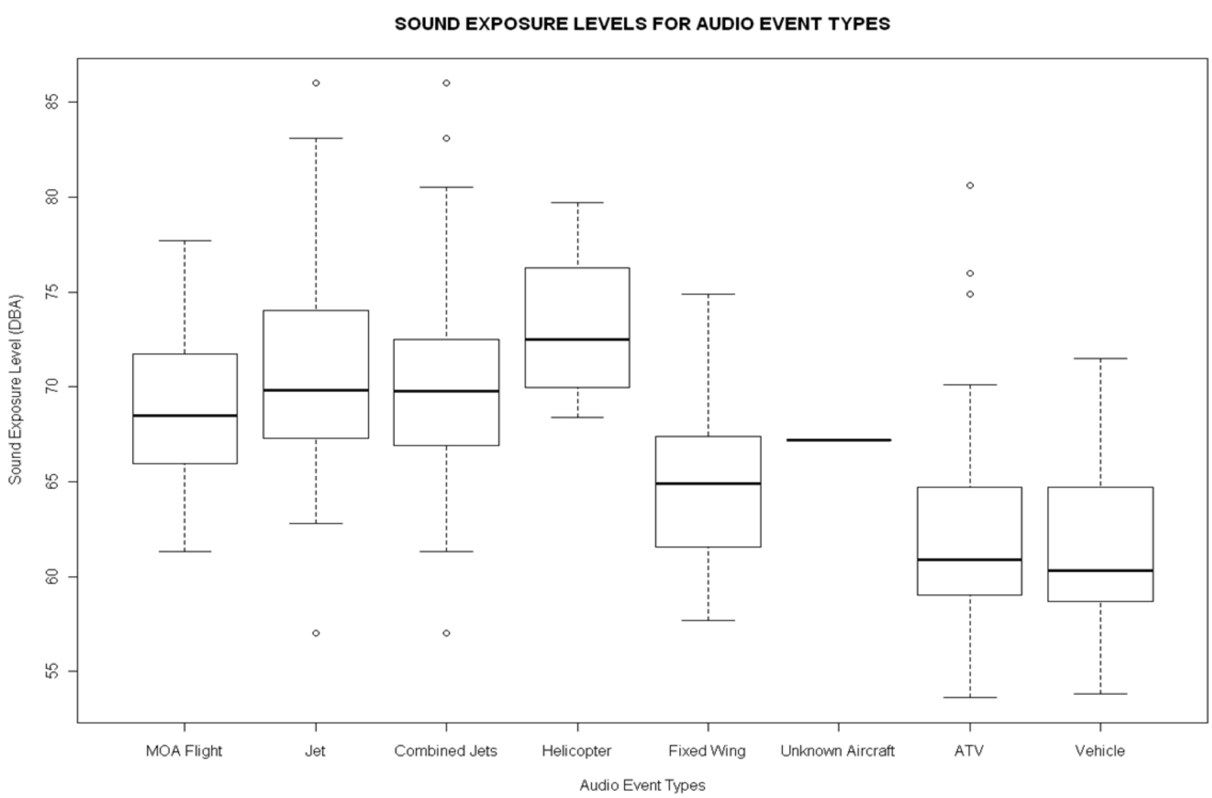




**Figure 9.** The number of events, by specific event category, identified on audio recordings at Nest 43 (top panel). The Sound Exposure Levels (dBA) recorded for each event (bottom panel). Sound Exposure Levels represent the total noise energy produced from a single event. They take into account A-weighted sound pressure levels measured at multiple frequencies over the duration of the event. The classification "Combined Jets" combines both MOA flights and other jets as these were indistinguishable on the audio recordings.

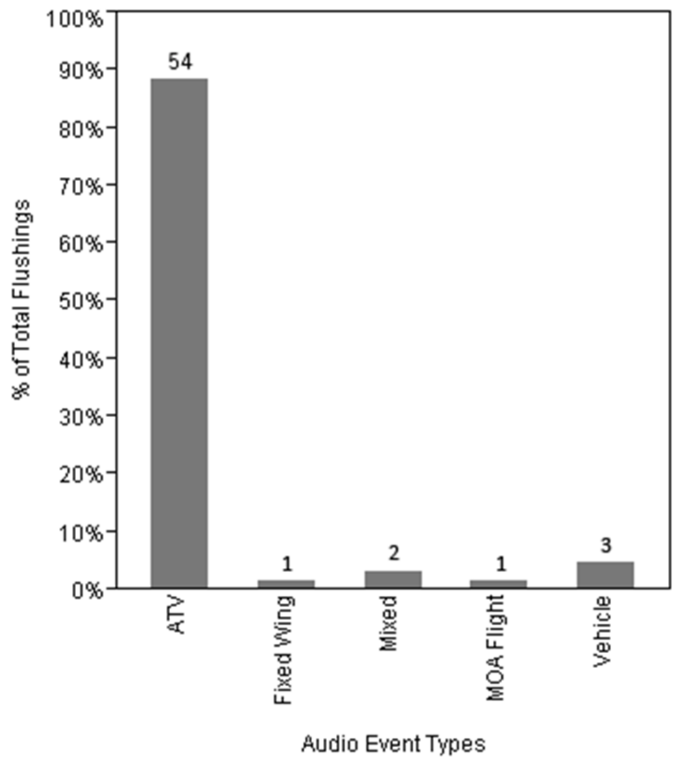



**Figure 10.** Percentages of events, by event type, which coincided with the incubating bird flushing from Nest 43. The numbers above the bars are the number of times that event type coincided with a bird flushing from the nest. The "Mixed" classification refers to instance when more than one event type occurred at the same time, such as a vehicle driving by at the same time a jet flew over.

## *Video Monitoring at Nests*

We monitored 32 nests (55% of 58 total nests found) with video recording equipment accumulating 11,904 hours of video data. As with the audio monitoring, we processed all video data collected from Nest 43 to provide an example of the full data extraction process and potential results. Events observed on the video from nest 43 included; the arrival of an oystercatcher at the nest, the departure of the incubating oystercatcher from the nest, the presence of other non-incubating oystercatchers, ghost crabs, researchers, pedestrians, all-terrain vehicles (ATVs), vehicles (defined as 4-wheel drive trucks, sport-utility vehicles, RVs, etc.), one instance of the shadow of an aircraft (confirmed as a helicopter from the audio recording), several events which were indiscernible, and a few other events such as boats and Willets. The most frequently recorded event was arrival of an oystercatcher at the nest or departure of the incubating individual from the nest (classified as “Arrive/Depart”). The most frequently recorded event types were ATVs and vehicles (Figure 12). We recorded instances of American Oystercatchers flushed off their nests by other oystercatchers, ATVs, researchers visiting the nest, pedestrians, vehicles, and a few unknown causes. ATVs were attributed the highest frequency of flushing events (69.3%) at Nest 43. Vehicles were attributed to 13.7% of the flushing events (Figure 13).

Despite its location well away from the dunes on the front beach, incubation rates were high at Nest 43. The nest was attended 90-100% of the time most days (Figure 14).

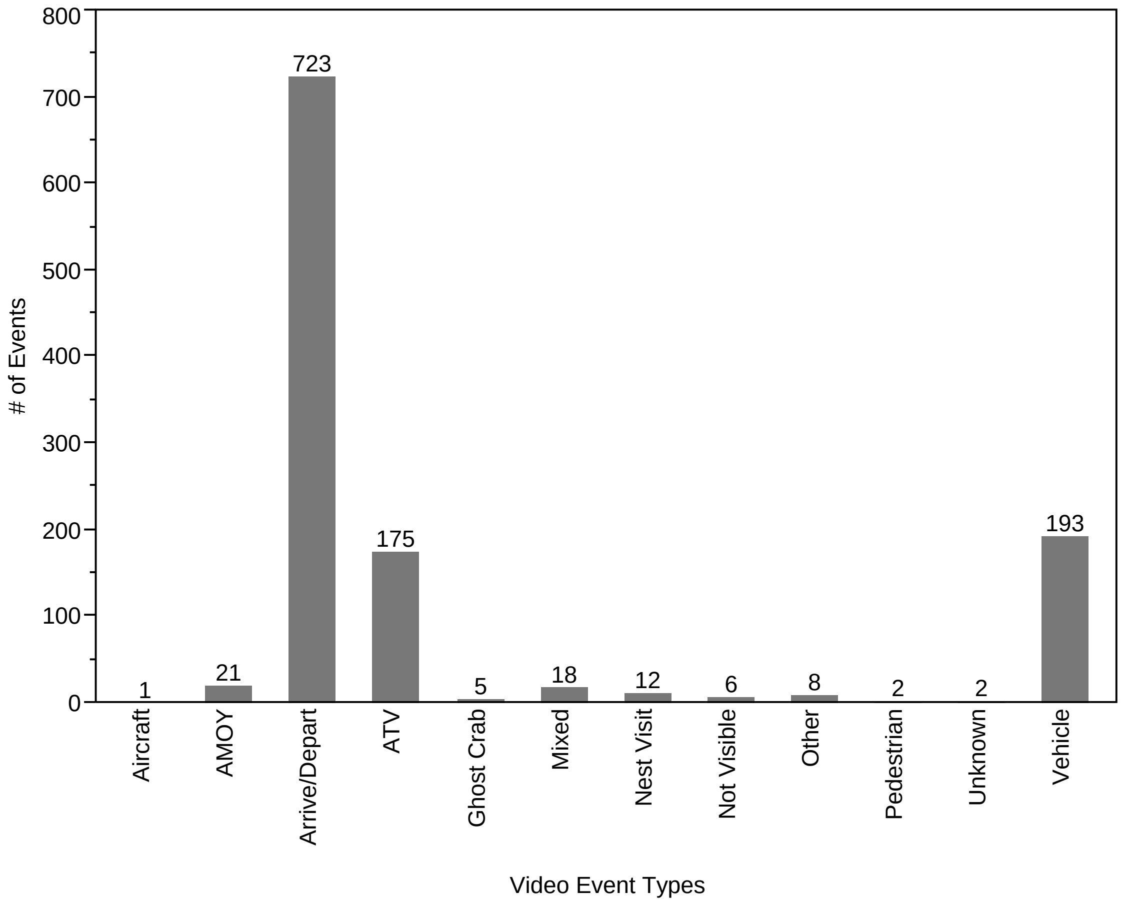



**Figure 12.** Events observed on video recordings at Nest 43. The "AMOY" category denotes when an American Oystercatcher is visible on the video, but it is not at the nest. The "Arrive/Depart" category refers to a bird arriving at the nest or departing from the nest. The "Mixed" category denotes instances when an ATV and a vehicle drive by at the same time. The "Nest Visit" category denotes a researcher approaching the nest to check its status or maintain monitoring equipment. "Not Visible" is when the activity at and around the nest cannot be seen (e.g. when the camera lens is fogged or heavy rain interferes with visibility). "Other" refers to events such as boats and Willets. "Unknown" is when an object on the video is indiscernible.

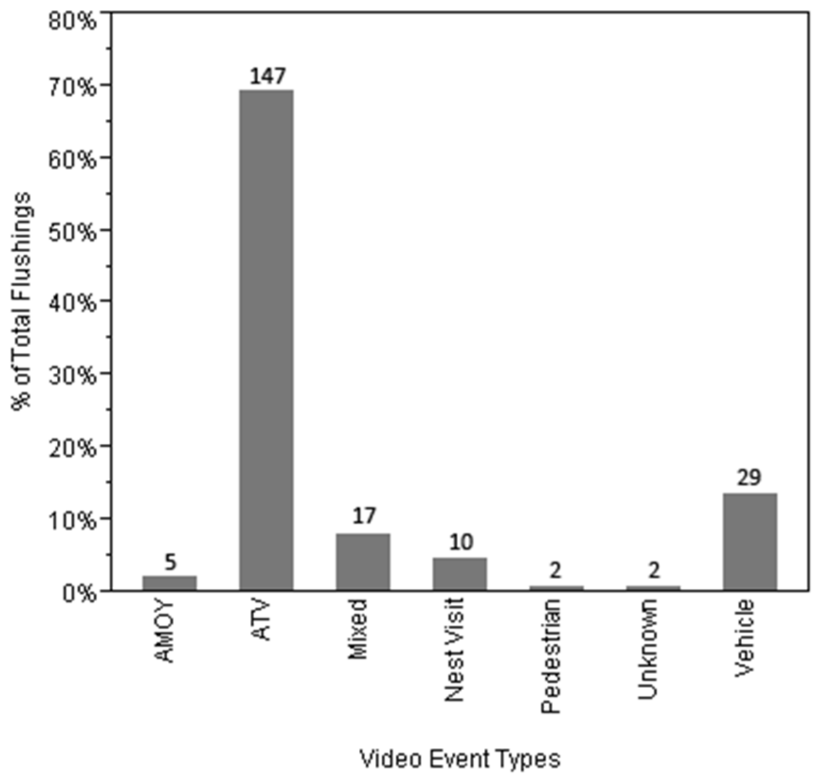



**Figure 13.** Percentages of events by type which flushed the incubating bird at Nest 43. The numbers above the bars are the number of times that event type caused a bird to flush. Along with categories which are more apparent, "AMOY" denotes a non-incubating American Oystercatcher on the video, "Mixed" is when an ATV and a vehicle drive by at the same time, "Nest Visit" denotes a researcher approaching the nest to check its status or maintain monitoring equipment, and "Unknown" denotes an indiscernible event which caused a flushing.

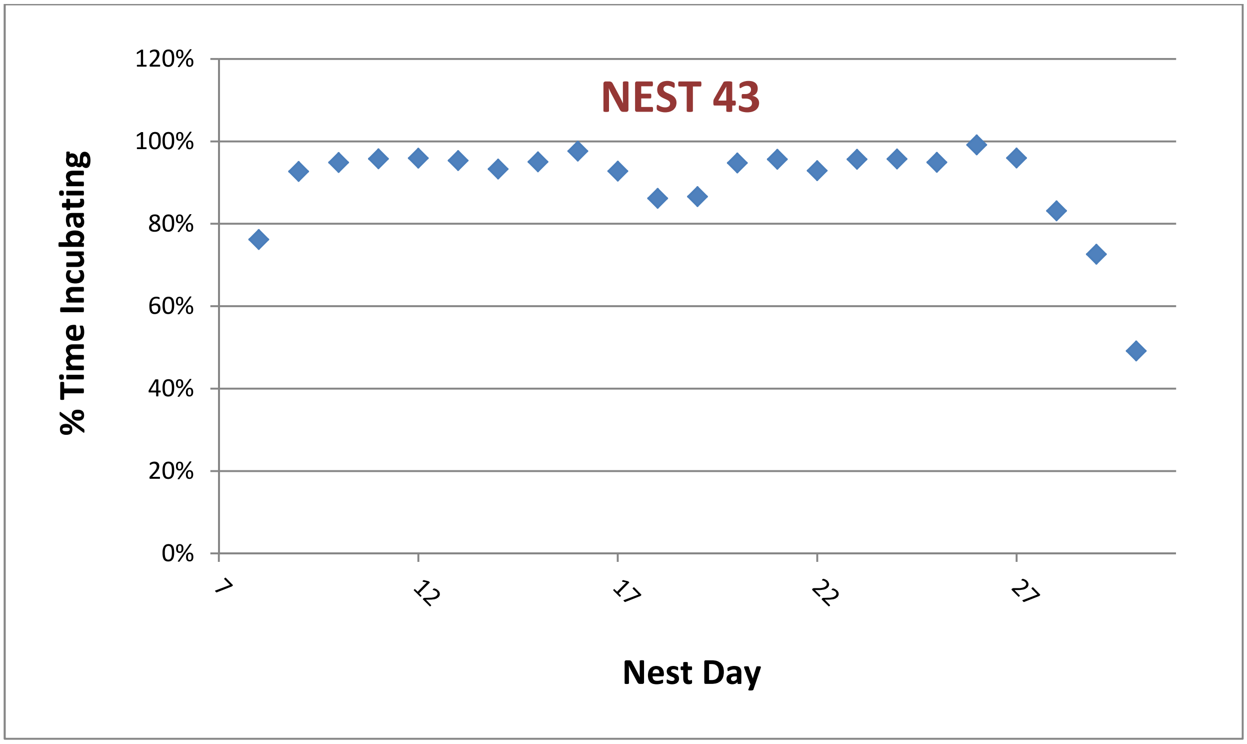



**Figure 14.** The percentage of time an oystercatcher pair spent on the nest incubating each day. Video monitoring occurred from 8th to the 30th day of incubation. The nest hatched on the 28th day of incubation.

### *Heart Rate Monitoring at Nests*

We monitored 18 nests (31% of 58 total nests found) with heart rate monitoring artificial eggs. Analyses to date indicate that American Oystercatcher heart rates range from 84 to 360 beats/minute with an average of 184 beats/minute (N=178, SD=25.0). We attempted to calculate a heart rate during all anthropogenic events identified on the audio recordings for Nest 43. This was often not possible because the bird was either off the nest or the heart rate recording was inaudible or indiscernible. The average heart rate from seven pairs of oystercatchers for the anthropogenic events which we could calculate a heart rate was 191 (range=144-360; N=36; SD=42.2). We also attempted to calculate a resting heart rate by searching the video recordings of all nests which were monitored with a heart rate egg for instances when incubating adults appeared to be sleeping (bill tucked into scapulars and motionless). Unfortunately, this behavior was not recorded very frequently so our current estimate for the resting heart rate is based on only 13 samples. The average resting heart rate calculated from four pairs of oystercatchers was 186 (range=126-288).

We would also like to determine heart rates of birds flushed from their nests by calculating their heart rates in the 10 seconds before they are flushed from the nest. These pre-flushing heart rates can be compared to heart rates during events, resting heart rates, and overall population heart rates (Figure 15).

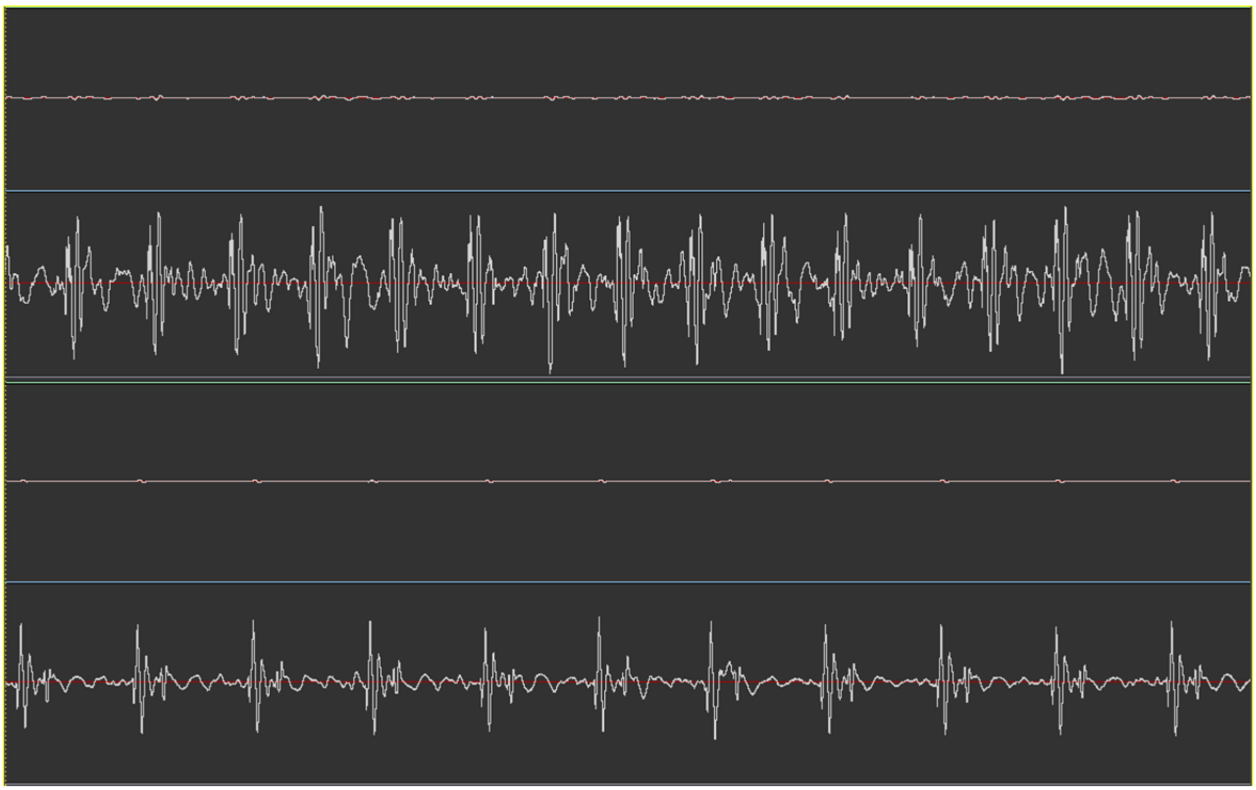


**Figure 15.** The top heart rate waveform is from an incubating American Oystercatcher which is about to be flushed off a nest and corresponds to a heart rate of 228 beats/minute. The bottom waveform is from an incubating American Oystercatcher with no apparent events occurring and corresponds to a heart rate of 168 beats/minute.

# Discussion

We will continue to process the remaining data collected in the 2010 breeding season from all other nests using subsampling to characterize patterns in the data. We are in the process of hiring additional lab technicians and purchasing additional computers to assist in processing the video, audio, and heart rate data over the next 18 months.

### *2011 Field Season*

We will continue video monitoring in a manner similar to the 2010 field season. Only 44 flights (of 206 flights) reported to us by the USMC were below an altitude of 10,000 feet, and only 24 of those low altitude flights were during the oystercatcher active nesting period. We, therefore, hope the 2011 field season will provide us with a larger sample of low altitude flights.

We hope to examine the relationship between nest location and predation and to compare nests in areas closed to ORV traffic to nests in areas with normal vehicle traffic more thoroughly in 2011. We are hoping to determine if birds use open beach habitats more readily in the absence of ORV traffic and if birds nesting on the open beach experience lower rates of nest predation.

We will also devote more effort to heart rate monitoring in 2011. The number of birds monitored successfully in 2010 was limited due to equipment failures. We feel heart rate monitoring will provide valuable ancillary information for evaluating the effects of various types of human activity on incubating birds.

# Acknowledgments

We thank John Wettroth, Maxim Integrated Products, for providing indispensible assistance in developing recording equipment and general support. We also thank Syed Hussain, North Carolina State

University, for developing motion detection software to assist in the processing of the video data, as well as assisting with general software issues. Many, many thanks go to Eli Rose, North Carolina State University, for assistance in all aspects of the project including countless hours spent designing and developing equipment and collecting, organizing and processing digital recordings. We are grateful to Jessica Stocking for her assistance with banding birds and study support. We are indebted to volunteers, Allison Nolker, Jessica Hampton, and Michael Fisk for processing digital recordings.

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# Appendices

**Appendix 1: American Oystercatcher productivity in North Carolina from 1995-2009**

| Year and Location | Breeding pairs | Nests | Nests hatched | Nest survival observed (SE) | Nest survival adjusted (SE) | Chicks fledged | Chick Survival (SE) | Chicks fledged/ breeding pair (SE) |
|---|---|---|---|---|---|---|---|---|
| **CAPE LOOKOUT** | | | | | | | | |
| North Core Banks | | | | | | | | |
| 1998 | 38 | 72 | 5 | 0.069 (0.030) | NA | 4 | NA | 0.105 (0.062) |
| 1999 | 39 | 61 | 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 | 11 | 0.208 (0.056) | 0.167 (0.049) | 1 | 0.091 (0.061) | 0.034 (0.034) |
| 2002 | 23 | 46 | 5 | 0.109 (0.046) | 0.093 (0.033) | 5 | 0.556 (0.166) | 0.217 (0.045) |
| 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) |
| 2009 | 29 | 40 | 7 | 0.175 (0.060) | 0.188 (0.056) | 8 | 0.533 (0.129) | 0.276 (0.121) |
| Island | 289 | 461 | 104 | 0.226 (0.019) | 0.224 (0.020) | 85 | 0.407 (0.034) | 0.294 (0.040) |
| 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 | | | | | | | | |
| 2006 | 2 | 1+ | 1 | NA | NA | 2 | NA | 1.000 (1.000) |
| 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 | 6 | 6 | 4 | 0.667 (0.192) | NA | 5 | NA | 0.833 (0.584) |

*From*: Simons and Schulte 2010.

*Note:* Because of natural barrier island changes and inlet closures, Middle Core Banks and Ophelia Banks are now a part of North Core Banks.

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Appendix 2: Cape Lookout National Seashore. Available at: http://www.nps.gov/calo/planyourvisit/upload/CALOmap1.pdf

# American Oystercatcher Conservation Initiative – North Carolina
# 2010 Annual Report

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## OVERVIEW

The American Oystercatcher *(Haematopus palliatus)* is an important indicator of ecological conditions on Atlantic coast beaches. Because of its conspicuousness and site fidelity, the oystercatcher is an ideal study species for monitoring factors affecting the conservation and management of beach-nesting birds. American Oystercatchers are listed as a "species of special concern" in North Carolina (North Carolina Wildlife Resources Commission 2008) and as a high priority species in the US Shorebird Conservation Plan (Brown *et al*. 2001), in large part because of threats associated with development and increasing recreational use of coastal breeding and wintering sites. Oystercatcher populations are declining in the mid-Atlantic states, despite rising numbers and an expansion of the breeding range to the north (Mawhinney and Benedict 1999;

Nol *et al*. 2000; Davis *et al*. 2001). These overall declines have triggered a large-scale, multi-state research effort to understand the bird's ecology and conservation needs.

A study of breeding American Oystercatchers in North Carolina 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. Studies of oystercatcher breeding success expanded further in 2002 and 2003 when the North Carolina Audubon Society initiated nest monitoring on islands in the mouth of the Cape Fear River. 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. She 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 the more often nests were disturbed the more likely they were to be found by predators. Simons and Schulte (2009) illuminated causes of chick loss and modeled hurricane effects on oystercatcher production. Since 2009, we have increased monitoring efforts on dredge and shell rake islands to clarify the role that these non-traditional habitats play for oystercatchers in North Carolina.

## OBJECTIVES IN 2011

Research objectives for the 2011 field season include:

1. Evaluating management strategies for increasing oystercatcher productivity.
2. Continued monitoring of long-term sites and a third-year of monitoring non-traditional sites for comparison of nest survival.
3. Assessing the response of breeding oystercatchers to an experimental removal of raccoons on South Core Banks, Cape Lookout National Seashore.
4. Assessing of the response of the South Core Banks raccoon population following the experimental removal to evaluate the effectiveness of predator management as a conservation strategy for ground nesting birds and sea turtles in North Carolina.
5. Determining feeding grounds for oystercatchers nesting on non-traditional islands.

## STUDY SITES

We currently monitor American Oystercatcher productivity at several locations along the North Carolina coast (Figure 1) in cooperation with staff from the National Park Service (NPS), the North Carolina Wildlife Resources Commission (NCWRC), and Audubon North Carolina. Habitat consists of a combination of natural and man-made islands: some provide public access and human habitation, while others are closed to public use. Cape Hatteras and Cape Lookout National Seashores comprise over 160 km of barrier island habitats and are monitored by the National Park Service. Audubon NC monitors islands in the Cape Fear River region.

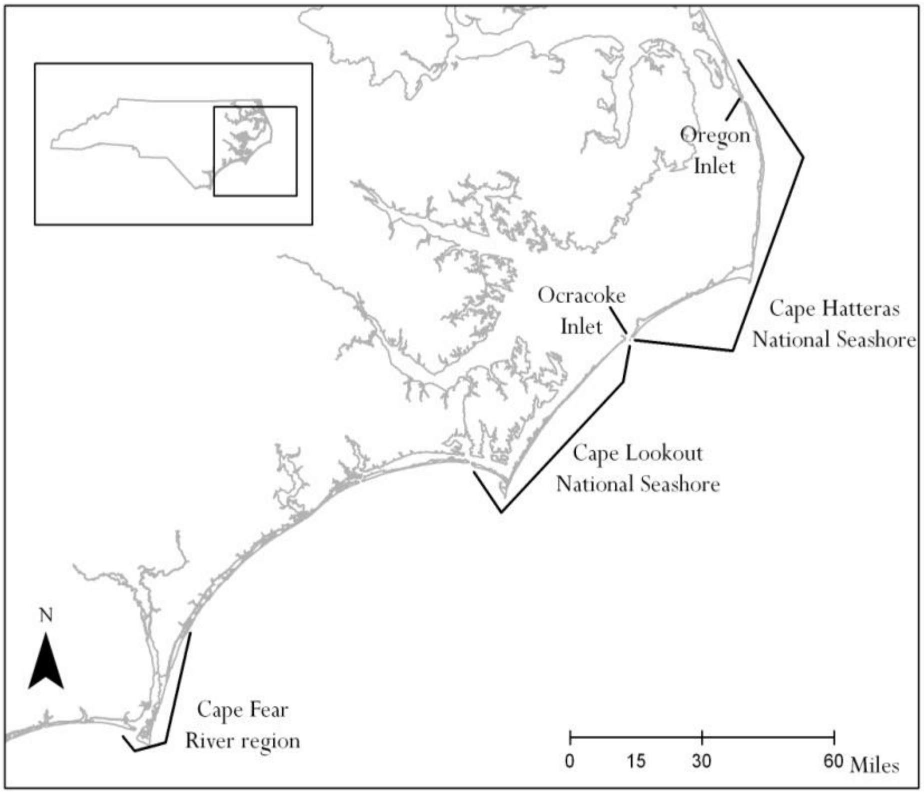


**Figure 1.** Regions of American Oystercatcher monitoring in North Carolina.

The Cape Hatteras National Seashore, at the north end of the study area, is approximately 107 km long and consists of three barrier islands: Bodie, Hatteras, and Ocracoke (north to south). The Seashore is accessible by a bridge on the north end and ferry transport from two southern sites. Twenty-three oystercatcher pairs nested at Cape Hatteras in 2010. The barrier islands in the National Seashore receive heavy recreational use.

Oregon Inlet, between Hatteras Island on the south and Bodie Island on the north, hosts nesting oystercatchers on six dredge spoil islands (created by strategic deposition of dredged material) and two natural islands. One of the natural islands is owned and monitored by the National Park Service, and the NCWRC manages the remaining islands; public use is not permitted during the breeding season. Thirteen pairs nested in the Oregon Inlet area in 2010. Ocracoke Inlet, between Ocracoke Island on the north and North Core Banks on the south, contains primarily shell islands and it supported sixteen pairs of nesting oystercatchers in 2010. NC Audubon monitors and manages these islands.

Cape Lookout National Seashore extends from Ocracoke Inlet to Beaufort Inlet and consists of three islands. North Core Banks and South Core Banks have a general northeast-southwest orientation and are 37 and 40 km long, respectively. Shackleford Island is 15 km long, lies to the southwest of these islands, and is oriented east-west. The islands are accessible only by boat, and commercial ferry services regularly run tourists and vehicles to the islands. Primary threats to oystercatcher nests and chicks include raccoon (*Procyon lotor*), storms/flooding, human disturbance, feral cats, and ghost crabs (Altman 2009). In 2010, 62 oystercatcher pairs nested on Cape Lookout National Seashore.

In 2003 Audubon North Carolina began monitoring nesting success on Lea and Hutaff Islands in Pender County, North Carolina. The islands joined when Topsail Inlet closed to form one island, 8 km long (McGowan *et al*. 2005). Lea-Hutaff is a barrier island similar to the islands in the National Seashores, but it is privately owned and offers limited public recreation. In 2009, Audubon increased monitoring efforts to include islands in the mouth of the Cape Fear River. Ferry Slip and South Pelican are dredge-spoil islands; Battery and Shellbed are natural islands. Seventy-one pairs of Oystercatchers were monitored on these islands in 2010.

## REPRODUCTIVE SUCCESS

### *Nest and chick survival*

We began surveys in mid-March 2010 as oystercatchers were establishing breeding territories. Nest searching was conducted on foot and from vehicles (trucks, ATVs, boats). Pairs that appeared to be active and defending a territory were monitored closely to locate nests and identify dates of nest initiation. Nests were then marked with a natural artifact for efficient relocation. Nests on the barrier islands were checked from a distance every 1-2 days to determine activity and approached only to document hatching or causes of nest loss. The interior sites were checked as frequently as possible, usually every 1-2 days unless access was precluded by low tides or storms. Nests were visited daily just prior to hatching to determine exact hatching dates.

Adult oystercatchers exhibit markedly different behavior patterns when they have chicks. They are much more aggressive toward intruders, and they give distinct alarms calls. It was generally possible to determine whether a pair of adult birds had chicks by observing adult behavior, even in the absence of visual verification. In most cases chicks were located by observing adults from a distance using a spotting scope. We monitored chicks every 1-3 days after hatching (occasionally less frequently for interior sites) until fledging, or until all the chicks died or disappeared. On the rare occasion that a chick was found dead, we attempted to determine the cause of death, although it is often not possible to determine the cause or exact timing of chick mortality. We calculated overall breeding success (productivity) as chicks fledged per breeding pair, by dividing the number of chicks that survived to fledging by the number of breeding pairs for each year in each location (Table 1).

Two hundred sixty nests were monitored in 2010 (Table 1, Figures 2-6). As in previous years, hatching success was highly variable between sites (see Simons and Schulte 2009). Observed hatching success for 2010 was 0.45 and ranged among sites from 0.239 at Cape Lookout to 0.789 on the Ocracoke Inlet islands. The low shell islands in Ocracoke Inlet are vulnerable to spring storms, but they suffered no nest losses due to overwash in 2010. Cape Hatteras National Seashore had the highest number of fledged chicks per pair, followed by the Ocracoke Inlet islands; the Oregon Inlet islands had the lowest productivity. Productivity at Cape Hatteras in 2010 was the highest recorded since monitoring began in 1999 (see Appendix 1).

**Table 1.** Reproductive success in 2010 by management area on the North Carolina coast.

| Site | Breeding pairs | Nests | Nests hatched | Apparent Nest Survival (SE) | Adjusted Nest Survival (SE) | Chicks fledged | Productivity |
|---|---|---|---|---|---|---|---|
| Oregon Inlet | 10 | 11 | 6 | 0.545 (0.150) | 0.537 (0.167) | 4 | 0.400 |
| Cape Hatteras | 23 | 28 | 21 | 0.750 (0.082) | 0.746 (0.083) | 30 | 1.304 |
| Ocracoke Inlet | 16 | 19 | 15 | 0.789 (0.094) | 0.859 (0.092) | 21 | 1.313 |
| Cape Lookout | 62 | 113 | 28 | 0.248 (0.041) | 0.275 (0.039) | 33 | 0.532 |
| Cape Fear | 71 | 89 | 54 | 0.449 (0.053) | 0.412 (0.010) | 33 | 0.465 |
| Total | 182 | 260 | 118 | 0.454 (0.031) | 0.472 (0.005) | 120 | 0.659 |

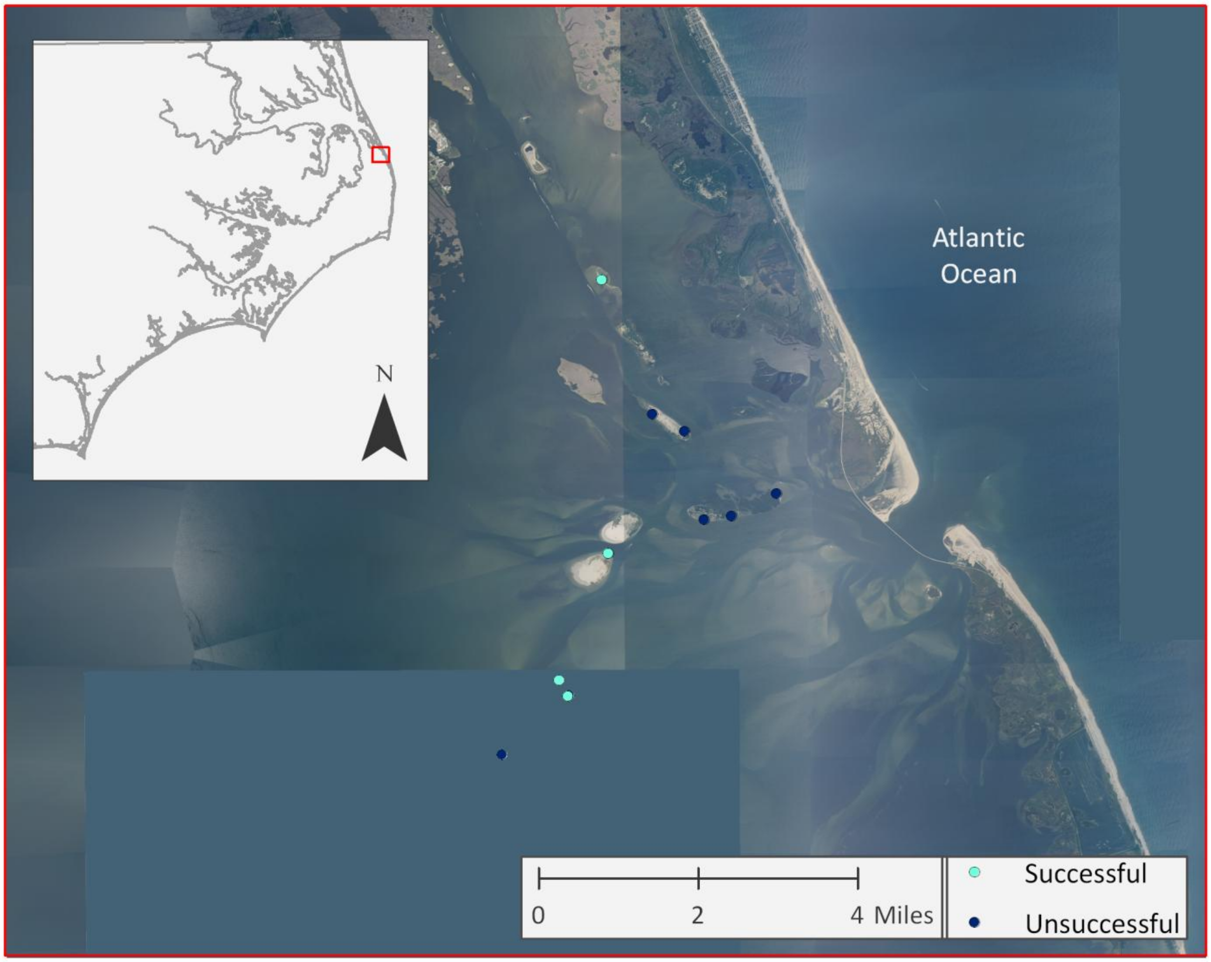


**Figure 2.** Oregon Inlet nests, monitored by N.C. Wildlife Resources Commission. This inlet is bordered by Bodie Island to the north and Hatteras Island to the south. (Note: Some islands are not shown in aerial photo; nests represent actual locations.)

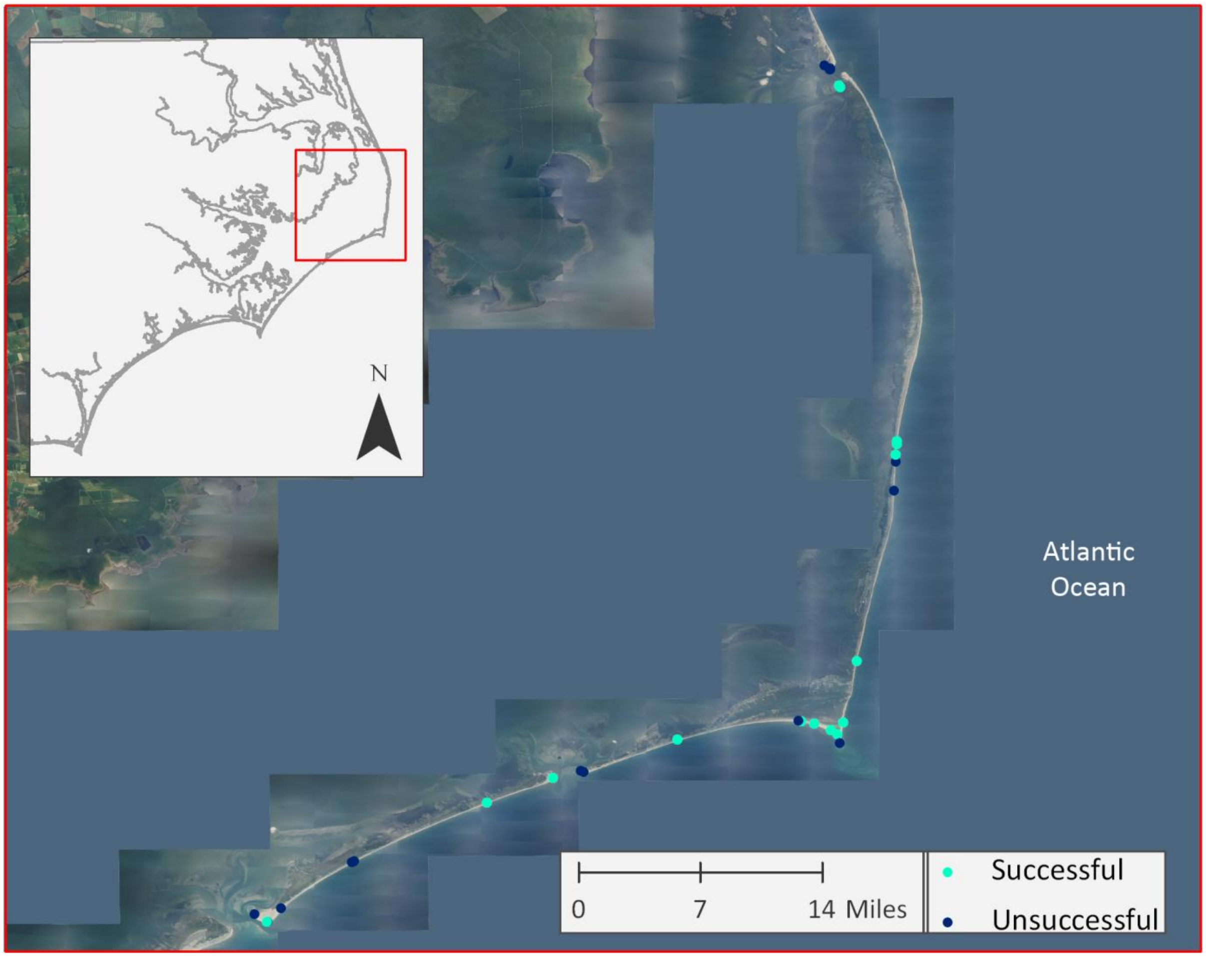


**Figure 3.** Cape Hatteras National Seashore nests, monitored by the National Park Service.

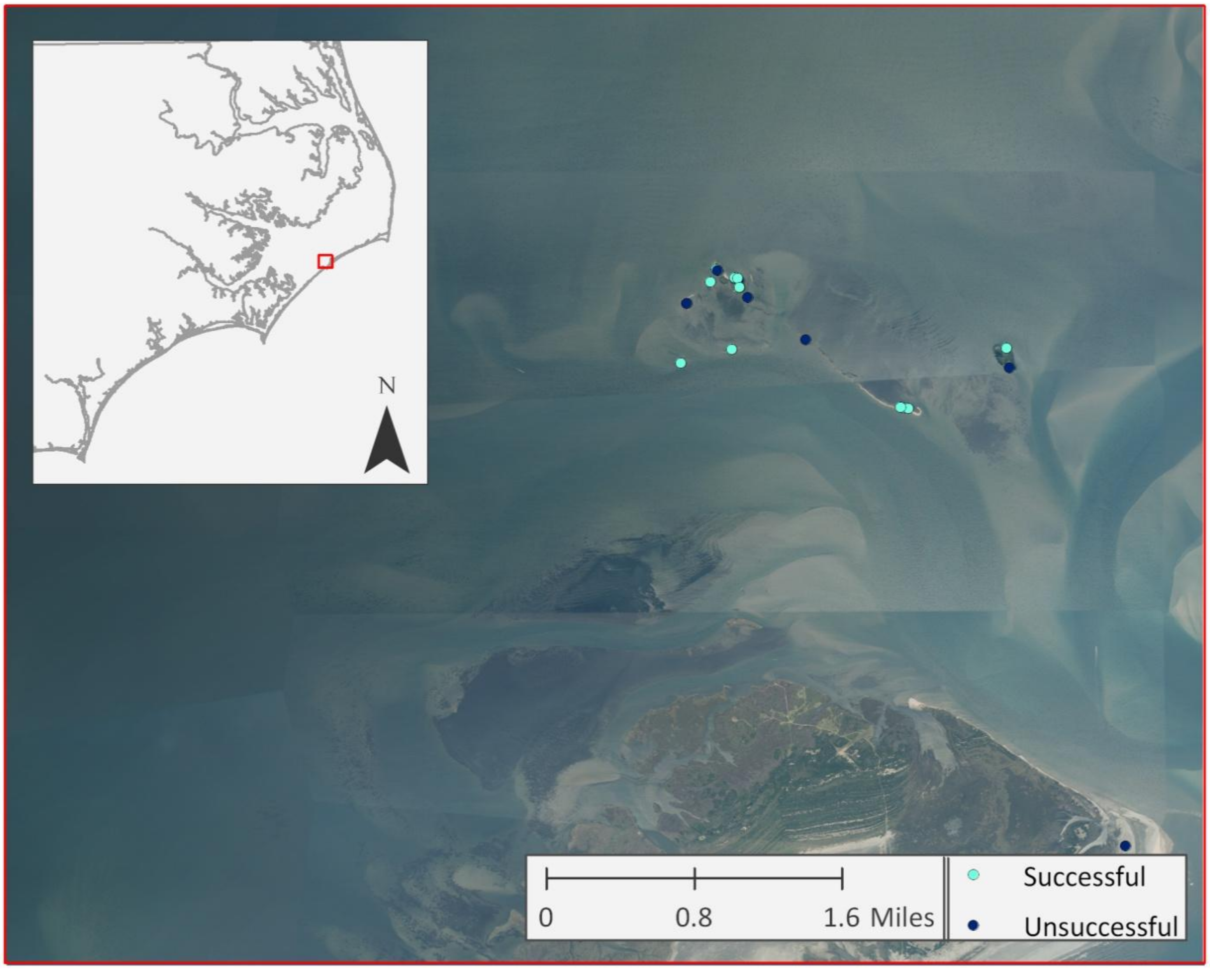


**Figure 4.** Ocracoke Inlet nests, monitored by Audubon NC. These are shell islands located in the inlet between Ocracoke Island and North Core Banks.

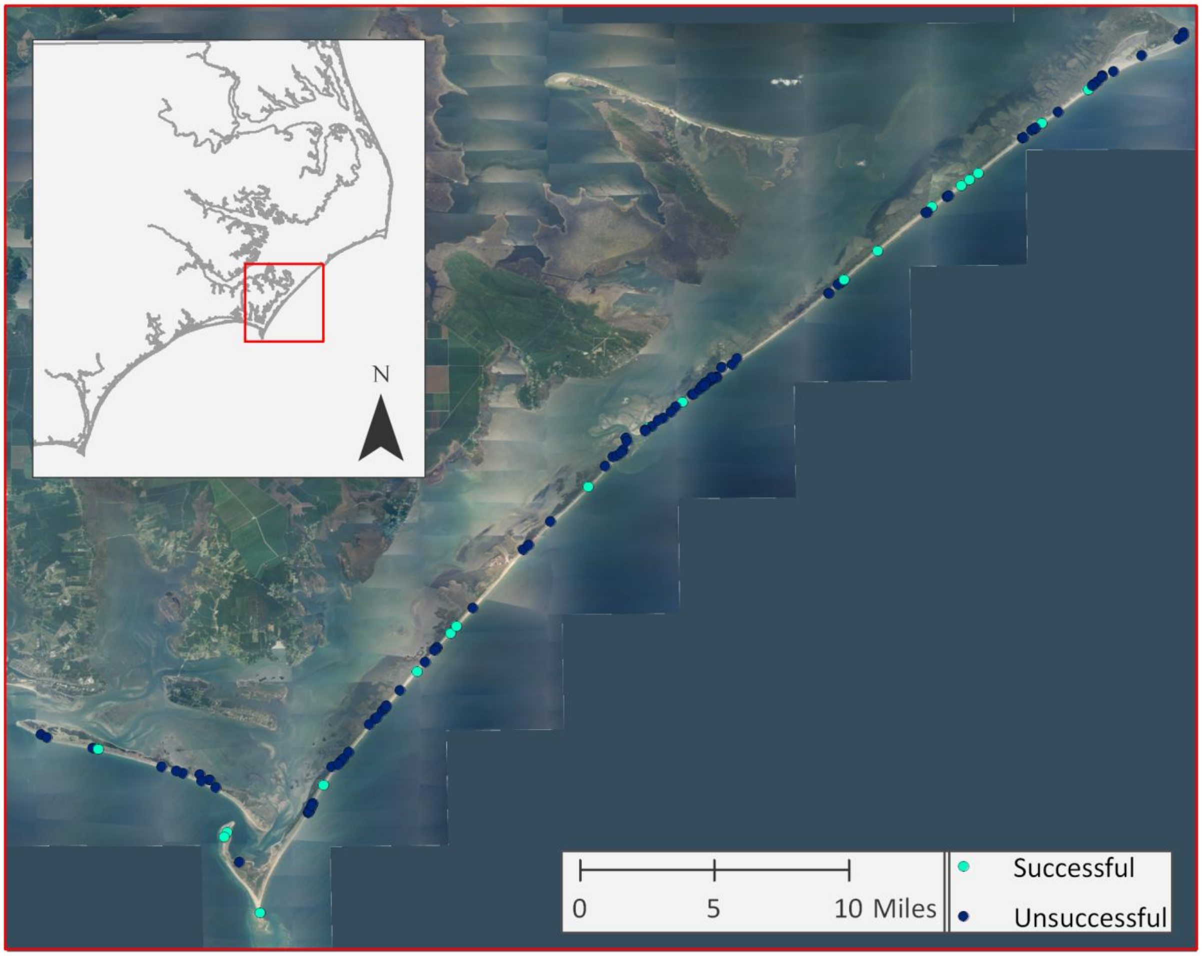


**Figure 5**. Cape Lookout National Seashore nests, monitored by the National Park Service.

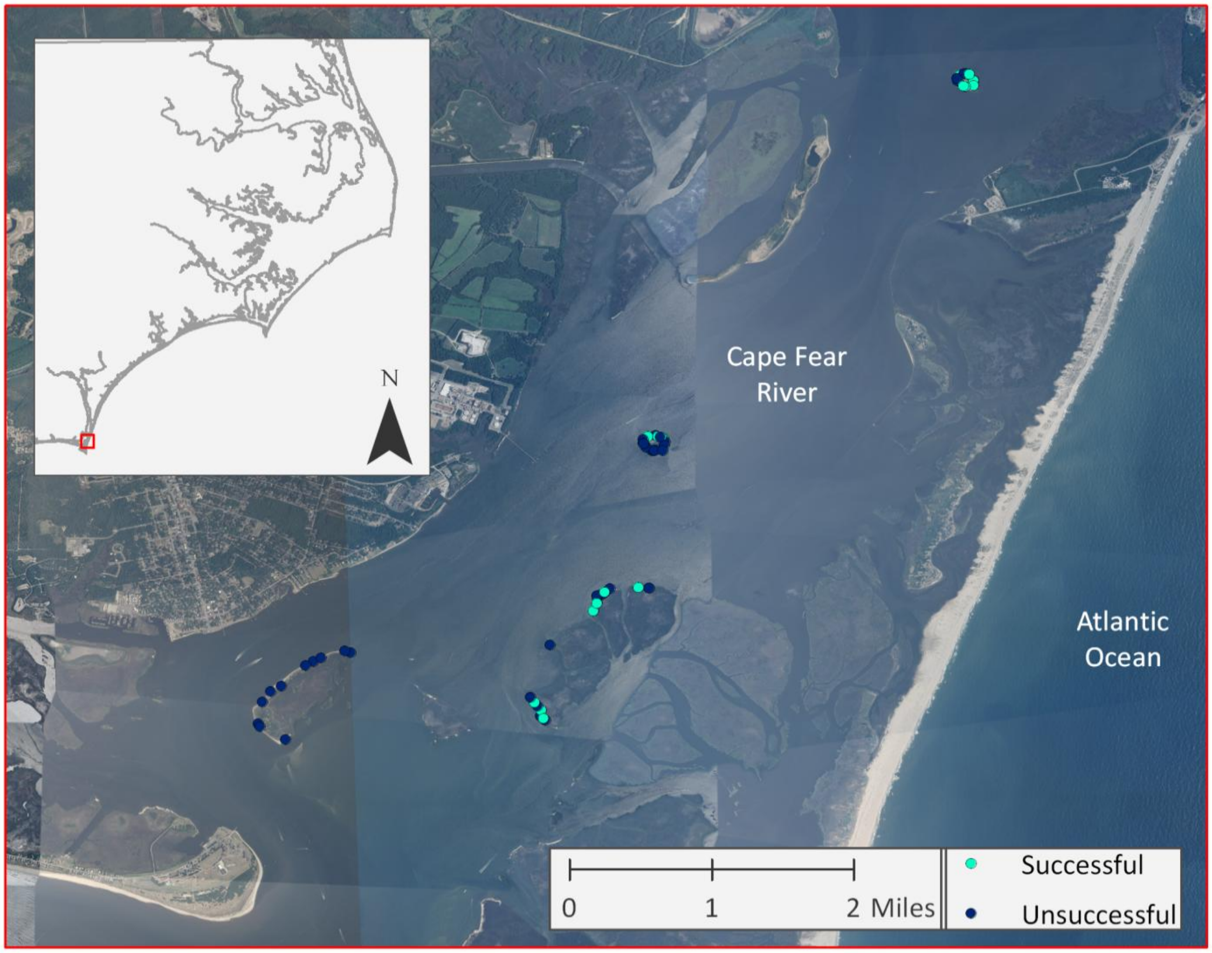


**Figure 6.** Nests in the Cape Fear River islands, monitored by Audubon N.C. Omitted are Lea-Hutaff Island, Masonboro and Masonboro Inlet, none of which fledged chicks.

***Survival Analysis***

Nest survival is often used as a measure of the status of avian populations. It is useful to assess overall population health to determine differences among populations. Several approaches have been used to characterize avian nest success, each with limiting assumptions. The most obvious metric is apparent success (see Table 1), which divides successful nesting attempts by total nesting attempts. This is the least informative approach and is positively biased because some nests fail before they are found.

The Mayfield method (Mayfield 1961, 1975) addressed this positive bias by accounting for exposure days, the number of days a monitored nest is active. The Mayfield method is widely used but relies on the strong assumption that nest survival is constant over the entire nesting interval. Dinsmore (2002) used Program MARK to model covariates in an attempt to explain variation in nest survival. This approach relaxed the biologically unrealistic assumption of constant survival because nest age was included as a covariate in the analysis. Schmidt *et al*. (2010) presented an approach for nest survival analysis in a Bayesian framework using random effects and including a measure of model fit through a Bayesian p-value. In short, Bayesian analysis combines prior knowledge in the form of a distribution with the data to develop a posterior distribution for parameter estimates (Figure 7). Random effects models allow for greater predictive power and a clearer partitioning of unexplained variation in success rates.

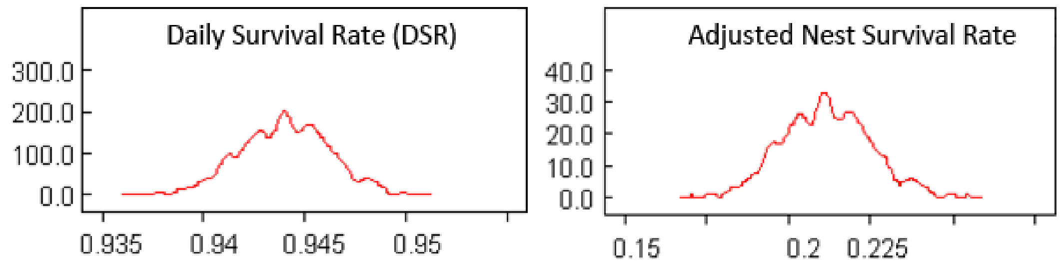


**Figure 7**. Examples of posterior distributions of survival rate using a Bayesian analysis of oystercatcher data produced with the WinBUGS software package (Intercept model).

We adapted Schmidt's model to several years of oystercatcher data, including random effects for Island and Year. The models offered no new biological insights in these preliminary analyses but did provide consistent estimates for common parameters (Table 2). The Deviance Information Criterion (DIC) is used to evaluate model fit in a similar way to the AIC in likelihood analysis (see Gelman and Hill 2007), where a lower value indicates better model fit. For these models, the predictive power of additional effects was minimal, so no further discussion of competing models is provided in this report. Future modeling efforts will examine both fixed effects and the random effects presented here (Table 2). Modeling fixed effects across all years and islands is difficult, so subsets of the data will be considered for future analyses if sample sizes are sufficient. We are particularly interested in modeling the effects of vehicle closures and predator management at Cape Hatteras National Seashore, and position of nests relative to primary dunes on barrier island sites. We will also examine whether accounting for spatial dependence improves models of nesting success.

**Table 2**. Estimates for Daily Survival Rate (DSR), Adjusted Survival Rate, and Significant Effects for each model. Signs (- or +) associated with significant year effects indicate the increase or decrease of the effect on the intercept, or DSR.

| Model Terms | Daily Survival Rate | Adjusted nest survival | Significant Effects | DIC |
|---|---|---|---|---|
| Intercept | 0.9440 (0.0022) | 0.2115 (0.0134) | none | 4820.02 |
| Year | 0.9432 (0.0060) | 0.2092 (0.0355) | 2003 (-), 2005 (+) | 4802.18 |
| Island | 0.9451 (0.0033) | 0.2184 (0.0210) | none | 4820.08 |
| Year + Island | 0.9443 (0.0053) | 0.2151 (0.0318) | 2003 (-), 2005 (+) | 4803.21 |

## MARK-RESIGHT STUDIES

Eleven adult oystercatchers were banded early in the 2010 season. The whoosh net was the primary capture technique, but bal-chatri traps proved more suitable on small shell-rake islands with uneven terrain. Geolocation devices (geolocators) were deployed for a second season in 2010 to track adults' migratory and winter movements. These devices collect data about location of a bird based on the angle of the sun and are accurate to within approximately 150 km. Eight geolocators were attached to the permanent leg bands of adult birds [Green KX, KY, UP, UR, UT, UU, UX, and UY] at Cape Lookout and Cape Hatteras. These devices have an average collection life of 2-3 years. We will begin retrieving geolocators in 2011.

One hundred thirty chicks were banded with the green Darvic pvc bands with unique alphanumeric codes, and three chicks (too small to wear the Darvic bands) were banded with the USGS metal bands. Banding was primarily focused in areas where monitoring took place but also included opportunistic banding when possible (Figure 8). Two banded chicks were found dead after banding of unknown causes; one was found with fishing line wrapped around its feet; one was found after being hit by a vehicle; and one chick was last observed on territory with an injured wing. Thirty-three chicks banded in 2010 have been resighted (observed after leaving the nesting territory) at the time of this report.

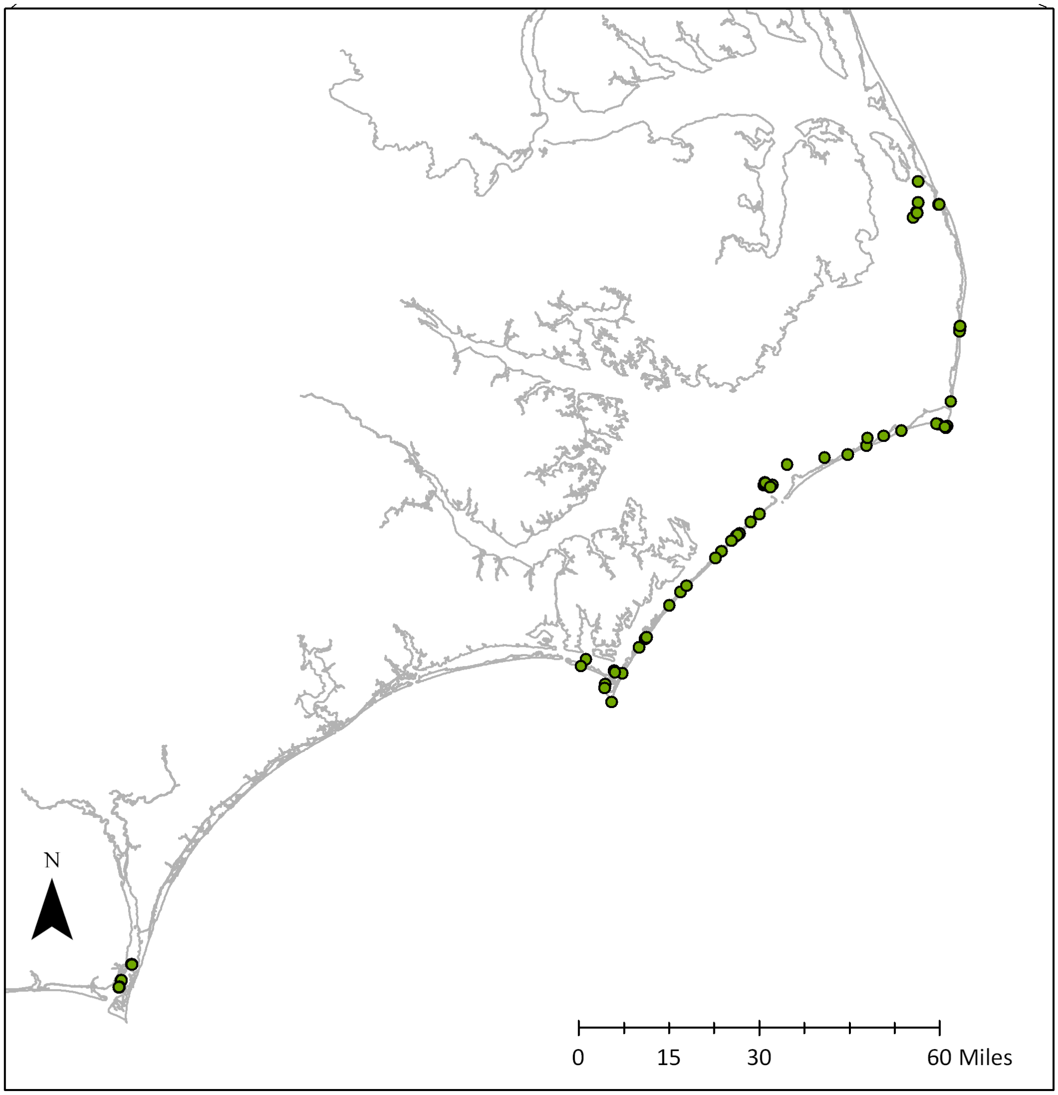


**Figure 8**. Locations of chicks banded in North Carolina in 2010. Primary banding efforts were focused in areas of monitored nests. Some points represent multiple chicks banded in a single brood.

**RACCOON REMOVAL**

Predator management to benefit breeding American Oystercatchers has been identified as a priority management strategy by the American Oystercatcher Working Group (Schulte *et al.* 2007). Raccoon populations on the barrier islands of North Carolina are artificially high because raccoons benefit from the food, water, and shelter provided by humans. Closed systems such as isolated barrier islands provide an ideal opportunity to manipulate predator populations with minimal confounding factors. In this study we are continuing research to evaluate the effects of reducing the raccoon population on South Core Banks, Cape Lookout National Seashore by 50% (Waldstein 2010). Results will be used to inform park management and other American Oystercatcher conservation programs about the costs and benefits of managing predator populations to benefit nesting oystercatchers.

Between 2007 and 2008, 131 raccoons were captured and marked with tags bearing unique alphanumeric combinations; 60 of those animals were also equipped with radio transmitters. Camera trapping of marked animals took place over 12 sampling periods from May 2007 to July 2009. In winter 2008 and spring 2009, 149 raccoons, an estimated one half of the population on the island, were humanely removed from South Core Banks (Waldstein 2010).

In the spring of 2010, we placed radio collars on an additional 12 raccoons, nine males and three females, restoring the number of active radio-collars in the population to 20. Locations were taken on the raccoons during all hours of the day and night, with 436 total locations over the 3-month study period. The 2010 and 2011 summer telemetry will be used as part of a comparison of pre- and post-removal territory qualities. Waldstein (2010) found no significant difference between home range size or overlap after the first season, but this may have been due to inter-year variation. The 2011 season will provide a third year of post-removal data.

Data from camera trapping is used to estimate the size of the raccoon population using capture-recapture methodologies. Cameras were run at night for one week in May, June, and July 2010 for a total of 190 camera trap-nights. We placed seven video cameras at camera trap sites in 2010 to determine the accuracy of camera trap data collected since 2007. The video cameras recorded continuously day and night during the week-long camera trapping sessions in 2010. We are currently comparing the animals captured on video to the animals captured with the camera traps to help us calibrate the population estimates derived from the camera trap data.

Telemetry and camera trapping will continue during the 2011 season to document changes in raccoon behavior and population dynamics following the 2009 removal. Findings will inform management decisions about the long term practicality and benefits of predator removal.

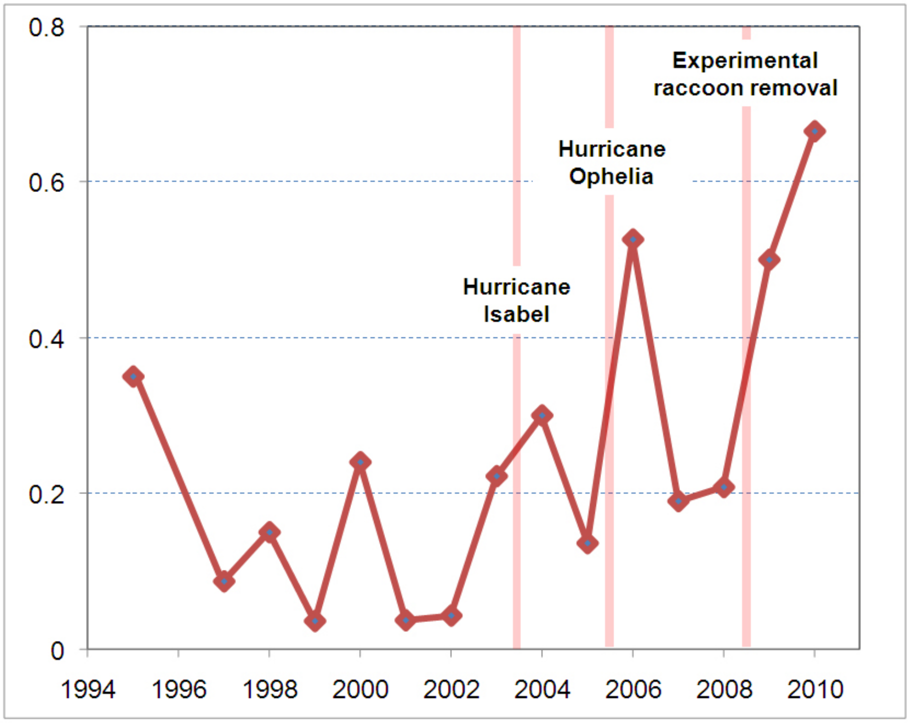


**Figure 9**. Chicks fledged per breeding pair on South Core Banks, illustrating major disturbances in predator populations.

American Oystercatcher nesting success was high on South Core Banks in 2010. Apparent nest success (0.739) was the highest recorded on South Core Banks since monitoring began in 1995 (Figure 9). In addition, more chicks fledged and productivity was higher on the island than in any previous year. Chick survival also increased on Cape Lookout after Hurricane Isabel in 2003 and Hurricane Ophelia in 2005 (Figure 9). These increase likely reflected the combined effects of habitat creation and predator reduction (Simons and Schulte 2009). Productivity gains following raccoon removal on South Core Banks suggests a pattern similar to that observed after major hurricanes. Ongoing monitoring in 2011 will determine whether oystercatcher productivity following predator management will mimic the pattern following hurricanes.

## USE OF NON-TRADITIONAL HABITATS

Historically American Oystercatchers have nested almost exclusively in beach-front habitats (Nol and Humphrey 1994). In recent decades, oystercatchers appear to have increased their use of marsh and sound-side nesting habitats (Frohling 1965, Post and Raynor 1964, Shields and Parnell 1990, Toland 1992, Traut *et al.* 2006). The reproductive success of birds in these novel habitats is variable (Toland 1992, Virzi 2008, McGowan *et al.* 2005). Nesting density depends on habitat type, with higher densities occurring on dredge spoil islands in areas where humans occupy nearby sand beaches (Lauro and Burger 1989, Lauro *et al.* 1992). Although these sites could provide valuable alternative nesting habitat as beach sites become unsuitable for oystercatchers, the quality of non-traditional nesting habitats is largely unknown.

This study attempts to describe some of the life history changes associated with nesting on interior sites. We increased monitoring of non-traditional sites in 2009, and that effort was continued in 2010. These sites included the dredge spoil islands in Oregon Inlet, shell islands in Ocracoke Inlet and dredge and shell islands in the Cape Fear River. In 2011, we will continue monitor nesting success at traditional and non-traditional nesting sites across the coastal region of NC, from Oregon Inlet to Cape Fear. We will measure nesting success, chick growth, fledging age and condition, and chick survival to evaluate differences in the breeding biology of oystercatchers using traditional and non-traditional nesting habitats. This information will help identify habitats serving as population sources or sinks so that future management and habitat acquisition efforts can be targeted to provide the greatest population level response.

***Chick Growth rates***

Estimating chick growth rates generally requires a series of measurements during a chick's development. It is often difficult to obtain multiple measurements of American Oystercatcher chicks because their mobility and cryptic plumage can make them very difficult to find after they are only a few days old. We attempted to measure individual chicks multiple times during the 2010 season, in the hopes of comparing average growth rates of chicks from barrier and interior territories. This did not prove feasible in Oregon or Ocracoke Inlets, where logistics make approaching birds substantially more difficult than on the barrier islands. At these sites, we were able to handle chicks a single time for measurements. We attempted to measure a point measurement on the linear portion of the growth curve (day 25) for all broods. The following measurements were recorded for all chicks approximately 25 days after hatching: weight, exposed culmen length, tarsus length and wing chord (Figure 10).


**Figure 10.** Culmen measurement of a young chick. Several measurements were taken for the purposes of comparing the growth rate of chicks in traditional and non-traditional habitats. (Photo: K. Caldwell)

Figure 11 illustrates preliminary results for wing chord growth. The measurement data were divided into two classes: Barrier and Non-traditional sites. This division is less than ideal, because we expect dredge islands to have a different growth response than natural (marsh and low shell) islands; the latter has foraging territories that are non-contiguous with nesting territories (Ens et al. 1992). Both dredge and natural interior islands are lumped as non-traditional in this analysis, due to the small number of chicks measured in each of those sub-categories. Also, we only included in this analysis chicks that were 20 days or older, due to the small number of chicks measured prior to that age. Measuring chicks at a given day (25) was accomplishable on the barrier islands but not on the interior sites. The result is that the distribution of ages at which we measured chicks is not equal (Figure 12), reducing the potential power of comparison for Figure 11. The “clumping” of the measurements at days 22 and 25 for non-traditional and barrier sites, respectively, gives the few points on the ends of the age distribution undue influence on the slope of the regression lines (Figure 12). Multiple weights per chick will provide individual growth lines, and sampling across the pre-fledging interval will make a comparison of slopes more meaningful.

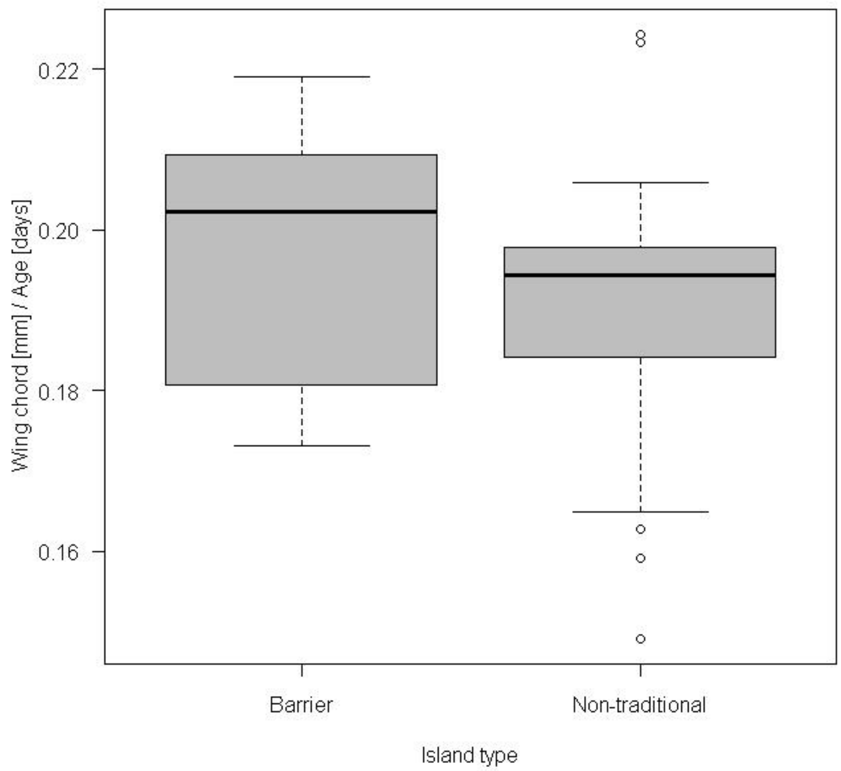


**Figure 11**. Boxplot of wing chord length divided by age for chicks from barrier (n=35) and non-traditional islands (n=18). Most of the non-traditional sites were naturally formed shell islands, where food is more readily available than on dredge islands. We will focus in 2011 on the difference between dredge and barrier sites, where we expect the greatest difference in chick growth.

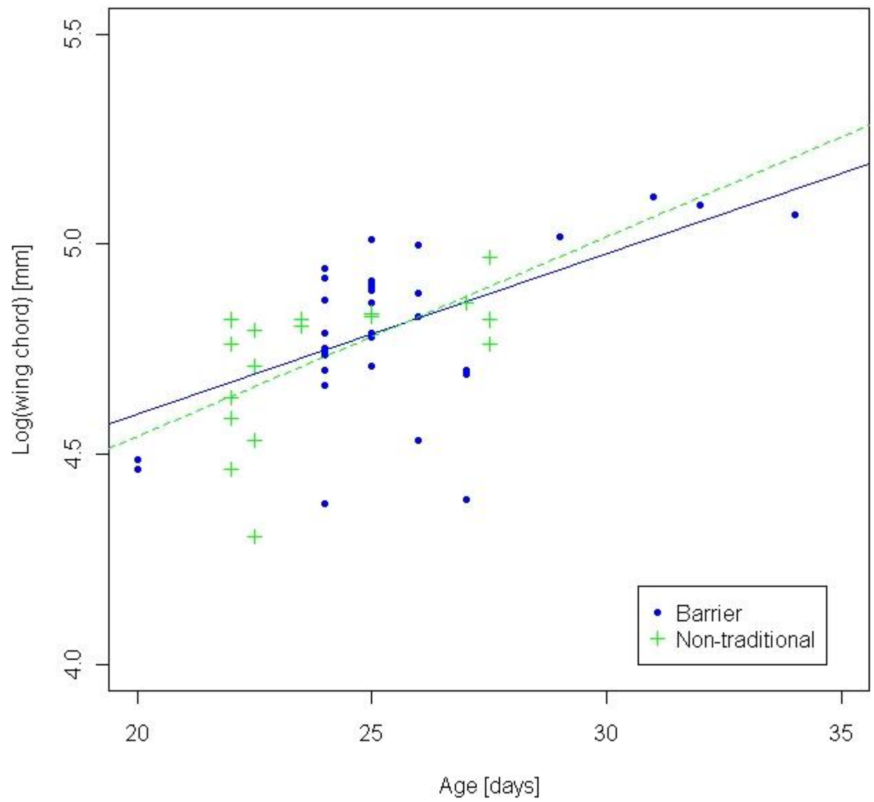


**Figure 12**. Wing chord (log transformed) and regression on Age for chicks at barrier (blue circles and solid line) and non-traditional (green pluses and dashed line) sites. The data points are clumped around 25 and 22 days for the two types of site, giving the points outside of the clumps undue influence on the slope of the line.

In 2011, we will attempt multiple weights on chicks from two dredge islands in the Cape Fear River. Those islands had not previously been attempted because nests are very close together and broods become very difficult to distinguish after chicks leave the nests. We plan to mark hatchlings in 2011 to identify broods and thus accurately determine the age of the chicks. This should provide us with sufficient samples to directly compare the growth rates of chicks from dredge and barrier islands.

J. Stocking

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Appendix 1: American Oystercatcher productivity in North Carolina from 1995-2009

| Year and Location | Breeding pairs | Nests | Nests hatched | Nest survival observed (SE) | Nest survival adjusted (SE) | Chicks fledged | Chick Survival (SE) | Chicks fledged/ breeding pair (SE) |
|---|---|---|---|---|---|---|---|---|
| CAPE LOOKOUT | | | | | | | | |
| North Core Banks | | | | | | | | |
| 1998 | 38 | 72 | 5 | 0.069 (0.030) | NA | 4 | NA | 0.105 (0.062) |
| 1999 | 39 | 61 | 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) |
| 2009 | 29 | 40 | 7 | 0.175 (0.060) | 0.188 (0.056) | 8 | 0.533 (0.129) | 0.276 (0.121) |
| 2010 | 31 | 58 | 16 | 0.276 (0.059) | 0.299 (0.056) | 14 | 0.467 (0.091) | 0.452 (0.089) |
| 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) |
| 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) |
| 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 | 17 | 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) |
| 2009 | 22 | 30 | 11 | 0.367 (0.088) | 0.374 (0.084) | 11 | 0.500 (0.107) | 0.500 (0.170) |
| 2010 | 23 | 43 | 10 | 0.233 (0.064) | 0.269 (0.062) | 17 | 0.680 (0.093) | 0.739 (0.092) |
| 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 (0.111) |
| 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) |
| 2009 | 10 | 13 | 2 | 0.154 (0.100) | 0.119 (0.078) | 2 | 0.667 (0.272) | 0.200 (0.200) |
| 2010 | 23 | 43 | 10 | 0.233 (0.064) | 0.269 (0.062) | 17 | 0.680 (0.093) | 0.739 (0.092) |
| **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) |
| 2009 | 4 | 6 | 2 | 0.333 (0.192) | 0.400 (0.212) | 0 | 0.000 (0.000) | 0.000 (0.000) |
| 2010 | 4 | 6 | 5 | 0.833 (0.152) | 0.849 (0.139) | 3 | 0.333 (0.147) | 0.750 (0.217) |
| 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 | 24 | 13 | 0.542 (0.102) | 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) |
| 2009 | 13 | 19 | 11 | 0.579 (0.113) | 0.555 (0.109) | 9 | 0.429 (0.108) | 0.692 (0.263) |
| 2010 | 15 | 17 | 13 | 0.765 (0.103) | 0.763 (0.103) | 23 | 0.719 (0.079) | 1.533 (0.233) |
| 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) |
| 2009 | 4 | 4 | 1 | 0.250 (0.217) | 0.274 (0.205) | 1 | 0.500 (0.354) | 0.250 (0.250) |
| 2010 | 1 | 2 | 1 | 0.500 (0.354) | 0.477 (0.353) | 0 | 0.000 (0.000) | 0.000 (0.000) |
| 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) |
| 2009 | 2 | 2 | 1 | 0.500 (0.354) | NA | 3 | 1.000 (0.000) | 1.500 (0.882) |
| 2010 | 3 | 3 | 2 | 0.667 (0.272) | 0.529 (0.337) | 4 | 0.667 (0.192) | 1.333 (0.385) |
| 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) |
| 2009 | 57 | 62 | 42 | 0.677 (0.059) | 0.509 (0.075) | 27 | 0.435 (0.063) | 0.474 (0.094) |
| 2010 | 50 | 63 | 39 | 0.619 (0.061) | 0.570 (0.071) | 37 | 0.514 (0.059) | 0.740 (0.062) |

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|---|---|---|---|---|---|---|---|---|
| Lea and Hutaff Islands | | | | | | | | |
| 2003 | 16 | 16 | 11 | 0.688 (0.116) | 0.617 (0.133) | 9 | 0.391 (0.102) | 0.563 (0.203) |
| 2009 | 18 | 22 | 4 | 0.182 (0.082) | 0.085 (0.050) | 1 | 0.143 (0.132) | 0.056 (0.056) |
| 2010 | 14 | 18 | 0 | 0.000 (0.000) | 0.006 (0.008) | 0 | 0.000 (0.000) | 0.000 (0.000) |
| **INLET ISLANDS** | | | | | | | | |
| Ocracoke Inlet Islands | | | | | | | | |
| 2009 | 15 | 23 | 7 | 0.304 (0.096) | 0.358 (0.102) | 2 | 0.167 (0.108) | 0.133 (0.091) |
| 2010 | 16 | 19 | 15 | 0.789 (0.094) | 0.859 (0.092) | 21 | 0.677 (0.084) | 1.313 (0.160) |
| Oregon Inlet Islands | | | | | | | | |
| 2009 | 11 | 12 | 10 | 0.833 (0.108) | 0.806 (0.123) | 7 | 0.350 (0.107) | 0.636 (0.279) |
| 2010 | 10 | 11 | 6 | 0.545 (0.150) | 0.537 (0.167) | 4 | 0.400 (0.155) | 0.400 (0.155) |
| **SUMMARY** | **1411** | **2095** | **667** | **0.318 (0.010)** | **0.278 (0.010)** | **531** | **0.424 (0.014)** | **0.376 (0.013)** |