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.

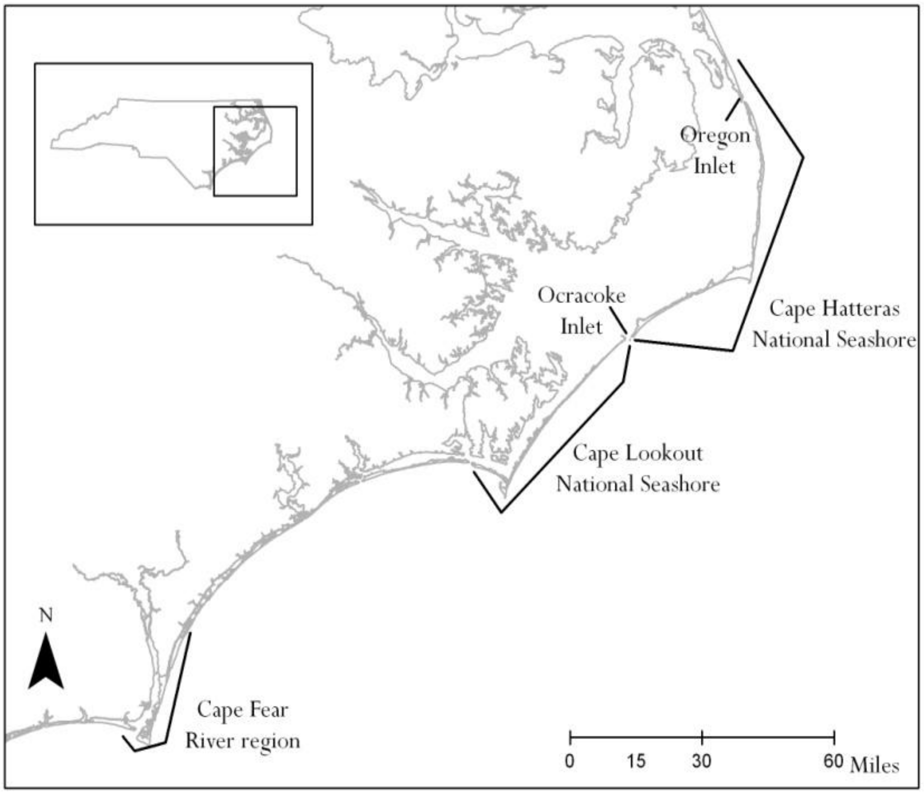

Figure 1. Regions of American Oystercatcher monitoring in North Carolina.

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

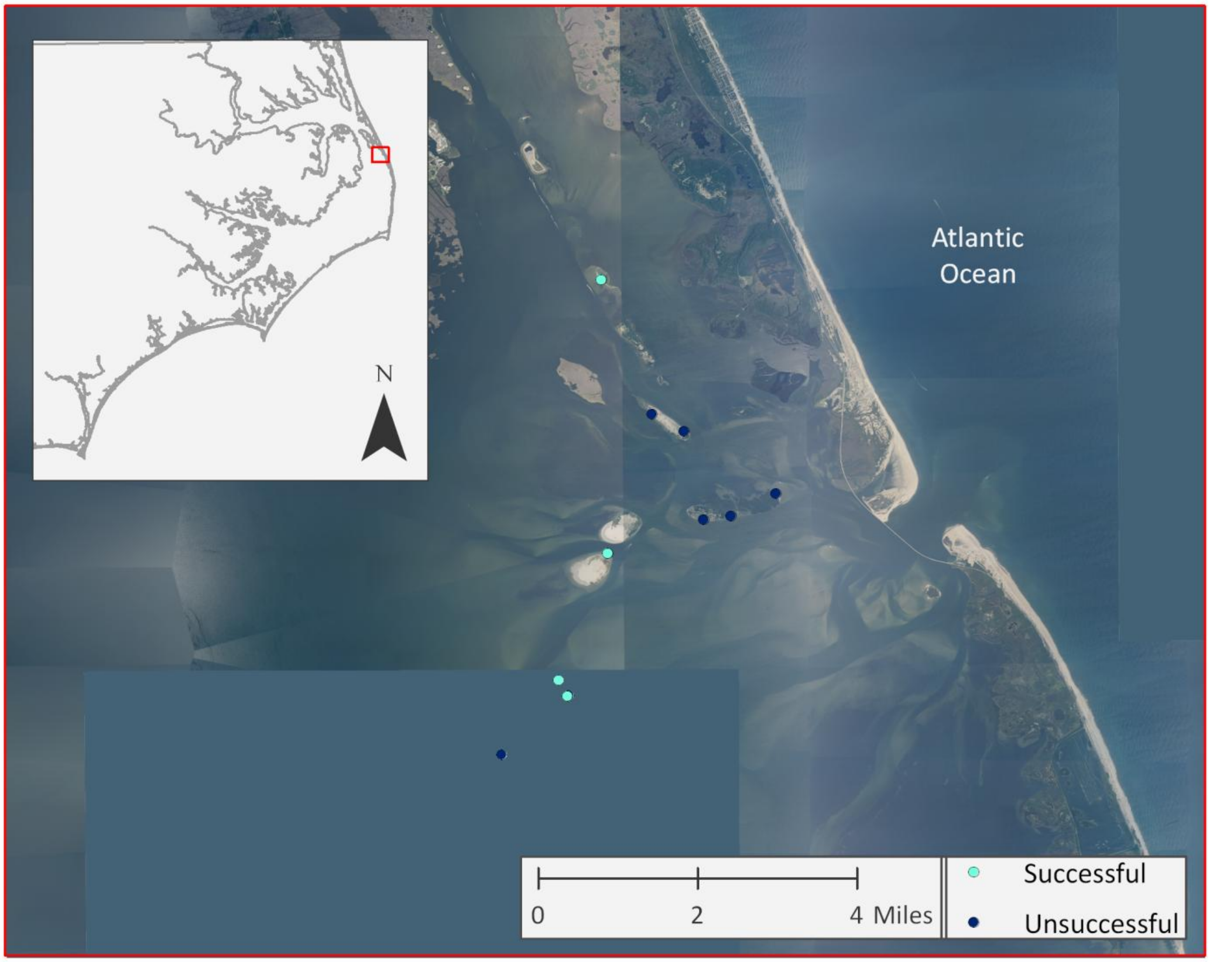

Figure 2. Oregon Inlet nests, monitored by N.C. Wildlife Resources Commission. This inlet is bordered by Bodie Island to the north and Hatteras Island to the south. (Note: Some islands are not shown in aerial photo; nests represent actual locations.)

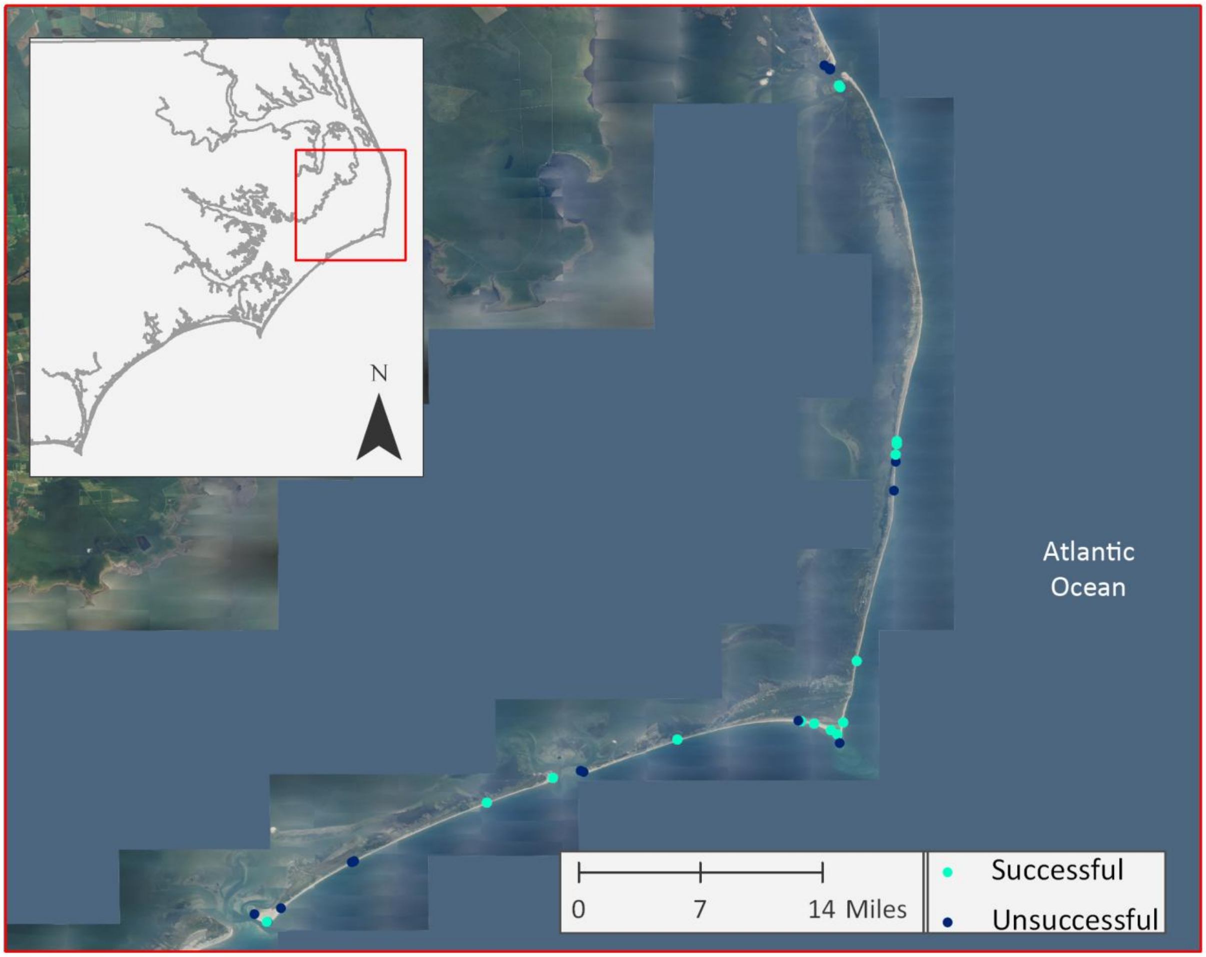

Figure 3. Cape Hatteras National Seashore nests, monitored by the National Park Service.

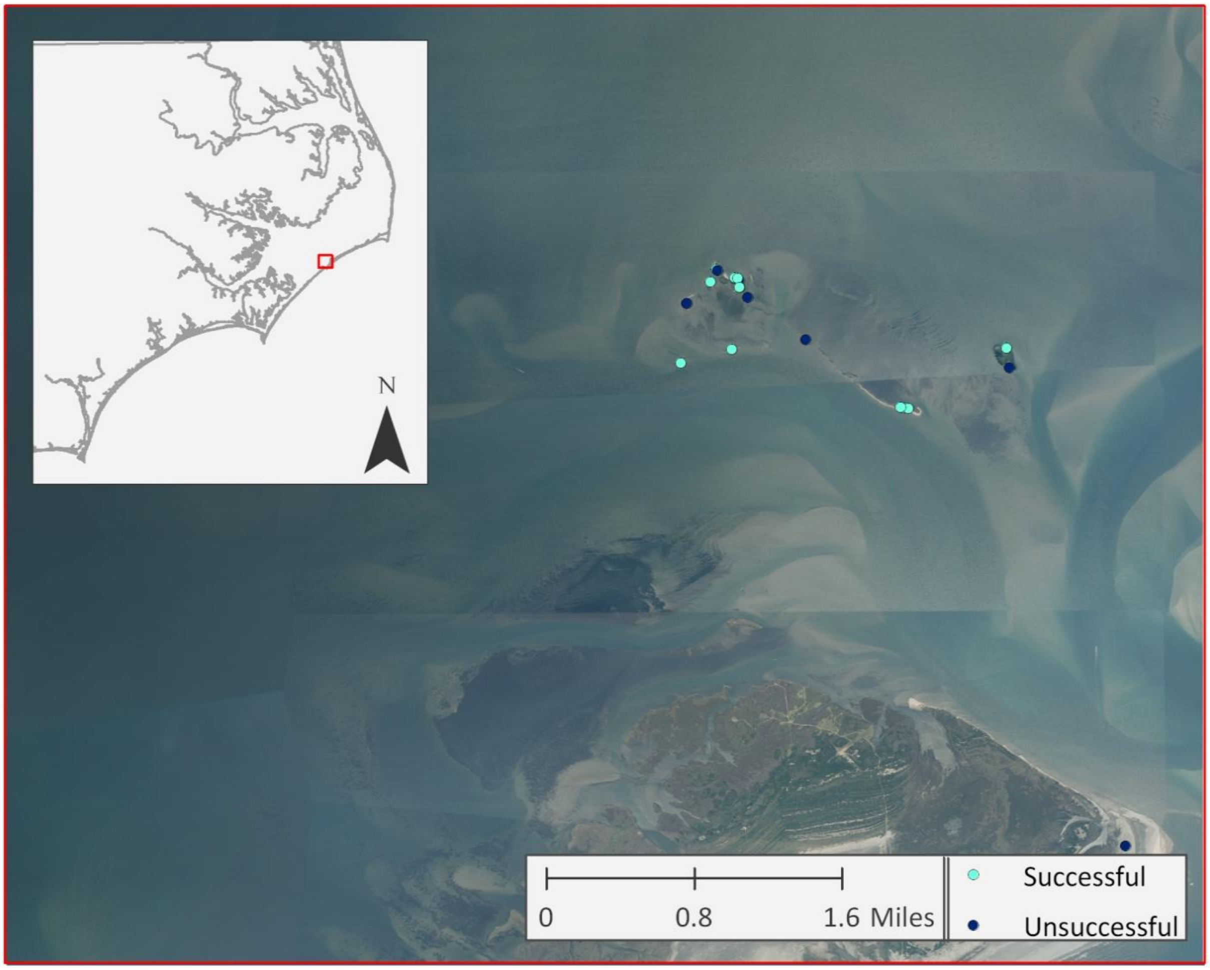

Figure 4. Ocracoke Inlet nests, monitored by Audubon NC. These are shell islands located in the inlet between Ocracoke Island and North Core Banks.

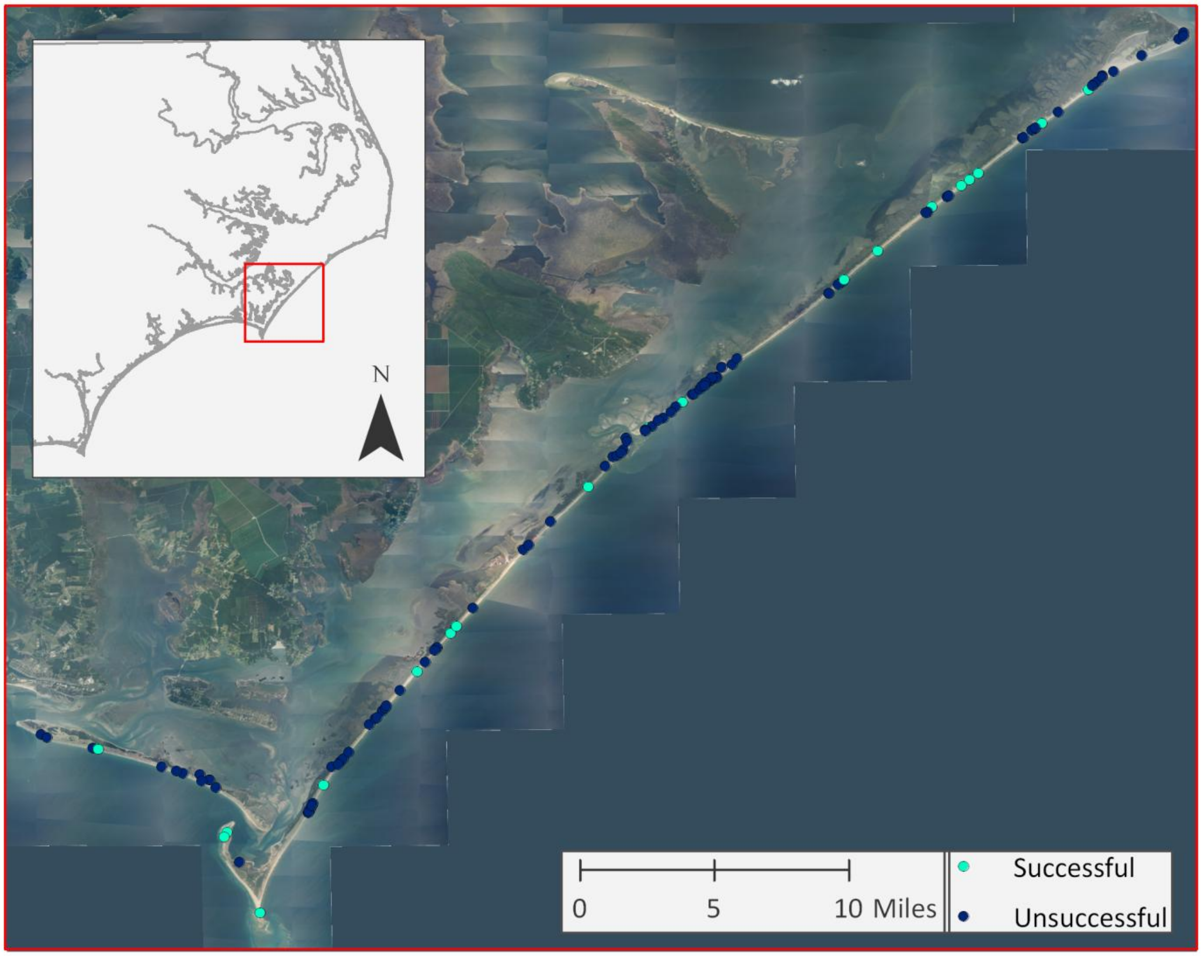

Figure 5. Cape Lookout National Seashore nests, monitored by the National Park Service.

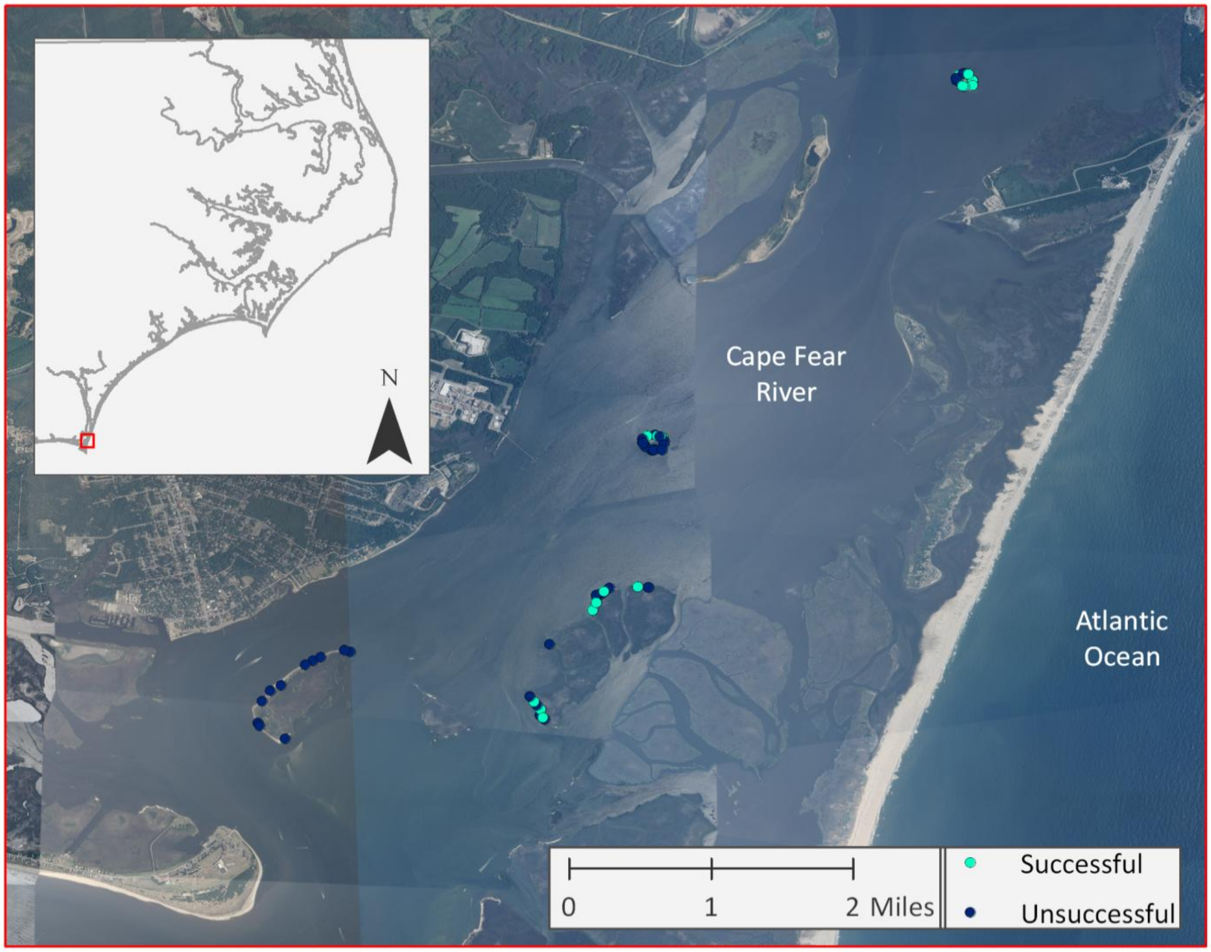

Figure 6. Nests in the Cape Fear River islands, monitored by Audubon N.C. Omitted are Lea-Hutaff Island, Masonboro and Masonboro Inlet, none of which fledged chicks.

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.

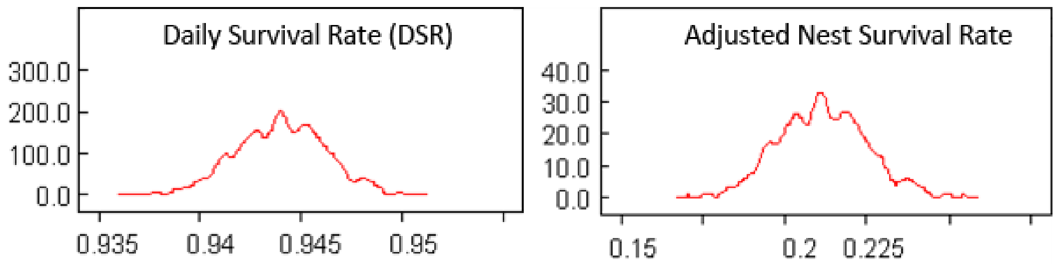

Figure 7. Examples of posterior distributions of survival rate using a Bayesian analysis of oystercatcher data produced with the WinBUGS software package (Intercept model).

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.

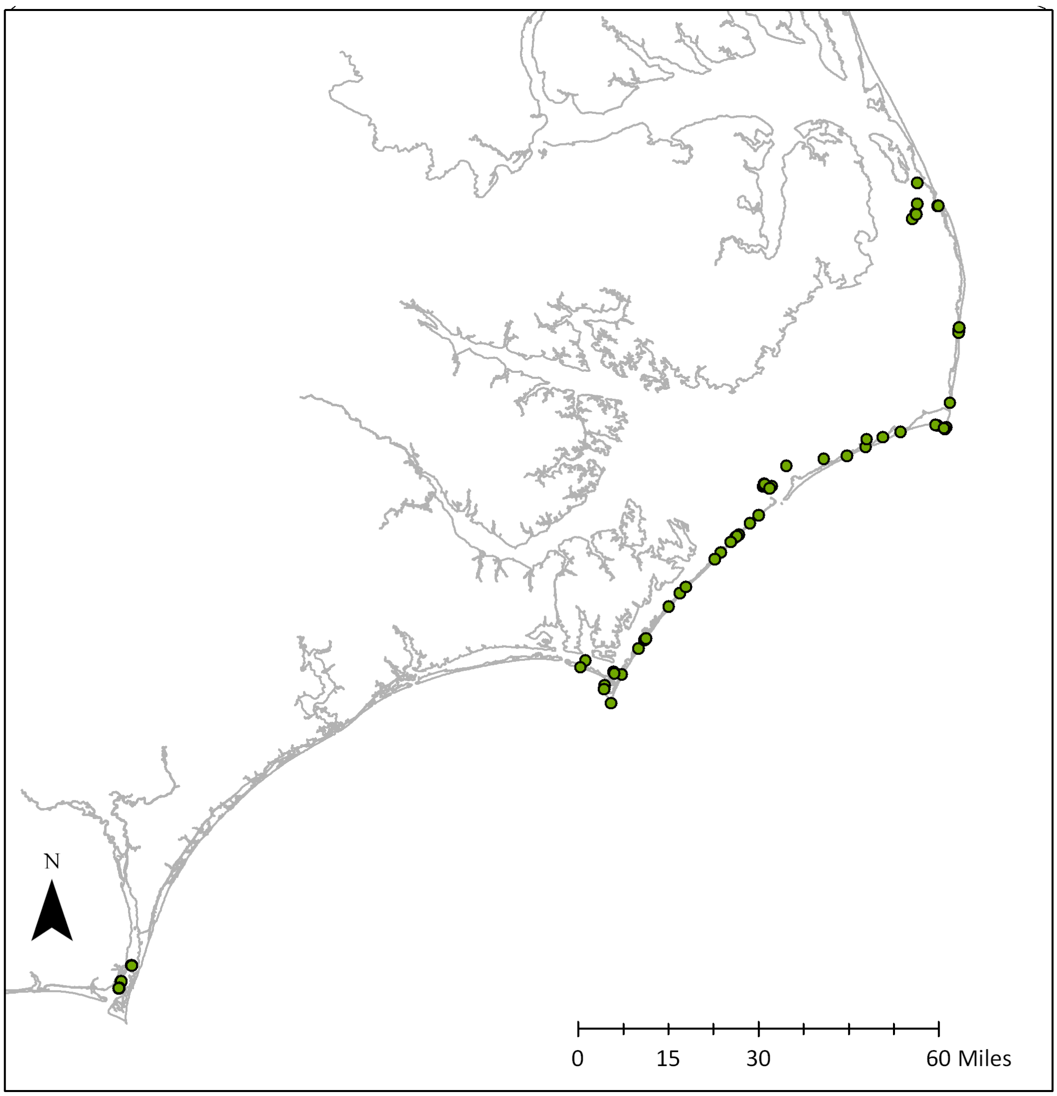

Figure 8. Locations of chicks banded in North Carolina in 2010. Primary banding efforts were focused in areas of monitored nests. Some points represent multiple chicks banded in a single brood.

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.

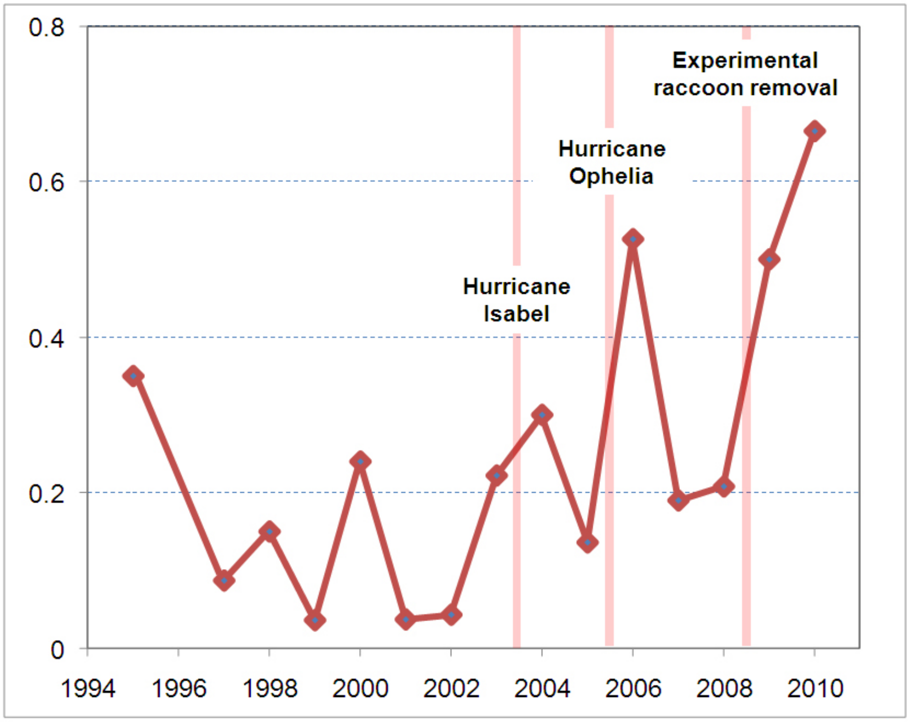

Figure 9. Chicks fledged per breeding pair on South Core Banks, illustrating major disturbances in predator populations.

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.

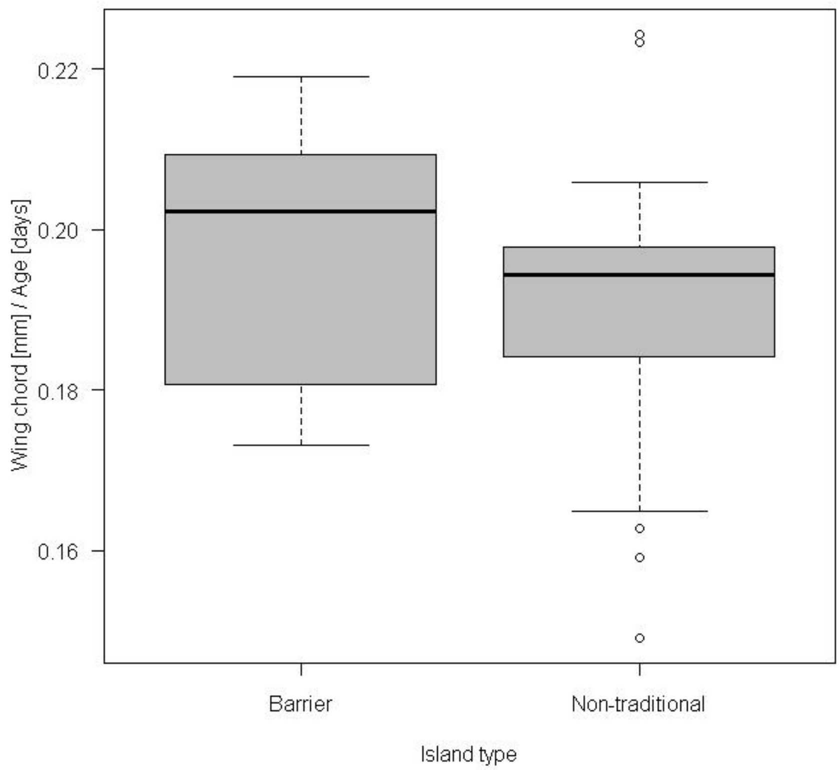

Figure 11. Boxplot of wing chord length divided by age for chicks from barrier (n=35) and non-traditional islands (n=18). Most of the non-traditional sites were naturally formed shell islands, where food is more readily available than on dredge islands. We will focus in 2011 on the difference between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

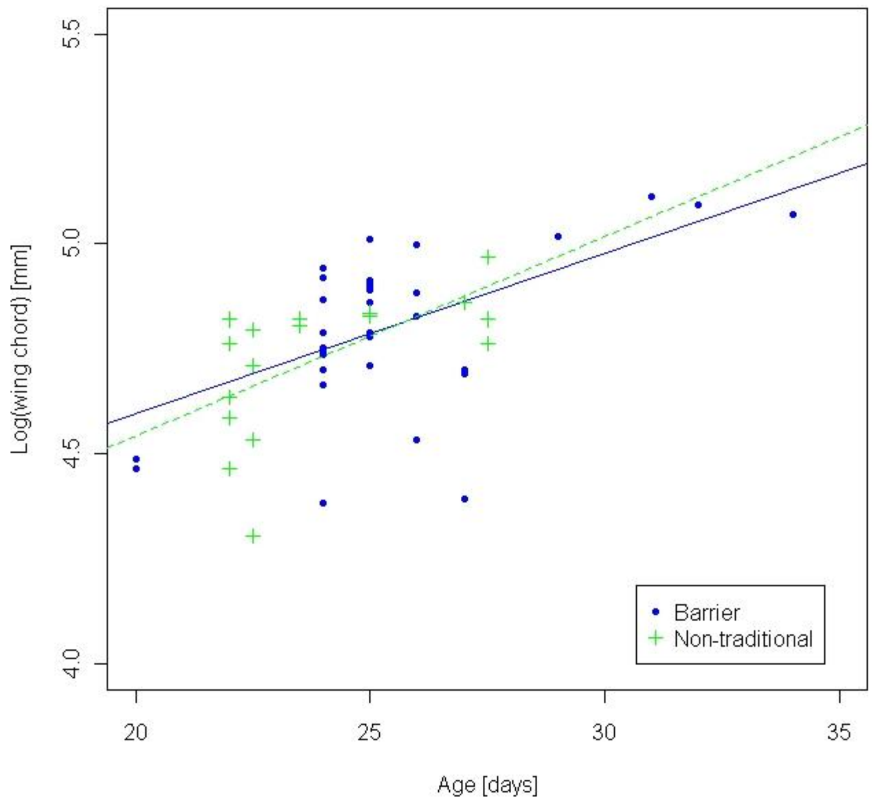

Figure 12. Wing chord (log transformed) and regression on Age for chicks at barrier (blue circles and solid line) and non-traditional (green pluses and dashed line) sites. The data points are clumped around 25 and 22 days for the two types of site, giving the points outside of the clumps undue influence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

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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)

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)**