From:	Mike Murray
To:	Sandra Hamilton; Doug Wetmore
Subject:	Fw: AMOY buffer distances
Date:	05/20/2010 03:12 PM
Attachments:	Camera Set-up Nest 1_for email.JPG Camera Bucket.JPG Camera Bucket_no shelf.JPG 2009_NC_AMOY_Report_2 with changes Ted.pdf Schulte and Simons AMOY Reproduction Draft 05_19_10.doc Simons Thoughts on CAHA Disturbance Study.docx

FYI

Mike Murray
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----- Forwarded by Mike Murray/CAHA/NPS on 05/20/2010 05:06 PM -----

"Ted Simons" <tsimons@ncsu.edu>

05/20/2010 04:49 PM

To <Mike_Murray@nps.gov>
cc <Britta_Muiznieks@nps.gov>, <Thayer_Broili@nps.gov>
Subject RE: AMOY buffer distances

Hello Mike,

I will respond briefly to your questions below and I would be happy to meet with you to discuss any of the these topics in more detail. In general my thoughts about buffer distances have not changed from the comments (Simons thoughts...attached) I sent you last year. The data available to date on flushing distances are limited and they are quite difficult to interpret because you will get different answers for different birds and with different sampling methods. I think we can all agree that there is a cost for an incubating bird when it is unnecessarily flushed from its nest during incubation. Conor McGowan and I showed that more frequent flushing was associated with higher nest predation rates, but we have all seen individual Oystercatchers who will sit tight with a steady stream of vehicles passing within 50m of their nest. In general, birds respond most readily to pedestrians, dogs, and ATV's and less to vehicles. Other contributing factors are the stage of incubation, the speed of the vehicle, and the noise level associated with the disturbance. This variability is behind the conservative buffer distances recommended by Sabine and Erwin et al.

We have started new research at CALO this spring that will help us understand disturbance factors of Oystercatchers much better. We are using continuous video monitoring of nests to examine the response of incubating birds to military overflights, vehicles, people, and other forms of disturbance. We will deploy as many as 50 cameras over the next two years to document these different forms of disturbance and the response of the birds. We are also making continuous sound recordings and these nests and monitoring the heart rate of incubating birds by adding dummy eggs with imbedded microphones and sound recorders to some of the video-monitored nests. This will allow us to quantify the behavior and physiological responses of birds to different types of disturbance. Photos of the cameras are attached.

I have also attached a copy of our 2009 American Oystercatcher Research summary report and a draft manuscript summarizing what we have learned about factors affecting the reproductive success that is currently in review in Waterbirds.

I am quite excited to be working with the staff at CALO and an NPS team in Ft. Collins on the development of an adaptive management approach as part of their ORV management planning process. The idea is to develop the plan under an ARM framework that establishes demographic (abundance, fecundity, survival) triggers for key species, including AMOY, that will result in management actions. Possible management actions include varying the number of permitted vehicles on the island, manipulating buffers and vehicle closures, and managing trash, by-catch, and predators. This approach will give greater flexibility in managing individual nests, and importantly, it will focus on population level objectives rather than managing at the level of an individual nest. I am happy to discuss this approach with you in greater detail if you are interested.

Other comments below. Please let me know if you would like more information or if you would like to meet to discuss these issues in greater detail.

Sincerely,

Ted

Ted Simons
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-----Original Message-----
From: Mike_Murray@nps.gov [mailto:Mike_Murray@nps.gov]
Sent: Wednesday, May 19, 2010 5:20 PM
To: Ted Simons
Cc: Britta_Muiznieks@nps.gov; Thayer_Broili@nps.gov
Subject: AMOY buffer distances

Ted,

I've included the email history below to refresh your memory of our earlier discussions regarding buffer distances during AMOY nest incubation and whether there is sufficent information to support a smaller "drive-by" buffer distance for vehicles driving past an incubating AMOY nest that is less than the full buffer (e.g., 137 m or 150 m) recommended by Sabine or USGS respectively.

As a result of comments received on our draft ORV management plan/EIS (DEIS), I have several questions on which I would appreciate hearing your professonal opinion.

Question #1: See page 2, item # 2 in the attached NC Wildlife Resource Commissions comments (on our DEIS) recommending "drive-through corridors for SMA closures". In your professional opinion, is such a buffer supported by any research or currently available information, including the research mentioned by WRC?

I ASSUME THE "DRIVE-THROUGH CORRIDORS" ARE PROPOSED DURING THE CHICK REARING PERIOD AS A WAY TO ALLOW VEHICLE ACCESS DURING THIS STAGE OF THE NESTING PERIOD. WE HAVE FOUND THAT CHICKS ARE VERY VULNERANBLE TO VEHICLES BEFORE THEY FLEDGE AT ABOUT 35 DAYS OF AGE. CORRIDORS, ESCORTED VEHICLES AND OTHER MITIGATING MEASURES ARE UNLIKELY TO SOLVE THIS PROBLEM BECAUSE IT IS VERY DIFFICULT TO SEE THE CHICKS WHICH OFTEN HIDE IN VEHICLE TRACKS AND DEBRIS ON THE BEACH.

Would there be a sound basis for allowing a 50 meter buffer for ORVs travelling past an AMOY nest? Would such a buffer provide adequate protection such that the nest is unlikely to be negatively impacted by disturbance?

AS I MENTIONED, THE CURRENT 150 M BUFFERS WERE PROPOSED AS A CONSERVATIVE ESTIMATE OF THE DISTANCE REQUIRED TO MINIMIZE DISTURBANCE OF INCUBATING BIRDS. INDIVIDUAL BIRDS WILL SHOW DIFFERENT TOLLERANCES, BUT AS I MENTIONED ABOVE THIS WILL VARY WITH THE BIRD, THE STAGE OF INCUBATION, AND THE TYPE OF DISTURBANCE. WE DO NOT HAVE DATA TO INDICATE THAT A 50 M BUFFER WOULD ENSURE THAT A NEST IS UNLIKELY TO BE NEGATIVELY IMPACTED BY DISTURBANCE.

Question # 2: Numerous other commenters suggested that we utilize a "a flush + 15 meter buffer" buffer for AMOY nests (rather than 150 m), pressumably to allow for more flexibility of access for ORVs and/or pedestrians. In your professional opinion, is such a buffer (flush + 15 m) supported by prior research or currently available information? Would there be a sound basis for allowing a "flush + 15 meter" buffer for an AMOY nest? Would such a buffer provide adequate protection such that the nest is unlikely to be negatively impacted by disturbance?

AGAIN, BIRDS WILL SHOW DIFFERENT RESPONSES DEPENDING ON THE TYPE OF DISTURBANCE, THEIR INDIVIDUAL TOLLERANCES, AND THE STAGE OF THE NESTING CYCLE. WE HAVE NO EVIDENCE THAT "FLUSH + 15 METER BUFFER" WILL ENSURE THAT A NEST IN UNLIKELY TO BE NEGATIVELY IMAPACTED BY DISTURBANCE.

(See attached file: NCWRC.Comments.051110.pdf)

I would apapreciate hearing your opinion on these issues.

Thank you,

Mike Murray
Superintendent

"Ted Simons"
<tsimons@ncsu.edu>

05/27/2009 04:20 PM

To: <Mike_Murray@nps.gov>

cc: <Darrell_Echols@nps.gov>, <Thayer_Broili@nps.gov>, <Britta_Muiznieks@nps.gov>

Subject: RE: AMOY research proposal

Hi Mike,

Here are some thoughts on possible future studies of AMOY disturbance at CAHA (Simons thoughts.... attached). I have also attached some related publications and a sample research budget. Please let me know if you would like to set up a time to talk about this in more detail. I'm happy to drive down for a visit if that would be helpful.

Regards,

Ted

Ted Simons

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-----Original Message-----
From: Mike_Murray@nps.gov [mailto:Mike_Murray@nps.gov]
Sent: Friday, May 22, 2009 3:51 PM
To: tsimons@ncsu.edu
Cc: Darrell_Echols@nps.gov; Thayer_Broili@nps.gov; Britta_Muiznieks@nps.gov
Subject: AMOY research proposal

Hi Ted,

We have a possible research project we'd like to get your thoughts on.

Background: My understanding is that the recommended nest buffer of 150 meters in the USGS protocols for American oystercatcher (AMOY) nests was based, in part, on John Sabine's study at Gulf Islands NS (2005 thesis). The buffer, as recommended by USGS, applies to ALL recreational activities (i.e., ORVs and pedestrians). In reading through Sabine's thesis on American oystercatchers (particularly Chapter 4, Effects of Human Activity on Behavior of Breeding American Oystercatchers) there are a number of statements indicating a marked difference between observed pedestrian and vehicular disturbance during nest incubation (i.e., suggesting that pedestrian disturbance is much more of a concern than vehicular disturbance during incubation; while vehicular disturbance is clearly a concern when chicks are present). Sabine's study makes a strong case for the pedestrian buffer of 137 m or more during incubation, but does not seem to make the same case for completely restricting all vehicular activity within 150 m of a nest during incubation. For example:

Page 45: "During incubation, pedestrian activity ?137 m of subjects reduced the proportion of time devoted to reproductive behavior, but pedestrian activity 138-300 m had no effect. Vehicular and boat activities had minimal effects on oystercatcher behavior during incubation."

Page 88 (Management Recommendations): "Although presence of vehicular activity altered behavior during incubation, reproductive behavior was not negatively impacted, suggesting that vehicular activity at CINS in 2003 and 2004 did not negatively impact hatching success. During brood rearing, foraging behavior was lower in the presence of vehicular activity, which may alter chick provisioning and ultimately chick survival. To minimize impacts on adult foraging behavior, I recommend the prohibition of beach driving in oystercatcher territories (within 150 m) when chicks are present . At all other times, beach driving should be limited to well below the high tide line and speeds should be limited to 10 mph or less, so drivers have ample time to see and react to birds in the path of travel." (underlining added for emphasis)

The apparent contrast between pedestrian disturbance and vehicular disturbance described in Sabine 2005 does not seem to support the recommendation of an absolute 150 m buffer for ALL recreation during AMOY incubation that is found in the USGS protocols (perhaps other references provided the basis for the 150 m vehicular restriction during incubation?). In managing the beach at Cape Hatteras, there are limited occasions in which being able to allow vehicles to pass some appropriate buffer distance from an AMOY nest during incubation (i.e., NOT when chicks are present) would be beneficial, provided the buffer distance is sufficient to prevent negative impacts from disturbance. For example, if a 150 m buffer for such a nest were to block the only means of access to an important recreation site such as Cape Point and if a lesser buffer for the activity of driving past the site to reach the open area beyond the closure were adequate to prevent disturbance during incubation (assuming that a full beach closure would occur when chicks are present), it could reduce the overall length of time that popular sites (such as Cape Point) were inaccessible to the public and could decrease public resentment about the duration and impact of the closures.

Research Project Concept: To follow up on specific negotiated rulemaking discussions that occurred during natural resources subcommittee meetings (which included Walker Golder among other stakeholders), I am interested in having research done at Cape Hatteras in the next few years that would evaluate the effectiveness/adequacy of having a buffer of less than 150 m for ORVs driving past AMOY nests during the incubation. My intent is to definitively determine for Cape Hatteras whether there may be limited, definable circumstances under which it may be appropriate to allow vehicles to drive past by an AMOY nest at a distance less than 150 m. Under what circumstances or conditions, if any, would a reduced buffer for vehicles driving by be effective/adequate? Under said conditions, what would be the effective/appropriate vehicular buffer size during incubation? Would restricting vehicles to traveling below the high tide line during incubation be adequate as p. 88 in Sabine's thesis suggests? Would controlling or restricting the number of vehicles per hour, or limiting travel time to limited time periods per hour, or would manipulating any other variable(s) within management control make a difference?

Underlying Management Objectives:

Ensure adequate protection of incubating AMOY nests

Determine if a reduced buffer distance (i.e., less than 150 m) for ORVs driving past an incubating AMOY nest is adequate to prevent disturbance and, if it is, determine what distance is adequate OR

Determine that a reduced buffer is NOT adequate (and put this issue to rest)

Questions:

Do you believe that such a study could produce the specific results the park would need for practical management purposes, or would it possibly only indicate that there is such variability in individual bird's reactions to ORV disturbance during incubation that the only way to prevent disturbance is to use the same conservative buffer size for all human disturbance situations?

Is there an adaptive management approach to managing these specific situations (AMOY nest buffer blocking the only access to an inlet or Cape Point, when the inlet or point itself is otherwise "open") that could be designed to determine the appropriate effective ORV "drive-by" buffer distance over time?

Request for a Proposal: If you believe that such a study could lead to a practical differentiation in buffer size for ORVs driving past an incubating nest vs. the buffer size needed to prevent disturbance from other human activities, I would appreciate it if you would develop a research proposal, with estimated costs, for such a study so that the Seashore can seek funding for it. Ideally, the project would be something that could be started in 2010 (or no later than 2011).

Thank you for your consideration. If you think it would be helpful to discuss this on the phone before responding, feel free to say so and we can set up a call to discuss it.

Mike Murray
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(See attached file: Simons Sample 3 and 5 year CAHA Research Budgets.xls)
(See attached file: Simons Thoughts on CAHA Disturbance Study.docx)(See attached file: Sabine et al 2008 Human activity effects on Amer Oystercatchers Waterbirds 31 70-82.pdf)(See attached file: CAHA OverviewFinal2.pdf)(See attached file: McGowan and Simons 2006 AMOY Disturbance.pdf)

Camera Set-up Nest 1_for email.JPG Camera Bucket.JPG

0026282

Camera Bucket_no shelf.JPG 2009_NC_AMOY_Report_2 with changes Ted.pdf

Schulte and Simons AMOY Reproduction Draft 05_19_10.doc Simons Thoughts on CAHA Disturbance Study.docx

Mike,

I will embed some comments below in response to your email. I would be happy to discuss this in greater detail if you like or come down and meet with you all.

Hi Ted,

We have a possible research project we'd like to get your thoughts on.

Background: My understanding is that the recommended nest buffer of 150 meters in the USGS protocols for American oystercatcher (AMOY) nests was based, in part, on John Sabine's study at ~~Gulf Islands~~Cumberland Island NS (2005 thesis).
The buffer, as recommended by USGS, applies to ALL recreational activities (i.e., ORVs and pedestrians). In reading through Sabine's thesis on American oystercatchers (particularly Chapter 4, Effects of Human Activity on Behavior of Breeding American Oystercatchers) there are a number of statements indicating a marked difference between observed pedestrian and vehicular disturbance during nest incubation (i.e., suggesting that pedestrian disturbance is much more of a concern than vehicular disturbance during incubation; while vehicular disturbance is clearly a concern when chicks are present). Sabine's study makes a strong case for the pedestrian buffer of 137 m or more during incubation, but does not seem to make the same case for completely restricting all vehicular activity within 150 m of a nest during incubation. For example:

Comment [TS1]: It is still not clear to me how the 150 m buffer was derived. I have a copy of the overview document by Cohen et al. and Sabine's 2008 paper in Waterbirds (both attached) that was derived from his 2005 thesis. The Cohen overview simply provides a recommended buffer of 150m, while Sabine uses 137 m based on the rationale below. If there are reasons for the current 150 m buffer I have not seen them.

Page 45: "During incubation, pedestrian activity ≤137 m of subjects reduced the proportion of time devoted to reproductive behavior, but pedestrian activity 138-300 m had no effect. Vehicular and boat activities had minimal effects on oystercatcher behavior during incubation."

From Sabine et al. 2008……

"Disturbance experiments were conducted on eleven oystercatcher pairs during the 2004 season, but because of nest locations and nest failure, all treatments could not be applied to all nests (Table 4). Oystercatcher displacement occurred during all trials of the 20-m pedestrian disturbance treatment. During 40- and 60-m disturbances, displacement occurred during 78% of trials. The mean distance for displacement of pooled nest means (all three treatments) was 113 m (N = 11, 95% CI = 90-137 m). No vehicle disturbance trials resulted in displacement from nests and only one pair displaced from an ATV disturbance trial. The upper value of the 95% CI (137 m) was used as a conservative threshold of tolerance of nesting American Oystercatchers on CINS."

If you look at Table 4 in Sabine et al. 2008 you will see that Sabine had people walk past 11 nests along transects parallel to the shoreline 20m below the nest, 10 nests along a line 40m below the nests, and 9 nests along a line 60 m below the nest, and he drove a vehicle past 9 nests along lines 50m below the nests and an ATV past 8 nests along a line 50m below the nests. He measured the proportion of nests where incubating birds flushed in response to the disturbance and he measured the distance from the disturbing person/vehicle to the nest. Birds did not respond to vehicles passing 50 m from their nests and 1 of 8 birds (0.13) responded to an ATV at 169.5m. The 137m figure comes from the upper 95% confidence limit of the disturbance distances of the pooled pedestrian data from 20, 40, and 60m.

So, as he states below, he found little evidence in this small sample of trials that birds are disturbed by vehicles driving along a line 50m below their nests (0/10 nests disturbed by vehicles, 1/8 nests disturbed by an ATV).

I am not aware of other empirical data on Oystercatcher flushing distances and do not know how the 150 m buffer in the consent decree was derived.

In my experience birds show a wide range of responses to different types of disturbance. I have attached a paper Conor McGowan and I published in the Wilson Bulletin in 2006. As you can see our results were quite different from John Sabine's. I think these types of findings are quite context dependant, a function of what the birds experience on a regular basis, and differences in habitat and predation risk. At CALO, where birds associate ATV's with researchers/park staff arriving to check their nests, they will often flush when and ATV is 200-300m from their nest. In general birds are much more tolerant of other vehicles, especially if the vehicles are >50 from their nests and if the vehicles are simply passing by at a moderate speed. CALO is implementing a new strategy this season by posting partial closures 100m on either side of active AMOY nests. The signs and symbolic fencing to the high tide line instruct visitors to drive through the closure without stopping. Birds seem to acclimate to this fairly well but we will have to see if it results in improved nest survival this year.

Page 88 (Management Recommendations): "Although presence of vehicular activity altered behavior during incubation, reproductive behavior was not negatively impacted, suggesting that vehicular activity at CINS in 2003 and
2004 did not negatively impact hatching success. During brood rearing, foraging behavior was lower in the presence of vehicular activity, which may alter chick provisioning and ultimately chick survival. To minimize impacts on adult foraging behavior, I recommend the prohibition of beach driving in oystercatcher territories (within 150 m) when chicks are present . At all other times, beach driving should be limited to well below the high tide line and speeds should be limited to 10 mph or less, so drivers have ample time to see and react to birds in the path of travel." (underlining added for emphasis) I agree that Sabine's data do not show a strong effect of vehicles during incubation. In general, as long as nests are not run over, most birds will acclimate to low levels of vehicle traffic adjacent to their nests. If traffic is not continuous, so that birds have access to foraging areas in front of their nests day and night, there is some likelihood their eggs will hatch. The challenge from a research standpoint is not documenting the distances at which birds will leave their nests in response to different forms of disturbance, but in documenting the consequences of disturbance on nest establishment, reproductive success, juvenile survival, and adult survival. It is very hard to do this in a setting like CAHA because of limited sample sizes and the difficulty of isolating an effect like vehicle traffic from confounding factors like variations in predator abundance, or habitat quality. Even so there are certainly things we can learn about disturbance that can inform management policies. See comments about research objectives below….

The apparent contrast between pedestrian disturbance and vehicular disturbance described in Sabine 2005 does not seem to support the recommendation of an absolute 150 m buffer for ALL recreation during AMOY incubation that is found in the USGS protocols (perhaps other references provided the basis for the 150 m vehicular restriction during incubation?).
In managing the beach at Cape Hatteras, there are limited occasions in which being able to allow vehicles to pass some appropriate buffer distance from an AMOY nest during incubation (i.e., NOT when chicks are present) would be beneficial, provided the buffer distance is sufficient to prevent negative impacts from disturbance. For example, if a 150 m buffer for such a nest were to block the only means of access to an important recreation site such as Cape Point and if a lesser buffer for the activity of driving past the site to reach the open area beyond the closure were adequate to prevent disturbance during incubation (assuming that a full beach closure would occur when chicks are present), it could reduce the overall length of time that popular sites (such as Cape Point) were inaccessible to the public and could decrease public resentment about the duration and impact of the closures.

Comment [TS2]: Yes, the vulnerability of chicks to vehicles can't be overstated. So, with closures related to Piping Plover and other species you are really talking about a 4-6 week period where modifications to AMOY closures might make a difference in how you manage vehicles.

This is an important strategic decision that deserves some careful thought. There are two possible approaches as I see it. They come down to managing at the population level or at the level of individual breeding pairs. You could manage at the level of individual birds and try to develop a standard for disturbance that is applicable to all birds in all habitats, or you could manage at the population level and set targets for population levels and nesting success for the entire Seashore. I think there is a case to be made that trading off some additional disturbance in very high demand visitor areas like Cape Point and Bodie Island Spit for greater protection in other areas (via closures, predator control) if the net effect is getting the Seashore moving in the direction of restoring the declines we have seen in AMOY populations over the past 15 years. Of course these trade-offs would have to be balanced with objectives for Piping Plover, Terns and other species who may rely more heavily on these popular recreational sites. In any event, there is no question that better information about disturbance and birds will improve your management decisions and I am happy to work with you to define some research objectives.

Research Project Concept: To follow up on specific negotiated rulemaking discussions that occurred during natural resources subcommittee meetings (which included Walker Golder among other stakeholders), I am interested in having research done at Cape Hatteras in the next few years that would evaluate the effectiveness/adequacy of having a buffer of less than 150 m for ORVs driving past AMOY nests during the incubation. My intent is to definitively determine for Cape Hatteras whether there may be limited, definable circumstances under which it may be appropriate to allow vehicles to drive past by an AMOY nest at a distance less than 150 m. Under what circumstances or conditions, if any, would a reduced buffer for vehicles driving by be effective/adequate? Under said conditions, what would be the effective/appropriate vehicular buffer size during incubation? Would restricting vehicles to traveling below the high tide line during incubation be adequate as p. 88 in Sabine's thesis suggests? Would controlling or restricting the number of vehicles per hour, or limiting travel time to limited time periods per hour, or would manipulating any other variable(s) within management control make a difference?

Underlying Management Objectives:

Ensure adequate protection of incubating AMOY nests Agree. Question is how to measure disturbance and protection. We can measure flushing distance and show how flushing distance changes with distance and the type of disturbance. The question then becomes one of picking a meaningful management threshold.

Determine if a reduced buffer distance (i.e., less than 150 m) for ORVs driving past an incubating AMOY nest is adequate to prevent disturbance and, if it is, determine what distance is adequate OR

Determine that a reduced buffer is NOT adequate (and put this issue to rest) Again, this depends on operational definition of disturbance. In the absence of measurable outcomes like hatching success these definitions can become very subjective.

Questions:

Do you believe that such a study could produce the specific results the park would need for practical management purposes, or would it possibly only indicate that there is such variability in individual bird's reactions to ORV disturbance during incubation that the only way to prevent disturbance is to use the same conservative buffer size for all human disturbance situations? In the specific cases of Cape Point and Bodie Island Spit this is almost impossible to determine because reducing the buffer results in such a massive change to the nesting environment. It would be hard to compare the effects of a 100m versus a 150m buffer for those nests when the 50m difference means the difference between essentially no people and thousands of people on the same section of beach.

Is there an adaptive management approach to managing these specific situations (AMOY nest buffer blocking the only access to an inlet or Cape Point, when the inlet or point itself is otherwise "open") that could be designed to determine the appropriate effective ORV "drive-by" buffer distance over time? Yes, an adaptive management approach would, almost by definition, focus on population level objectives. It would provide the flexibility to apply different management policies in different locations in order to minimize both the political and the economic cost of management and find the most efficient path to your management objective (in this case some population, productivity, and survival targets).

Request for a Proposal: If you believe that such a study could lead to a practical differentiation in buffer size for ORVs driving past an incubating nest vs. the buffer size needed to prevent disturbance from other human activities, I would appreciate it if you would develop a research proposal, with estimated costs, for such a study so that the Seashore can seek funding for it. Ideally, the project would be something that could be started in 2010 (or no later than 2011).

I would appreciate the opportunity to continue working with you and your staff on these issues and would be happy to develop a detailed research proposal over the next few months. I have attached a generic budget to give you a rough idea of the costs I would envision for this research. A focused 3-year MS level study of incubating adult time activity budgets and response to various types of vehicle/pedestrian disturbance would cost about

$180K, and more ambitious 5-year PhD level study to develop an adaptive approach to AMOY management would cost about $300K.

Thank you for your consideration. If you think it would be helpful to discuss this on the phone before responding, feel free to say so and we can set up a call to discuss it.

Yes, if you want to pursue this I think it would be very helpful to meet and discuss possible approaches. Please let me know if you would like to set up a time for a conference call or a visit.

Sincerely,

Ted

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Factors affecting the reproductive success of American Oystercatchers in North Carolina

SHILOH SCHULTE and THEODORE R. SIMONS

USGS North Carolina Cooperative Fish and Wildlife Research Unit
Department of Biology, North Carolina State University
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Abstract. - We took an information-theoretic approach to the analysis of factors affecting the survival of American Oystercatcher nests and broods on the Outer Banks of North Carolina. Variation in nest and brood survival was evaluated with respect to nesting island, year, time of season, brood age, distance to tide, presence of off road vehicles, and proximity of foraging. The mean daily nest survival rate was 0.981 (SE 0.002). Nest survival was affected by year and island, but tended to decline over the nesting season. Raccoons and other mammalian predators were the primary cause of nest failure, accounting for 54% of identified failures. Mean daily brood survival was 0.981 (SE 0.002). Brood survival varied by island and increased non-linearly with age, with highest mortality during the first week after hatch. Our model predicted that direct access to sandflats and marshes would have a positive effect on brood survival, while the presence of off road vehicles would have a negative effect. We studied Oystercatcher chick behavior and survival using radio telemetry and direct observation and found that vVehicles directly caused mortality and affected behavior and resource use of Oystercatcher chicks. Oystercatcher chicks move extensively and use the entire beach and dune system. This behavior often placed broods at risk from vehicles on the beach, and several chicks were killed by vehicles during the course of the study. Chicks on beaches closed to vehicles used the beach and intertidal zone more frequently than chicks on beaches with vehicles, and spent less time hiding in the dunes. Chick predators were identified by daily radio tracking of individual chicks and included Great Horned Owls, Fish Crows, Feral Cats, Mink, Raccoons, and Ghost Crabs.

Keywords: - American Oystercatcher, Barrier Islands, Breeding Ecology, Brood Survival *Haematopus palliatus*, Nest Survival, Off Road Vehicles

Running Head: American Oystercatcher reproductive success

American Oystercatchers (*Haematopus palliatus*) are large, conspicuous shorebirds that are strictly tied to the coastal zone throughout the year. Unlike many shorebirds that breed in the Arctic and migrate to coastal regions in the winter, Oystercatchers breed along the Atlantic Coast from Cape Cod to Florida, and along the Gulf Coast from Florida to Mexico (Nol and Humphrey 1994). The winter range extends from central New Jersey south through the Gulf of Mexico. An aerial survey of the species' winter range resulted in a population estimate of 10971 individuals (+/-298), with 7500-8000 wintering on the Atlantic Coast (Brown et al. 2005). The survey estimated a winter population of Oystercatchers in North Carolina at 647 birds. A 2007 breeding season survey estimated North Carolina's summer population at 717 individuals, with 339 breeding pairs (Cameron and Allen 2007).

American Oystercatchers are listed in both Georgia and Florida as "threatened", and as a "species of special concern" in North Carolina (North Carolina Wildlife Resources Commission 2008). The American Oystercatcher Conservation Plan lists American Oystercatchers as a high priority species (American Oystercatcher Working Group, 2007), in part because of significant threats from development and heavy recreational use of coastal breeding habitats. Human population density in the United States is highest in coastal regions. The rate of population growth is expected to increase substantially, particularly in the southeastern states (Crossett et al. 2004). As more humans inhabit the coastal zone, recreational use of beaches, salt marshes, and waterways will continue to rise as well. Many visitors to the coast seek out undeveloped beaches. As coastal islands and beaches are developed, more visitors are concentrated onto the remaining undeveloped areas. Coastal development, recreational activity, and altered predator communities have substantially reduced the amount of suitable nesting and foraging habitat for beach nesting birds in North Carolina. Roads and artificial dunes along nesting beaches can limit access to foraging habitats for beach nesting species like Piping Plovers (*Charadrius melodus*) and American Oystercatchers. Nesting and roosting sites can also be lost when jetties and revetments alter the normal process of longshore transport of sand and accelerate erosion of adjacent beaches.

Like many long-lived species, Oystercatcher reproductive rates tend to be highly variable but generally low (Evans 1991, Nol and Humphrey 1994, Davis et al. 2001, Wilke et al. 2005, McGowan et al. 2005a, Traut et al. 2006). This means that the species is unable to recover quickly from population declines. These traits also make it difficult to assess the status of a population because populations can persist for many years, even if reproductive success is low. Recent surveys indicate that populations in the Mid-Atlantic States are declining (Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). The breeding population of Virginia's barrier islands, a historical stronghold for Oystercatchers, fell from 619 breeding pairs in 1979 to 255 breeding pairs in 1998 (Davis et al. 2001). A 2004 survey that covered the same region estimated the population at 302 breeding pairs (Wilke et al. 2005). This survey also covered lagoon and marsh habitat and found an additional 223 pairs. These results and earlier work (Lauro and Burger 1989) suggest populations may be moving into non-traditional habitats, and highlight the need for additional surveys in marsh and upland habitats not normally associated with Oystercatchers. During the period of apparent decline in the mid-Atlantic, the species expanded its breeding range into the northeastern United States (Davis 1999, Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). Understanding the causes of local, regional, and continental population trends will require region-wide studies of the species' population structure and demographics.

A study of breeding American Oystercatchers was initiated on South Core Banks, Cape

Comment [EN1]: Citing Lauro and Burger would be good here as they documented that shift a while ago (Auk 1989 or 1988?)

Lookout National Seashore in 1995 to document nesting success (Novick 1996). The scope of the original study has expanded to include all of the islands of Cape Lookout and Cape Hatteras National Seashores. The study of Oystercatcher breeding success further expanded in the state in 2002 and 2003 when the North Carolina Audubon Society initiated nest monitoring on dredge spoil islands at the mouth of the Cape Fear River, and on Lea and Hutaff Islands. Although the undeveloped barrier islands that comprise the National Seashores were thought to be ideal breeding habitat for American Oystercatchers, nest survival was much lower than expected. Novick (1996) attributed low hatching rates to human disturbance. Davis (1999) continued the work on Cape Lookout and used nest monitoring and predator tracking stations to determine the causes of nest failure. Davis determined that a majority of nests were lost to mammalian predators. Subsequent studies in North Carolina have supported the conclusion that mammals are the primary nest predators, but they also suggested an interaction between human disturbance and nest predation rates (McGowan 2004, McGowan and Simons 2006). McGowan and Simons (2006) found an inverse relationship between the number of visits an Oystercatcher made to the nest and the nest survival rate, suggesting that more disturbed nests are more likely to be found by predators.

Although a considerable amount of research has been conducted on nesting American Oystercatchers, relatively few studies have focused on chick survival. The sources and timing of mortality are very difficult to determine for precocial shorebird chicks (Nol 1989; Ens et al. 1992). Chicks often leave the nest within a few hours of hatching, after which they are cryptic and highly mobile. When chicks are lost to predators, exposure, or other sources, it is often difficult to determine the cause of death. Studies of other shorebird species have identified chick age, mass at hatching, human disturbance, habitat quality, access to foraging sites, rainfall, and an array of predator species as factors affecting chick survival (Dinsmore et al. 2002, Ruhlen et al. 2003, Ruthrauff and McCaffery, 2005, Colwell et al. 2007). Because many breeding attempts fail during the chick-rearing stage, several recent studies have stressed the need for a better understanding of the factors affecting American Oystercatcher chick survival (Davis et al. 2001, McGowan et al. 2005a). In 2004 we initiated a study of American Oystercatcher chick behavior on Cape Hatteras National Seashore. Relatively little was known about how Oystercatcher broods used their habitat and responded to human activity. Anecdotal observations suggested that breeding adult Oystercatchers altered their behavior in the presence of humans and vehicles by hiding their chicks in the dunes and keeping them off the beach. The objectives of this study were to identify patterns of chick behavior and habitat use, quantify the effects of vehicles on Oystercatcher chick behavior, and compare the effects of two management actions (closed beach versus partial beach closures). In 2005, 2006 and 2007 we used radio telemetry to track Oystercatcher chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore to identify the timing and sources of chick mortality. Here we summarize the results of reproductive success monitoring on the Outer Banks and take an information theoretic approach to examine variation in nest and chick survival with respect to age, season, year, island, presence of off road vehicles, and habitat quality.

Comment [EN2]: Sounds like it is from a thesis? 'this chapter'

METHODS

Study sites

Cape Lookout and Cape Hatteras National Seashores (Figure 1) comprise over 160 km of barrier island habitat in North Carolina. The islands are characterized by wide barrier beaches with a primary and secondary dune complex broken by flats and overwash fans. The dunes fade into wax myrtle (*Myrica cerifera*) scrub and then to saltmarsh bordering the back bays and sounds. This system is subject to periodic washover events, followed by recolonization by dune grasses. Cape Lookout and Cape Hatteras support approximately 90 breeding pairs of Oystercatchers which nest on the sand flats and dunes and forage along the beach and salt marsh. Off road vehicles are permitted on beach and interdune roads in both parks except in designated wilderness areas or sensitive bird or turtle nesting areas. Cape Hatteras has a permanent road system and several small towns along the length of the islands.

Comment [EN3]: repetitious

Nest Survival

Surveys of breeding Oystercatchers on the Outer Banks began in early April each year. Nests were located by walking or slowly driving along the barrier beach and back-road system. When an adult Oystercatcher was located, observers watched for behavioral cues that indicated the bird had a nest. Although nesting Oystercatchers do not usually employ “broken-wing” distraction displays typical of smaller shorebirds, they do exhibit easily identifiable behaviors such as false incubating and alarm calling. When breeding behavior was observed, scrapes were found by following the tracks of the adult birds, or by systematic searches. Once located, nests were marked with a small wooden stick placed at least 5m from the nest and concealed to prevent detection by predators, or by using adjacent natural landmarks like driftwood, shells, etc. as a reference. The location of each nest was recorded with a handheld GPS. Nests were checked every 1-4 days until hatching or failure. We made every effort to minimize disturbance and reduce any effect of our observations on nesting success. If a bird was?s seen incubating from a distance, the nest was considered active and it was only checked to determine if the chicks had hatched. We avoided walking directly to nest sites, and spent a minimal amount of time in the vicinity of the nest to minimize cues for predators. If a nest failed, we attempted to determine the cause of failure by searching the area for signs of predators, storm overwash, or other sources of nest failure. For example, when a storm event washes out a nest, the nest scrape is usually gone and a debris line is evident above the nest's original location. Unfortunately, such evidence does not last long on a barrier beach, so it was not always possible to determine the causes of nest failure.

We developed a set of hypotheses to explain variation in nest survival on the Outer Banks from 1999 to 2008. The hypotheses described below were incorporated into candidate models as covariates.

1) *Year*. Year to year variation in weather patterns, timing of storms, prey abundance, predator abundance, and numerous other factors that were not explicitly measured could affect Oystercatcher nest survival

2) *Island*. The study area is composed of six islands in two national parks. Human use of the seashores varies considerably from island to island, along with predator composition and abundance. Differences in these and other factors could explain variations in nest survival.

3) *Presence of Off Road Vehicles*. Vehicle activity can affect nesting behavior (McGowan and Simons 2006) and nest survival for beach nesting birds (Buick and Paton, 1989, Novick 1996, Davis 1999, Carney and Sydeman 1999). Although many of the nests in the study area were protected from direct impact by signs and symbolic fencing, we hypothesized that the indirect effects of adjacent vehicle traffic would lower survival for nests on beaches open to vehicles. We considered a beach open for vehicle traffic if vehicles were allowed to pass above or below the nest, even if the nest itself was in a closed

area. We did not attempt to include distance from nests to vehicles or the number of vehicles using the beach, as these data were unavailable for most of the nests.

4) *Distance to the high tide line*. Oystercatchers nest anywhere from within a few meters of the high tide line to hundreds of meters away on large sand flats. Overwash from storms and spring tides is a major source of nest failure. In addition, the majority of vehicle traffic is located near the high tide line. We hypothesized that nest survival would increase with distance from the high tide line.

5) *Direct access to foraging habitat.* Oystercatchers will forage on the ocean beach, but most birds maintain primary foraging territories in the creeks and mudflats on the back side of the barrier islands. If a nesting oystercatcher has to fly a long way to get to their foraging site they are unavailable to help their mate defend the nest from predators. Perhaps more importantly, nest sites adjacent to foraging territories may be very important during chick rearing (Ens et al. 1992, Heg and van der Velde 2001, Kersten and Brenninkmeijer 1995, van de Pol 2007). Older, more experienced birds are likely to occupy these prime territories, so this covariate may be an indirect measure of adult quality. We hypothesized that direct access to primary foraging habitat would increase nest survival.

6) *Time of the nesting season.* The nesting season on the Outer Banks of North Carolina spans approximately five months. We fit linear and quadratic time trend models to the null model of constant survival to evaluate temporal

variation in nest survival within the nesting season. For the linear model we predicted that survival would decrease thorough the season. The quadratic model allowed for a non-linear change in nest survival to account for more than one survival peak or valley.

Previous analyses compared estimates of apparent nesting success using the binomial proportion of successful nests to failed nests, with Mayfield nest survival estimates (Mayfield 1961, 1975, Davis, 1999, McGowan 2004). As expected, these results showed that apparent nest success overestimated survival because of nests that failed and were never found. We analyzed our nest survival database from the period 1999-2008 using the nest survival module in Program Mark (White and Burnham 1999, Dinsmore et al., 2002). This method is similar to the Mayfield method in that a daily survival rate is calculated from nest observation days and thus accounts for missed nests. Daily nest survival is defined as the probability of surviving from day i to i + 1. Program Mark uses a maximum likelihood method to estimate the nest failure date when the time between nest checks is greater than 1 day, and it allows for modeling covariates to explain variations in nest success and the comparison of alternative models using Akaike's Information Criteria (AIC) (Akaike 1973, Burnham and Anderson 2002).

Based on our hypotheses and predictions described above, we evaluated seven covariates; Linear time trend, quadratic time trend, year, island, foraging access, distance to the tide line, and presence of off road vehicles. Foraging access was a binary individual covariate based on access to foraging sites for nesting pairs. The covariate was positive if a pair had direct walking access to a primary foraging site. Primary foraging sites were defined as mudflats, saltmarsh creeks, tide pools and intertidal oyster beds. The individual covariate "distance to high tide line" was measured by calculating the distance between nest locations and recorded high tide lines in

ArcMap (Esri 2009). Presence of off road vehicles was recorded for each nest based on beach closure records from the National Park Service. Off road vehicles were considered to be present if any part of the beach above or below the nest was open to vehicle traffic, regardless of whether the nest itself was in a vehicle exclosure. We did not account for differences in traffic volume or exclosure size, as these data were not available for the majority of our nests. We used a three-step hierarchical process to evaluate different models. In the first step we created models with linear and quadratic time trends as well as a null model of constant survival. We then added effects of year and island to the best model(s) (ΔAICc ~<2.0). Finally we added the covariates for tide distance, foraging, and ORV access to the new best model(s).

Brood Survival

When a nest hatched, the young were observed every 1-4 days until fledging, or until all the chicks died or disappeared. We documented habitat use and behavior of Oystercatcher broods on Cape Hatteras National Seashore from 2004 to 2007 using behavioral observations. We did not have the option of experimentally manipulating the disturbance level or closed/open status of the beach (e.g. Simons and Tarr 2008), so this was strictly an observational study. We conducted observations in hour-long intervals, taking instantaneous habitat information at two minute intervals. Broods were observed through scopes from a distance where observer presence did not affect the bird's behavior. Habitats were designated as; below the tide line, open beach, and dunes or grass. Watches continued if the birds went out of sight as long as we could still determine the habitat type. This prevented a negative bias for dune and grass habitats where the birds are less visible. We observed chicks of all ages from hatching through fledging at all times of day and stages of the tide. We were not able to conduct behavior watches at night, but we did periodically check on the location of broods at night to document habitat use. Observation windows were randomly assigned to active Oystercatcher broods throughout the nesting season. We used t-tests to compare habitat use on beaches open and closed to vehicles.

With careful monitoring it was possible to determine annual productivity, or the number of chicks fledged per pair, per year, although usually not the cause or exact timing of chick mortality. Adult Oystercatchers exhibit markedly different behavior patterns when they have chicks. They are much more aggressive toward intruders, and they give distinct alarms calls. It was generally possible to determine whether a pair of adult birds had chicks by observing adult behavior, even if we could not locate the chicks. In most cases chicks were located by observing adults from a distance using a spotting scope, and occasionally a portable blind. On the rare occasion that a chick was found dead, we attempted to determine the cause of death.

In our analysis of factors affecting chicks during the pre-fledging period, we considered chick survival and brood survival separately. Chick survival was defined as the probability of a single chick surviving from hatch to fledging, while brood survival was defined as the probability of at least one chick in a brood surviving to fledging. Because of the difficulty in determining the status of individual chicks during each monitoring check, we developed hypotheses and analyzed covariates associated with brood survival, rather than individual chick survival. We developed models incorporating these hypotheses using the nest survival module in Program Mark. Our hypotheses about factors affecting brood survival were similar to nest survival. We did not include an effect of distance to high tide because Oystercatcher chicks are highly mobile. We also examined the effect of brood age on survival, hypothesizing that daily survival would increase with brood age. Covariates included in the brood survival models were year, island, presence of Off Road Vehicles, direct access to foraging habitat, time of the nesting season (linear and quadratic trends), and age of the brood (linear and quadratic trends).

We used a multi-step approach to model construction, similar to the nest survival analysis. In the first step we ran models with linear and quadratic time and brood age trends as well as a simple null model of constant survival. We then added the effects of year and island to the best model(s). Finally we added the covariates for presence of off road vehicles and foraging access to the best model (inclusive of year and/or island effects) to see if they contributed any useful information to the best model.

In addition to the analysis of brood survival from the full dataset, we looked at factors affecting individual chick survival and sources of mortality for a subset of chicks using radio telemetry. From 2005 to 2007 we radio tagged a total of 121 chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore. Chicks were radio tagged as soon as they were mobile, usually within 24-48 hours of hatching. We attached ATS A2420 transmitters (1.3 grams) to the scapular region of the chick using surgical grade skin glue (Figure 2). Chicks were checked every 24 hours for the first week, and every 1-3 days thereafter. Transmitter range was 400-1000 meters depending on terrain. When a chick died, we tried to locate the remains and determine the cause of death. We estimated survival probability for radio tagged chicks using the Kaplan-Meier known fate procedure (Kaplan and Meier 1958). Day zero was defined as the day of hatch regardless of capture date. Multiple chicks from the same brood were tagged and followed, which violates the assumption of independent observations. The result is that the survival estimator was unbiased, but the standard error was likely underestimated (Pollock et al. 1989).

In 2005 and 2006 we exchanged the ATS transmitters for larger PD2 model transmitters from Holohil Systems when the chicks reached four weeks of age. These transmitters were designed to last at least six months and were attached to a permanent leg band (Figure 2).

RESULTS

Nest survival

This analysis is based on a sample of 1172 nests monitored on six islands from 1999-2008 where sufficient data were collected for nest survival analysis. Nests were monitored during a 126-day window (April 2 to August 6) during the 10-year period for a total of 15736 exposure days. Overall observed hatching success from the beginning of egg laying to hatching for all years and locations was 0.280 (SE 0.013). The single estimate of daily survival from Program Mark (null model) was 0.950 (SE 0.002). The average incubation period for Oystercatcher nests is 27 days (Nol and Humphrey 1994). To obtain the probability of nest survival to hatching (period nest survival) we raised estimates of daily survival rates (DSR) to the 27th power. Period survival for the null model was $0.950^{27} = 0.250$ (SE 0.011).

Variation in nest survival was best explained by a model with a linear within-season time trend and additive covariates for year and island (Table 1). The quadratic time effect was not supported (~ one unit increase in AICc, for a one parameter increase, lower model weights, and 95% CI for the beta coefficient overlapping zero). A linear time effect was supported in all the top models, indicating that nest survival declined over the nesting season (B = -0.005, CL = -0.008, -0.001). The 95% confidence intervals for the beta coefficients of five of the ten years (2000, 2001, 2003, 2007, and 2008) overlapped zero, indicating no significant difference in survival from the baseline year (1999). In contrast, the entire confidence interval for the coefficient for 2002 was below zero, while the intervals for 2004, 2005 and 2006 were all above zero. 2004 had the highest beta coefficient of any year (B = 0.882, CL = 0.522, 1.241). Nests on the island of South Core Banks had lower overall survival (B = -0.327, CL = -0.499, -0.156) than

North Core Banks, while Ocracoke (B = 0.407, CL = 0.136, 0.677) and Hatteras (B = 0.323, CL = 0.107, 0.538) were higher than North Core Banks over the course of the study. The 95% confidence intervals for the beta coefficients of Middle Core Banks and Bodie Island overlapped zero, indicating no significant difference in survival from North Core Banks.

One of the top two models by AICc rank included a covariate for ORV presence. In this model nests with ORV access had a lower survival rate, but support for the ORV covariate was weak as the 95% confidence interval for the beta included zero (B = -0.196, 95% CL = -0.472, 0.080) and there was no change in AICc. Models that included covariates for access to foraging habitat, and distance to tide line also received some support (ΔAICc <2), but the confidence interval of the beta coefficient for each of these covariates also included zero.

Mammalian depredation was the major identifiable cause of nest failure at our study sites, accounting for approximately 54% of identified nest failures (Figure 3). Over-wash and other weather related causes accounted for 29% of identified failures. The remaining identified failures (17%) were caused by human activity, avian predators, ghost crabs, or unknown reasons (Figure 3). Human activity was defined as a human action directly leading to nest failure, such as physical destruction of the eggs, and did not include indirect effects of disturbance. We could not identify the causes of failure for 52% of failed nests. The sources of nest mortality were similar on Cape Hatteras and Cape Lookout, but the relative proportion of nests lost to each source varied by year and location (Figures 4 and 5),

Clutch size averaged 2.35 eggs/nesting attempt (SE 0.01). A nesting attempt was defined as a nest with at least one egg. Pre-nesting scrapes were not considered nesting attempts. When a nest failed Oystercatcher pairs waited 9-14 days before initiating a new clutch. If a nest hatched successfully pairs did not re-nest unless the chicks were lost while still very young (<7 days). Oystercatcher pairs initiated between one and five nests per season with an average of 1.55 (SE 0.01). The average number of clutches per pair (y) was logarithmically related to overall nest survival (x) (y = -0.375Ln(x) + 1.0873, Figure 6).

Comment [EN4]: Repeats above

Brood and Chick Survival

Our analysis of factors affecting brood survival is based on a sample of 306 broods on Cape Lookout and Cape Hatteras National Seashores from 1999 to 2008. Mean brood size at hatch was 1.99 chicks (SE 0.042), while the mean daily brood survival was 0.981 (SE 0.002). Mean period survival for the 40 day pre-fledging period was 0.471 (SE 0.030).

Our best model of factors affecting brood survival included covariates for the age of the brood, island, presence of off road vehicles, and access to foraging habitat. This model was the only supported model in our set (model weight = 0.991, ΔAIC of next model = 9.443). Within-season time trends and year effects were not useful in explaining variability in brood survival rates. The best model included a quadratic term for brood age (Table 2), with daily survival rates increasing rapidly for the first two weeks, and then leveling off (Figures 8 and 9). Brood survival varied between islands. Survival was highest on Middle Core Banks, Cape Lookout National Seashore (B = 0.722, CL = -0.379, 1.823) and lowest on Bodie Island, Cape Hatteras National Seashore (B = -0.72597, CL = -1.819, 0.367). The within-island variability in survival was very high however, and only South Core Banks had a beta coefficient with a confidence interval that did not include zero (B = -0.688, CL = -0.213, -0.164). Predicted brood survival was lower when off road vehicles were present (Figure 7, B = -0.991, CL = -1.381, -0.601) and higher when broods had direct access to foraging areas (Figure 8, B = 0.717, CL = 0.277, 1.156).

Individual chick survival and sources of chick mortality were determined from the radio telemetry study. One hundred and twenty-one chicks were tracked from hatching to fledging or death. Chick predators included Great Horned Owls (*Bubo virginianus*), Fish Crows (*Corvus ossifragus*), Feral Cats (*Felis catus*), Raccoons, *(Procyon lotor)*, American Mink (*Mustela vison*), and Ghost Crabs (*Ocypode quadrata*) (Figure 9), and accounted for 54.1% of all identified mortalities. Human activity (vehicle collisions and disturbance) was directly responsible for 16% of known chick mortality. Several chicks died of exposure during storm events shortly after hatching. We were unable to determine the cause of mortality in 51% of the chicks monitored (N=39). Typically this occurred if the transmitter was lost when the chick died. Highest chick mortality rates occurred in the first week after hatching, and during the week of fledging (Figure 10). The cumulative probability of surviving the pre-fledging period varied with the definition of "fledged". Thirty-five days is the minimum age we observed chicks achieving sustained flight (>100m). Survival to 35 days was estimated at 0.438 (SE 0.0459). A few chicks took up to 46 days to fledge, however, which reduced the survival probability to 0.280 (SE 0.168). The wide confidence interval after 40 days is a result of very few chicks in the sample still alive and unfledged at this age.

After fledging, radio-marked chicks were tracked daily until mid-August, when field personnel were no longer available. No fledgling mortality was documented during this time. Survey flights in late August and early September in 2005 and 2006 covered the Outer Banks from Nags Head to Morehead City. The oldest chicks began to migrate out of the study area by the end of August, but several still remained at their natal sites on the last survey flight on September 18 2005 and September 25 2006.

We conducted 169 hours of behavioral observation on 63 chicks on Cape Hatteras National Seashore over four years (2004-2007). Over 90% of the observations were of chicks in full-beach closures because most of the locations where chicks hatched were subsequently closed under Park Service policy. Chicks on beaches where vehicles were present spent significantly more time hiding in the dunes and less time at or below the high tide line than chicks on beaches closed to vehicles. (Figure 11, $t = 2.00$, $p = 0.047$). Chicks on beaches open to vehicles often ran back and forth from the beach to the dunes in response to vehicles, humans and dogs. Oystercatchers with chicks showed a stronger reaction to humans with dogs than to humans alone. We did not document any dog-related mortality, but dogs were observed chasing adult Oystercatchers on several occasions. Most adults began to bring their chicks to the waterline to forage within 24 hours of hatching. Broods ranged up and down the beach from their nest sites, often moving 500 meters or more each day. This pattern continued throughout the chick-rearing stage. Night observations of chicks invariably found the broods on the open beach or below the tide line on both open and closed sections of beach. During the day chicks spent most of their time hiding in the dunes, particularly in areas open to vehicles. Parents always brought their chicks to the beach around sunset. We observed Oystercatchers of all ages that became disoriented by vehicle headlights at night and walked, ran, or flew toward the light source. We also observed adult Oystercatchers who were startled and apparently disoriented by headlights and abandoned their chicks until the vehicles had passed. In most cases adults returned quickly to their chicks, but in at least one case the adults were kept away by multiple vehicles passing, which resulted in the deaths of their young chicks, presumably due to exposure or lack of food.

We estimated total productivity as the number of chicks fledged per nesting pair, from 1036 pairs and 1581 clutches monitored between 1995 and 2008. Productivity was highly variable among years and among locations (Appendix 1). A total of 320 chicks fledged from all study sites between 1995 and 2008. On average, 0.309 (SE 0.020) chicks fledged per nesting pair. Total productivity (P) is defined as the number of fledged chicks per nesting pair (pair that laid at least one egg). Productivity is a function of nest survival (S_N), chick survival (S_C), chicks hatched per successful nest (H_C), and total nests per breeding pair. As we have seen, the number of nests per pair is a function of nest survival (Figure 6), so the equation for productivity can be written as:

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

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

DISCUSSION

The factors affecting American Oystercatcher reproductive success on the Outer Banks of North Carolina differed for the incubation and chick-rearing stages. This is not particularly surprising given the semi-precocial nature of oystercatcher chicks. One would expect different sources of mortality after the chicks leave the nest and begin to move about their environment. It is instructive from both an ecological and a management standpoint to examine where the differences occur and how different factors influence overall reproductive success. Nest survival through the incubation period was primarily influenced by the date of nest initiation, the nesting island, and year to year variation in nesting conditions. Nest survival showed a linear decline over the nesting season. There was little support for a quadratic model where the rate of change in nest survival could vary across the season. Numerous studies have found trends in daily survival rates when they relax the common assumption of constant survival over the season or the age of the nests (Ainley and Schlatter 1972, Klett and Johnson 1982, Dinsmore et al. 2002).

The decline in nest survival over the season could be the result of multiple factors. Heat stress, human activity, and predator abundance and distribution may all change over the course of the season. Predators were directly responsible for the majority of failures (61%) where the source of nest loss could be determined. Differences in nest survival among islands and years may largely be a result of differences in the suite of nest predators and changes in predator abundance. In the absence of comprehensive data on predator populations this explanation is hypothetical, but there is some evidence to support the idea. On Hatteras Island, Cape Hatteras National Seashore, the nest survival rate fell from 0.272 (SE 0.048) in the period 1999–2001 to 0.030 (SE 0.023) in 2002, after foxes colonized the island. Predator control measures were initiated in 2003 and the nest survival rate increased to 0.506 (SE 0.050) from 2003-2008. On North Core Banks, Cape Lookout National Seashore, the proportion of nests positively identified as lost to predators dropped from 0.31 to 0.10 after Hurricane Isabel flooded the island in September 2003 and apparently reduced predator populations (Schulte and Simons in prep).

Comment [EN5]: From thesis again?

Given the importance of depredation as a source of nest failure, human actions that affect predator populations or the ability of predators to locate nests will have the greatest effect on nest survival. McGowan and Simons (2006) found that oystercatcher nests that were frequently disturbed were more likely to be depredated. Frequent disturbance may make the nest more visible to avian predators and increase the number of scent trails leading to the nest. We hypothesized that nests on beaches open to vehicle traffic would have a lower survival rate as oystercatchers often move away from their nests in response to vehicle traffic. We considered a beach to be open to vehicle traffic if any part of the shoreline was open, even if the upper beach was closed off with symbolic fencing. One of our top two models indicated support for this hypothesis, showing a negative correlation between the presence of off road vehicles and nest survival. This covariate had a large amount of variability and the 95% confidence interval of the beta coefficient just included zero. Much of this variability likely stems from differences in physical conditions, human activity, and oystercatcher behavior across the islands of the Outer Banks. The effect of vehicle traffic on nest survival could be quite different for a nest on a low-traffic, wider beach and a high-traffic narrow beach. Oystercatcher behavioral responses may also vary from pair to pair, with some birds habituating to human activity and others becoming more sensitized. Finally the linkage between disturbance and nest failure should vary with the local predator population. The negative effect of disturbance should be greater in areas with higher predator populations. Our beach closure status covariate is not sensitive to these potentially interacting , but it does provide a general measure of the correlation between the presence of vehicles and nest survival. An experimental approach that manipulated disturbance levels and controlled for other factors could effectively reduce the uncertainty in this relationship. Tarr et al (in revision) used this approach to evaluate the effect of vehicle disturbance on shorebird roosting and foraging behavior during fall migration on Cape Lookout National Seashore.

Storms and high tides are another source of nest failure. Breeding season storms can result in significant nest loss as nests are flooded out or sanded over. A strong storm at the wrong time of year can eliminate most of the active nests, which sets back the reproductive cycle by 2-6 weeks. Hurricanes and strong winter storms do not directly affect nest success because they usually occur outside of the breeding season. These storms can have beneficial effects as they create new nesting habitat and may reduce predators. We predicted that nest survival would increase with distance from the high tide line. This hypothesis was not supported by our data. Models with the tide covariate received less support than the same models without the covariate and the confidence interval of the beta coefficient for the tide covariate encompassed zero. Height above high tide may be a better predictor of success, as some nests on low-lying flats may be hundreds of meters from the high tide line but still flood during storms. Unfortunately, measurements of height above high tide were not available for our nests.

Proximity to foraging area was another factor we considered. We predicted that pairs with adjacent foraging habitat other than the ocean beach would have higher nest survival. Birds with nearby foraging habitat should spend less energy on flight, and both adults would be present to defend the nest and territory as needed. We did not include the ocean beach in this analysis because it is typically not the primary foraging habitat and almost every pair had access to the beach. In addition, oystercatcher pairs that are able to maintain territories near high-quality food resources may be older, more experienced birds. European oystercatchers may wait years for the chance to establish a territory in high-quality habitat adjacent to feeding areas (Ens at al 1995, Heg and van der Velde 2001, van de Pol 2007). In our study we found no effect of forage proximity on nest survival.

We were not able to observe the causes of most nest failures directly. We relied on indirect evidence, such as eggshell fragments, or predator tracks, to infer the causes of nest failures. Nests reported as undetermined generally represent nests where wind or rain erased any clues of the causes of failure. We believe that the vast majority of our unidentified failures are a result of nest predators. Storm losses were usually easy to identify as the tide line following the storm was often evident above the level of the nest, or the nests were completely sanded over. Identification of different nest predators was much more difficult. Avian predators can leave little or no sign at the nest, and the tracks of mammals such as raccoons and cats are quickly blown away. Even during calm weather, predator tracks were often obscured by Oystercatcher tracks as the pair returned and walked around the nest scrape after a predation event. The difficulty of identifying different sources of failure suggests that storm losses may be over-represented in our estimates of identified nest failures (Figure 3). It is also possible that avian predators are under-represented in these estimates because these predators often leave little evidence. Losses from avian predators usually result in clutch reductions as often only a single egg is taken. Most nest failures occur overnight with the loss of an entire clutch of eggs, suggesting mammalian depredation.

Oystercatcher Brood survival did not change with the date of the nesting season, but survival was affected by the age of the brood. Most brood losses occurred in the first week to ten days after hatching. This pattern resembles that of other species with precocial young (Colwell et al. 2007, Ruthrauff and McCaffery 2005). Young chicks are mobile but cannot fully thermoregulate and are more susceptible to temperature and weather extremes. Smaller chicks are also vulnerable to a wider range of predators. Parental behavior may draw attention to younger chicks that have to be brooded more often and thus stay close to one of the parents. This is particularly true for oystercatcher chicks as they are the one of the only shorebird chicks that are fully dependant on their parents for food (Nol and Humphrey 1994). The Oystercatcher's ability to bring food to their young allows them to exploit nesting sites without local food resources. Broods raised at these sites should be expected to have generally lower survival because parents must bring food from a separate foraging territory. A long-term study of breeding Eurasian Oystercatchers found that pairs with walking access to foraging habitat had significantly higher productivity than pairs that had to fly to their foraging territories (Ens et al. 1992). Our best model predicted lower survival for broods without direct access to foraging habitat (figure 7), which is consistent with our a priori hypothesis.

Comment [EN6]: Well if I said that it is not strictly true...Pluvianellus chicks also depend on their parents for food. Add 'one of the only'

Comment [S7R6]: Oops. Good catch!

Brood survival was directly and indirectly affected by the presence of off road vehicles. Broods on beaches open to vehicles survived at a lower rate than broods on closed beaches (Figure 7). Radio tracking young chicks provided insights into possible mechanisms shaping this pattern. Very young chicks are highly mobile, much more so than previously believed. Movement between the dunes and the waterline places young chicks at considerable risk from beach traffic. We regularly observed chicks hiding in vehicle tracks in response to adult alarm calls and also observed chicks, and even some adults, running or flying directly at the headlights of oncoming vehicles at night. Shortly after we initiated the radio tracking study, we documented the loss of a brood of two-day old chicks to a vehicle on Cape Lookout National Seashore. We radio-tagged the recently hatched brood at the nest on June 16 2005. That same evening the chicks were relocated hiding in seaweed at the tide line with the adult pair. The following morning we tracked the transmitter signals to a nearby location and found two of the chicks crushed in a fresh all terrain vehicle tire track, just above the high tide line (Figure 12). After this incident, Cape Lookout National Seashore initiated a policy under which they closed sections of beach with unfledged chicks to vehicle traffic, and re-routed traffic around the birds via a back road. After the beach sections were closed, chicks were regularly observed on the open beach and at the tide line during daylight hours, suggesting that vehicle traffic was altering chick behavior and foraging patterns. Multiple instances of vehicle related mortality have been documented in both parks and highlight the vulnerability of shorebird chicks to vehicle traffic.

We found that disturbance by vehicles during the chick-rearing phase produces measurable differences in Oystercatcher chick behavior, habitat use, and survival. Despite limitations on our ability to observe chicks on beaches open to vehicles, the differences in habitat use between birds in full and partial beach closures (Figure 11) are very apparent. In addition to being at risk from direct mortality from vehicles, chicks in partial closures spend more time in the dunes, which subjects them to greater heat stress, limits feeding opportunities, and may expose them to greater risk from predators such as cats, mink, and raccoons. The increased risk from nocturnal predators probably explains why adults move their chicks from the dunes to the beach every night even if vehicles are present.

Radio tracking individual chicks allowed us to identify a suite of predators responsible for mortality of chicks prior to fledging. Although feral cats and raccoons both preyed on chicks, ghost crabs and avian predators such as Great Horned Owls and Fish Crows, appeared to play a larger role in chick depredation than nest depredation. The Kaplein-Meier survival curve for radio-tagged chicks showed that chicks were most vulnerable during the first week after hatching when they are most susceptible to exposure and ghost crab depredation (Figure 10). This result is consistent with the predicted age-related brood survival curve from our best model (Table 2, Figures 7 and 8). This study highlighted the difficulty of documenting the mortality of young Oystercatcher chicks. Without radio telemetry keeping track of broods can be difficult, and locating dead chicks is almost impossible. Even with radio tags we were only able to identify the source of mortality about 50% of the time. Many chicks simply disappeared from one day to the next. We suspect that predators carried these chicks out of range of our receivers or the remains washed away if they died below the high tide line.

Total nesting productivity, or the number of chicks fledged per breeding pair, reflects the ability of an Oystercatcher population to navigate the hazards associated with reproduction from egg-laying through fledging. Predators, storms, habitat quality, and management actions combine to shape the annual success or failure of each breeding pair. Management actions that affect chick survival will generally have the greatest effect on overall productivity. In 2008 Cape

Hatteras National Seashore increased predator trapping efforts and expanded buffer zones for chicks to 300 meters. Chick survival on Cape Hatteras in 2008 was the highest recorded during the study period (0.81), which resulted in a final productivity of 0.714, over twice as high as the average annual productivity in North Carolina. The extent to which predator management versus vehicle management contributed to this elevated productivity is not clear. Given the importance of predators at all stages of the breeding cycle, a better understanding of predator population dynamics would likely go a long way toward explaining temporal and spatial variability in Oystercatcher productivity.

ACKNOWLEDGEMENTS

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Table 1: Model selection results for factors affecting survival of American Oystercatcher nests on Cape Hatteras and Cape Lookout National Seashores from 1999-2008. Models are ranked by ΔAICc. Wi represents model weight and k is the number of parameters. Model factors include linear and quadratic daily variation over the nesting season (Day and Day^2), year, island, presence of off road vehicles, access to foraging areas, and distance to the high tide line.

Model	ΔAICc[a]	k	W_i	Deviance
Day + Year + Island	0	16	0.294	4807.560
Day + Year + Island + Vehicle	0.015	17	0.291	4805.570
Day + Year + Island + Forage	0.851	17	0.192	4806.406
Day + Year + Island + Tide	1.465	17	0.141	4807.020
Day + Year + Island + Tide + Forage + Vehicle	2.534	19	0.083	4804.080
Day + Year	51.755	11	0	4869.332
Day + Island	56.952	7	0	4882.540
Day	116.954	2	0	4952.548
Day^2	118.750	3	0	4952.342
Constant	121.374	1	0	4958.968

[a]The lowest AICc score in this model set was 4839.594

Table 2: Model selection results for factors affecting survival of American Oystercatcher chicks on Cape Hatteras and Cape Lookout National Seashores from 1999-2008. Models are ranked by ΔAICc. W*i* represents model weight and k is the number of parameters. Model factors include linear and quadratic daily variation, linear and quadratic age, year, island, presence of off road vehicles, and access to foraging areas.

Model	ΔAICc[a]	k	W*i*	Deviance
Age^2 + Island + Vehicle + Forage	0.000	10	0.991	1018.194
Age^2 + Island + Vehicle	9.442	9	0.009	1029.641
Age^2 + Island + Forage	24.476	9	0.000	1044.675
Age^2 + Island	32.170	8	0.000	1054.374
Age^2 + Year + Island	34.334	17	0.000	1038.474
Age^2 + Year	40.623	12	0.000	1054.804
Age^2	42.491	3	0.000	1074.711
Day + Age^2	44.139	4	0.000	1074.356
Day^2 + Age^2	45.220	5	0.000	1073.435
Age	47.293	2	0.000	1081.515
Day + Age	48.958	3	0.000	1081.178
Day^2 + Age	50.779	4	0.000	1080.997
Day	77.079	2	0.000	1111.300
Day^2	79.076	3	0.000	1111.296
Constant	91.888	1	0.000	1128.111

[a]The lowest AICc score in this model set was 1038.223

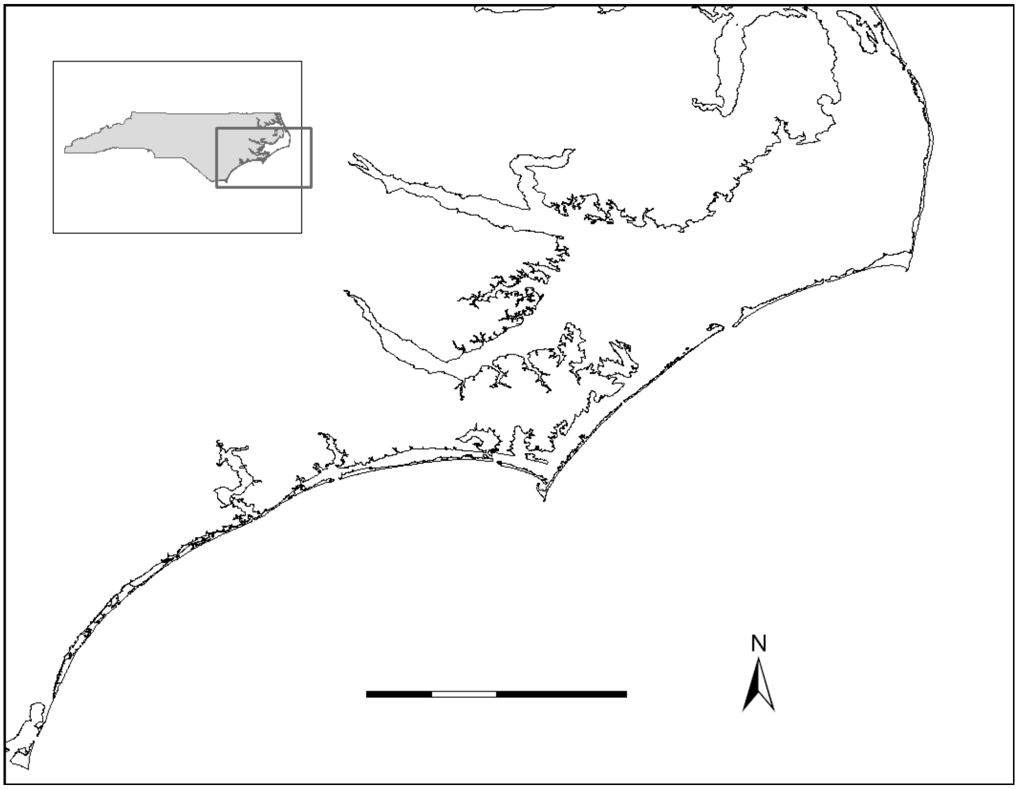

Figure 1. American Oystercatcher study sites in North Carolina.

Figure 2. Radio tagged American Oystercatcher chicks. Recently hatched American Oystercatcher chicks with glue-on transmitter (right) and post-fledging immature with leg-band transmitter (left).

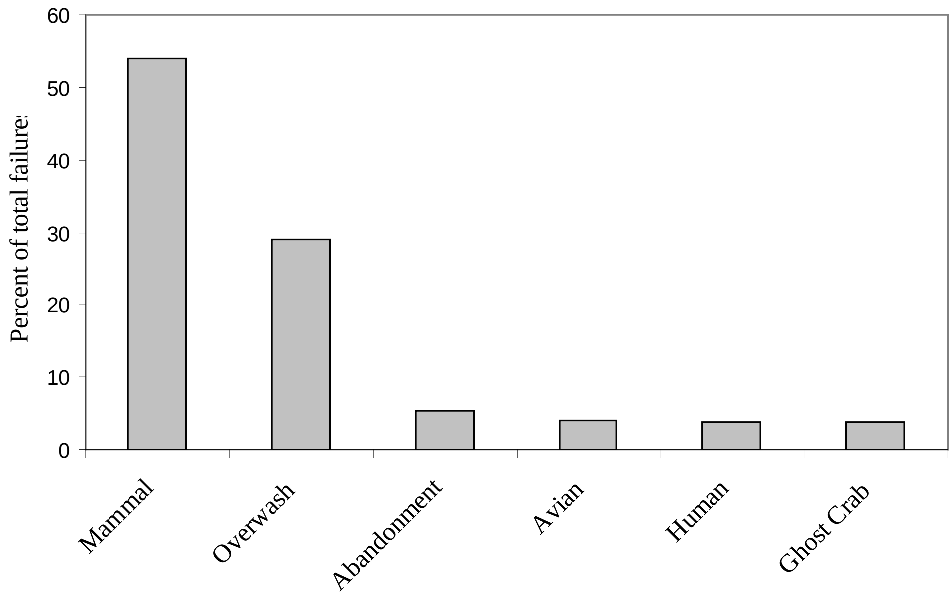

Figure 3. Sources of American Oystercatcher nest failure on the Outer Banks of North Carolina from 1998-2008 where cause of failure could be determined (N=481). Cause of failure could not be determined for 49% of nest failures (N=464).

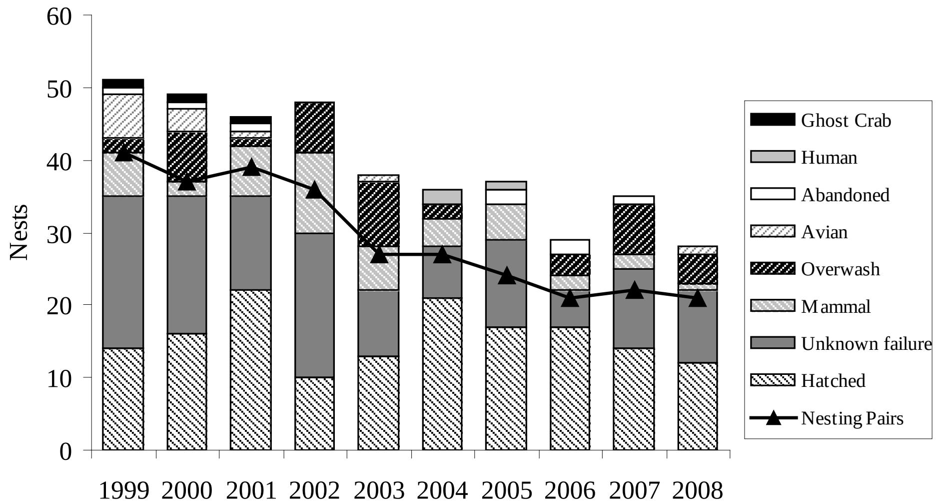

Figure 4. Nest fates for American Oystercatcher nests on Cape Hatteras National Seashore from 1999 to 2008. Column segments represent the number of nests in each outcome category.

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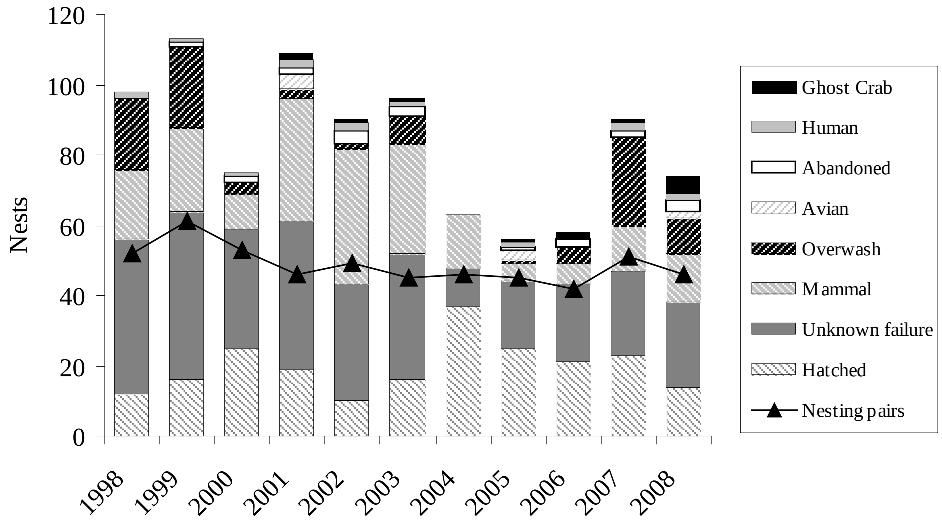

Figure 5. Nest fates for American Oystercatcher nests on Cape Lookout National Seashore from 1998 to 2008. Column segments represent the number of nests in each outcome category.

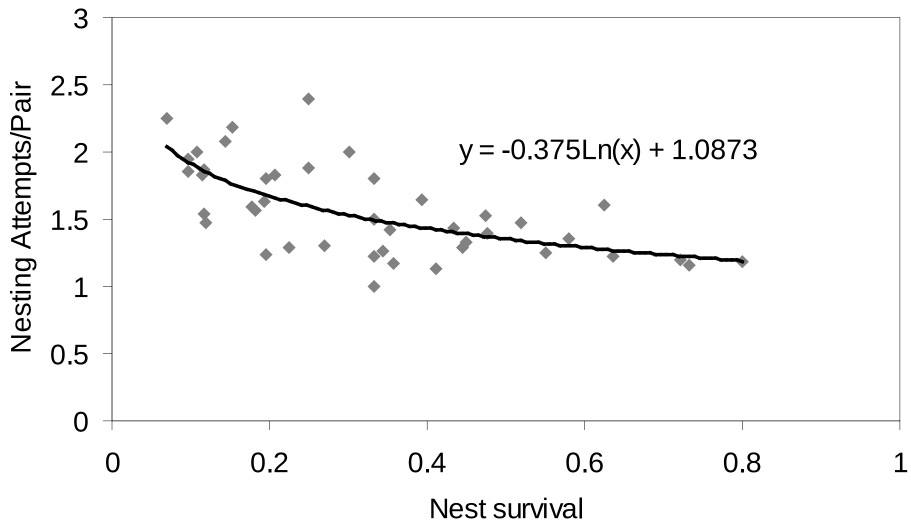

Figure 6. The number of nesting attempts per pair as a function of nest survival on Cape Lookout and Cape Hatteras National Seashores. 1998-2008. N=44 location/years, 1234 nesting attempts.

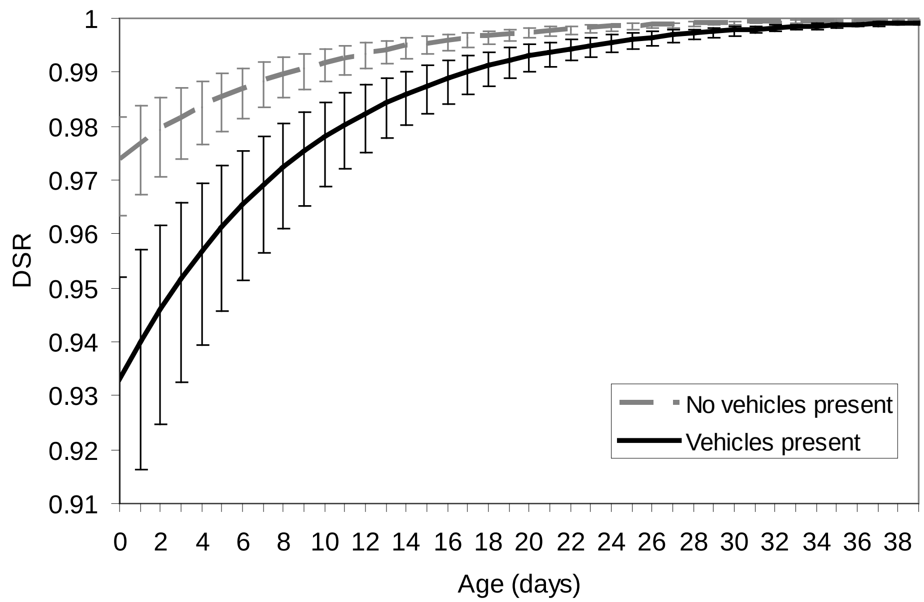

Figure 7. Survival curves for American Oystercatcher broods on beaches with and without off road vehicles. Daily survival rates and confidence intervals were estimated from the model with the lowest ΔAICc score (Table 2).

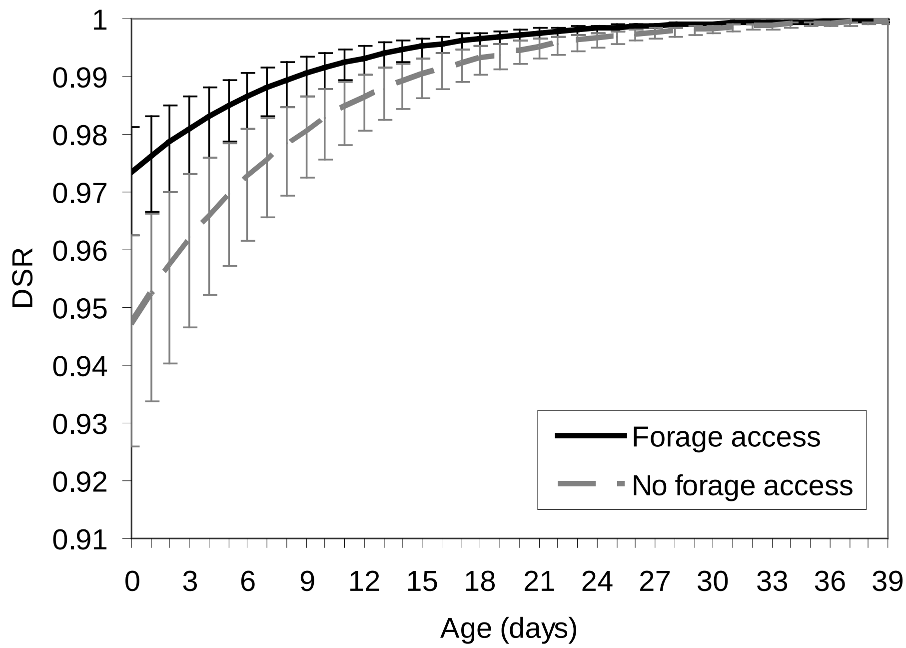

Figure 8. Survival curves for American Oystercatcher broods with and without direct access to foraging sites. Daily survival rates and 95% confidence intervals were estimated from the model with the lowest ΔAICc score (Table 2).

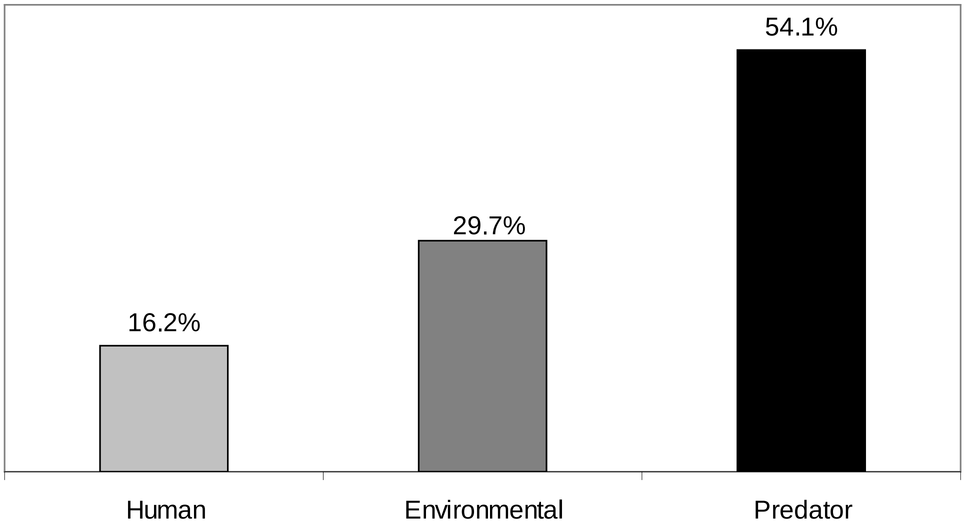

Figure 9. Sources of pre-fledging American Oystercatcher chick mortality at Cape Hatteras and Cape Lookout National Seashores from 2005-2007 (N=37). Source of mortality could not be determined for 51% of chick deaths (N=39 chicks).

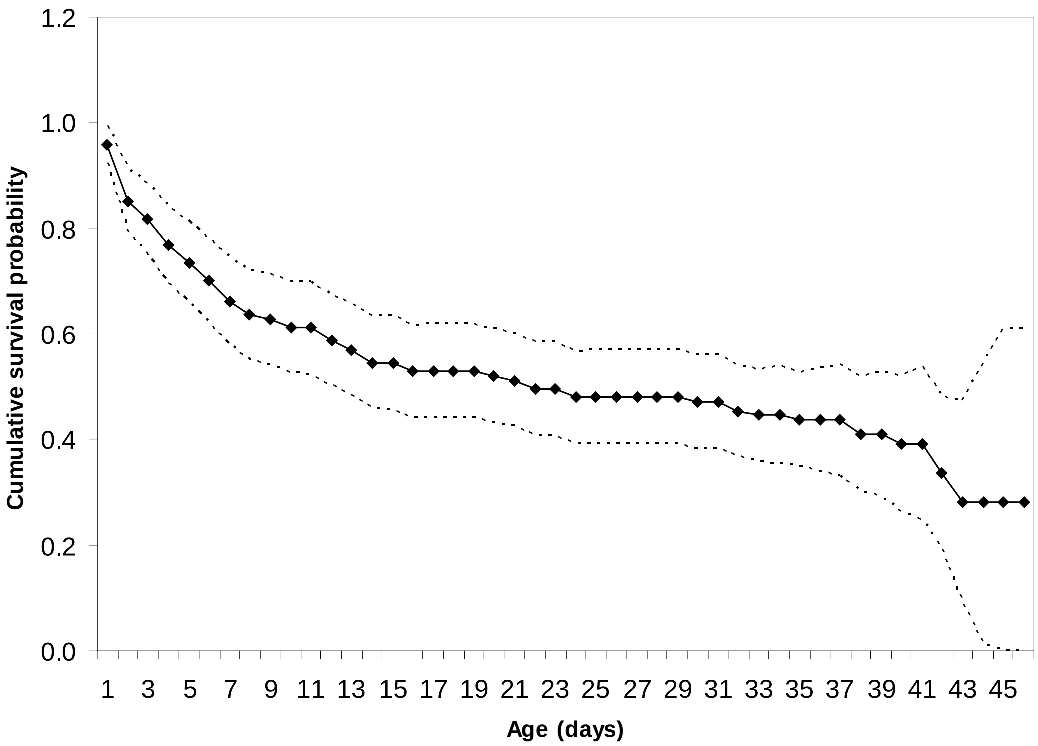

Figure 10. Kaplan-Meier survival curve and 95% confidence interval for pre-fledging American Oystercatcher chicks on Cape Hatteras and Cape Lookout National Seashores from 2005 through 2007 (N=121 chicks).

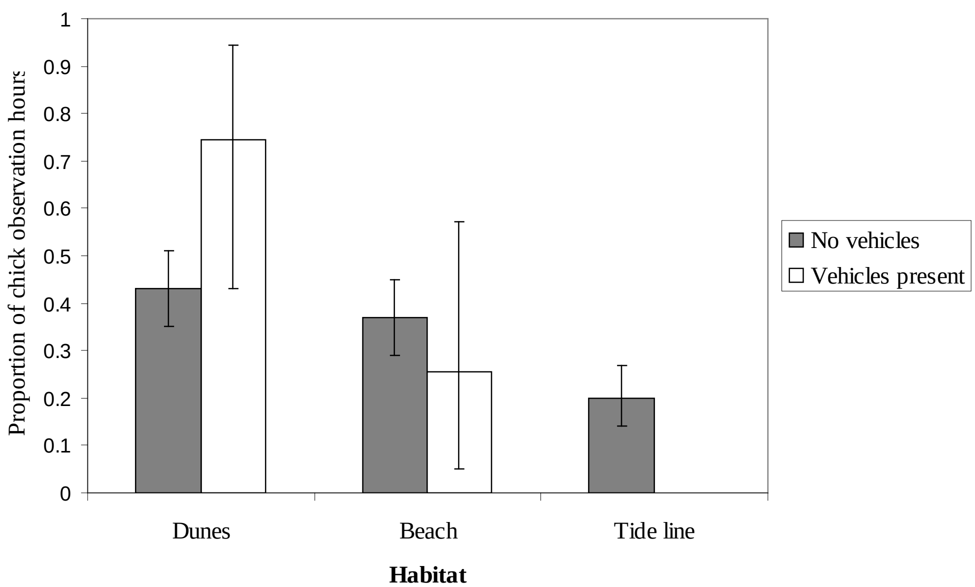

Figure 11. Habitat use by American Oystercatcher chicks on Cape Hatteras National Seashore on beaches with and without vehicles present (2004-2007). 54 chicks, 157 observation hours on beaches closed to vehicles , 9 chicks, 12 observation hours on beaches open to vehicles..

Figure 12. Radio-marked American Oystercatcher chicks crushed by a vehicle June 16 2005, Cape Lookout National Seashore.

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

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

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

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

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

Mike,

I will embed some comments below in response to your email. I would be happy to discuss this in greater detail if you like or come down and meet with you all.

Hi Ted,

We have a possible research project we'd like to get your thoughts on.

Background: My understanding is that the recommended nest buffer of 150 meters in the USGS protocols for American oystercatcher (AMOY) nests was based, in part, on John Sabine's study at ~~Gulf Islands~~Cumberland Island NS (2005 thesis).
The buffer, as recommended by USGS, applies to ALL recreational activities (i.e., ORVs and pedestrians). In reading through Sabine's thesis on American oystercatchers (particularly Chapter 4, Effects of Human Activity on Behavior of Breeding American Oystercatchers) there are a number of statements indicating a marked difference between observed pedestrian and vehicular disturbance during nest incubation (i.e., suggesting that pedestrian disturbance is much more of a concern than vehicular disturbance during incubation; while vehicular disturbance is clearly a concern when chicks are present). Sabine's study makes a strong case for the pedestrian buffer of 137 m or more during incubation, but does not seem to make the same case for completely restricting all vehicular activity within 150 m of a nest during incubation. For example:

Comment [TS1]: It is still not clear to me how the 150 m buffer was derived. I have a copy of the overview document by Cohen et al. and Sabine's 2008 paper in Waterbirds (both attached) that was derived from his 2005 thesis. The Cohen overview simply provides a recommended buffer of 150m, while Sabine uses 137 m based on the rationale below. If there are reasons for the current 150 m buffer I have not seen them.

Page 45: "During incubation, pedestrian activity ≤137 m of subjects reduced the proportion of time devoted to reproductive behavior, but pedestrian activity 138-300 m had no effect. Vehicular and boat activities had minimal effects on oystercatcher behavior during incubation."

From Sabine et al. 2008……

"Disturbance experiments were conducted on eleven oystercatcher pairs during the 2004 season, but because of nest locations and nest failure, all treatments could not be applied to all nests (Table 4). Oystercatcher displacement occurred during all trials of the 20-m pedestrian disturbance treatment. During 40- and 60-m disturbances, displacement occurred during 78% of trials. The mean distance for displacement of pooled nest means (all three treatments) was 113 m (N = 11, 95% CI = 90-137 m). No vehicle disturbance trials resulted in displacement from nests and only one pair displaced from an ATV disturbance trial. The upper value of the 95% CI (137 m) was used as a conservative threshold of tolerance of nesting American Oystercatchers on CINS."

If you look at Table 4 in Sabine et al. 2008 you will see that Sabine had people walk past 11 nests along transects parallel to the shoreline 20m below the nest, 10 nests along a line 40m below the nests, and 9 nests along a line 60 m below the nest, and he drove a vehicle past 9 nests along lines 50m below the nests and an ATV past 8 nests along a line 50m below the nests. He measured the proportion of nests where incubating birds flushed in response to the disturbance and he measured the distance from the disturbing person/vehicle to the nest. Birds did not respond to vehicles passing 50 m from their nests and 1 of 8 birds (0.13) responded to an ATV at 169.5m. The 137m figure comes from the upper 95% confidence limit of the disturbance distances of the pooled pedestrian data from 20, 40, and 60m.

So, as he states below, he found little evidence in this small sample of trials that birds are disturbed by vehicles driving along a line 50m below their nests (0/10 nests disturbed by vehicles, 1/8 nests disturbed by an ATV).

I am not aware of other empirical data on Oystercatcher flushing distances and do not know how the 150 m buffer in the consent decree was derived.

In my experience birds show a wide range of responses to different types of disturbance. I have attached a paper Conor McGowan and I published in the Wilson Bulletin in 2006. As you can see our results were quite different from John Sabine's. I think these types of findings are quite context dependant, a function of what the birds experience on a regular basis, and differences in habitat and predation risk. At CALO, where birds associate ATV's with researchers/park staff arriving to check their nests, they will often flush when and ATV is 200-300m from their nest. In general birds are much more tolerant of other vehicles, especially if the vehicles are >50 from their nests and if the vehicles are simply passing by at a moderate speed. CALO is implementing a new strategy this season by posting partial closures 100m on either side of active AMOY nests. The signs and symbolic fencing to the high tide line instruct visitors to drive through the closure without stopping. Birds seem to acclimate to this fairly well but we will have to see if it results in improved nest survival this year.

Page 88 (Management Recommendations): "Although presence of vehicular activity altered behavior during incubation, reproductive behavior was not negatively impacted, suggesting that vehicular activity at CINS in 2003 and
2004 did not negatively impact hatching success. During brood rearing, foraging behavior was lower in the presence of vehicular activity, which may alter chick provisioning and ultimately chick survival. To minimize impacts on adult foraging behavior, I recommend the prohibition of beach driving in oystercatcher territories (within 150 m) when chicks are present . At all other times, beach driving should be limited to well below the high tide line and speeds should be limited to 10 mph or less, so drivers have ample time to see and react to birds in the path of travel." (underlining added for emphasis) I agree that Sabine's data do not show a strong effect of vehicles during incubation. In general, as long as nests are not run over, most birds will acclimate to low levels of vehicle traffic adjacent to their nests. If traffic is not continuous, so that birds have access to foraging areas in front of their nests day and night, there is some likelihood their eggs will hatch. The challenge from a research standpoint is not documenting the distances at which birds will leave their nests in response to different forms of disturbance, but in documenting the consequences of disturbance on nest establishment, reproductive success, juvenile survival, and adult survival. It is very hard to do this in a setting like CAHA because of limited sample sizes and the difficulty of isolating an effect like vehicle traffic from confounding factors like variations in predator abundance, or habitat quality. Even so there are certainly things we can learn about disturbance that can inform management policies. See comments about research objectives below….

The apparent contrast between pedestrian disturbance and vehicular disturbance described in Sabine 2005 does not seem to support the recommendation of an absolute 150 m buffer for ALL recreation during AMOY incubation that is found in the USGS protocols (perhaps other references provided the basis for the 150 m vehicular restriction during incubation?).
In managing the beach at Cape Hatteras, there are limited occasions in which being able to allow vehicles to pass some appropriate buffer distance from an AMOY nest during incubation (i.e., NOT when chicks are present) would be beneficial, provided the buffer distance is sufficient to prevent negative impacts from disturbance. For example, if a 150 m buffer for such a nest were to block the only means of access to an important recreation site such as Cape Point and if a lesser buffer for the activity of driving past the site to reach the open area beyond the closure were adequate to prevent disturbance during incubation (assuming that a full beach closure would occur when chicks are present), it could reduce the overall length of time that popular sites (such as Cape Point) were inaccessible to the public and could decrease public resentment about the duration and impact of the closures.

Comment [TS2]: Yes, the vulnerability of chicks to vehicles can't be overstated. So, with closures related to Piping Plover and other species you are really talking about a 4-6 week period where modifications to AMOY closures might make a difference in how you manage vehicles.

This is an important strategic decision that deserves some careful thought. There are two possible approaches as I see it. They come down to managing at the population level or at the level of individual breeding pairs. You could manage at the level of individual birds and try to develop a standard for disturbance that is applicable to all birds in all habitats, or you could manage at the population level and set targets for population levels and nesting success for the entire Seashore. I think there is a case to be made that trading off some additional disturbance in very high demand visitor areas like Cape Point and Bodie Island Spit for greater protection in other areas (via closures, predator control) if the net effect is getting the Seashore moving in the direction of restoring the declines we have seen in AMOY populations over the past 15 years. Of course these trade-offs would have to be balanced with objectives for Piping Plover, Terns and other species who may rely more heavily on these popular recreational sites. In any event, there is no question that better information about disturbance and birds will improve your management decisions and I am happy to work with you to define some research objectives.

Research Project Concept: To follow up on specific negotiated rulemaking discussions that occurred during natural resources subcommittee meetings (which included Walker Golder among other stakeholders), I am interested in having research done at Cape Hatteras in the next few years that would evaluate the effectiveness/adequacy of having a buffer of less than 150 m for ORVs driving past AMOY nests during the incubation. My intent is to definitively determine for Cape Hatteras whether there may be limited, definable circumstances under which it may be appropriate to allow vehicles to drive past by an AMOY nest at a distance less than 150 m. Under what circumstances or conditions, if any, would a reduced buffer for vehicles driving by be effective/adequate? Under said conditions, what would be the effective/appropriate vehicular buffer size during incubation? Would restricting vehicles to traveling below the high tide line during incubation be adequate as p. 88 in Sabine's thesis suggests? Would controlling or restricting the number of vehicles per hour, or limiting travel time to limited time periods per hour, or would manipulating any other variable(s) within management control make a difference?

Underlying Management Objectives:

Ensure adequate protection of incubating AMOY nests Agree. Question is how to measure disturbance and protection. We can measure flushing distance and show how flushing distance changes with distance and the type of disturbance. The question then becomes one of picking a meaningful management threshold.

Determine if a reduced buffer distance (i.e., less than 150 m) for ORVs driving past an incubating AMOY nest is adequate to prevent disturbance and, if it is, determine what distance is adequate OR

Determine that a reduced buffer is NOT adequate (and put this issue to rest) Again, this depends on operational definition of disturbance. In the absence of measurable outcomes like hatching success these definitions can become very subjective.

Questions:

Do you believe that such a study could produce the specific results the park would need for practical management purposes, or would it possibly only indicate that there is such variability in individual bird's reactions to ORV disturbance during incubation that the only way to prevent disturbance is to use the same conservative buffer size for all human disturbance situations? In the specific cases of Cape Point and Bodie Island Spit this is almost impossible to determine because reducing the buffer results in such a massive change to the nesting environment. It would be hard to compare the effects of a 100m versus a 150m buffer for those nests when the 50m difference means the difference between essentially no people and thousands of people on the same section of beach.

Is there an adaptive management approach to managing these specific situations (AMOY nest buffer blocking the only access to an inlet or Cape Point, when the inlet or point itself is otherwise "open") that could be designed to determine the appropriate effective ORV "drive-by" buffer distance over time? Yes, an adaptive management approach would, almost by definition, focus on population level objectives. It would provide the flexibility to apply different management policies in different locations in order to minimize both the political and the economic cost of management and find the most efficient path to your management objective (in this case some population, productivity, and survival targets).

Request for a Proposal: If you believe that such a study could lead to a practical differentiation in buffer size for ORVs driving past an incubating nest vs. the buffer size needed to prevent disturbance from other human activities, I would appreciate it if you would develop a research proposal, with estimated costs, for such a study so that the Seashore can seek funding for it. Ideally, the project would be something that could be started in 2010 (or no later than 2011).

I would appreciate the opportunity to continue working with you and your staff on these issues and would be happy to develop a detailed research proposal over the next few months. I have attached a generic budget to give you a rough idea of the costs I would envision for this research. A focused 3-year MS level study of incubating adult time activity budgets and response to various types of vehicle/pedestrian disturbance would cost about

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$180K, and more ambitious 5-year PhD level study to develop an adaptive approach to AMOY management would cost about $300K.

Thank you for your consideration. If you think it would be helpful to discuss this on the phone before responding, feel free to say so and we can set up a call to discuss it.

Yes, if you want to pursue this I think it would be very helpful to meet and discuss possible approaches. Please let me know if you would like to set up a time for a conference call or a visit.

Sincerely,

Ted

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

2009 Annual report

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EXECUTIVE SUMMARY

Natural communities in coastal regions are under increasing pressure from human use, introduced predators, and habitat change. The American Oystercatcher *Haematopus palliatus* is a useful focal species to study the effect of rapid anthropogenic change on coastal ecosystems. American Oystercatchers are long-lived shorebirds that breed from Maine to Florida and are closely tied to intertidal ecosystems throughout the year. One hundred seventy-nine Oystercatcher pairs and 232 nests were monitored in North Carolina in 2009. Overall observed nest survival was 0.421 (SE 0.032), while adjusted nest survival was 0.351 (SE 0.032). Overall productivity, or the number of chicks fledged per nesting pair, was 0.384 (SE 0.044).

We took an information-theoretic approach to the analysis of factors affecting the survival of American Oystercatcher nests and broods on the Outer Banks of North Carolina. Variation in nest and brood survival was evaluated with respect to nesting island, year, time of season, brood age, distance to tide, presence of off road vehicles, and proximity of foraging. The mean daily nest survival rate was 0.951 (SE 0.001). Nest survival was affected by year and island, but tended to decline over the nesting season. Raccoons and other mammalian predators were the primary cause of nest failure, accounting for 54% of identified failures. Mean daily brood survival was 0.982 (SE 0.002). Brood survival varied by island and increased non-linearly with age, with highest mortality during the first week after hatch. Our model predicted that direct access to sandflats and marshes would have a positive effect on brood survival, while the presence of off road vehicles would have a negative effect. We studied Oystercatcher chick behavior and survival using radio telemetry and direct observation and found that Vehicles directly caused mortality and affected behavior and resource use of Oystercatcher chicks. Oystercatcher chicks move extensively and use the entire beach and dune system. This behavior often placed broods at risk from vehicles on the beach, and several chicks were killed by vehicles during the course of the study. Chicks on beaches closed to vehicles used the beach and intertidal zone more frequently than chicks on beaches with vehicles, and spent less time hiding in the dunes. Chick predators were identified by daily radio tracking of individual chicks and included Great Horned Owls, Fish Crows, Feral Cats, Mink, Raccoons, and Ghost Crabs.

Three hundred and sixty-six American Oystercatchers have been individually color-banded in North Carolina since 1999. Through resightings of individually marked birds we estimated an annual adult survival rate of 92% and an age of first breeding of approximately 4 years. Working in cooperation with other researchers and volunteers we have discovered that Oystercatchers with a breeding or natal site in North Carolina disperse in winter from Virginia to Florida. 32% remained in North Carolina for the winter, 20% moved to South Carolina, 18% to NW Florida with the remainder split up among Virgina, Georgia, and the rest of the Florida coast. Oystercatchers have strong fidelity to breeding and wintering territories.

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INTRODUCTION

American Oystercatchers (*Haematopus palliatus*) are large, conspicuous shorebirds that are strictly tied to the coastal zone throughout the year. Unlike many shorebirds that breed in the Arctic and migrate to coastal regions in the winter, Oystercatchers breed along the Atlantic Coast from Cape Cod to Florida, and along the Gulf Coast from Florida to Mexico (Nol and Humphrey 1994). The winter range extends from central New Jersey south through the Gulf of Mexico. An aerial survey of the species' winter range resulted in a population estimate of 10971 individuals (+/-298), with 7500-8000 wintering on the Atlantic Coast (Brown et al. 2005). The survey estimated a winter population of Oystercatchers in North Carolina at 647 birds. A 2007 breeding season survey estimated North Carolina's summer population at 717 individuals, with 339 breeding pairs (Cameron and Allen 2007).

American Oystercatchers are listed in both Georgia and Florida as "threatened", and as a "species of special concern" in North Carolina (North Carolina Wildlife Resources Commission 2008). The American Oystercatcher Conservation Plan lists American Oystercatchers as a high priority species (American Oystercatcher Working Group, 2007), in part because of significant threats from development and heavy recreational use of coastal breeding habitats. Human population density in the United States is highest in coastal regions. The rate of population growth is expected to increase substantially, particularly in the southeastern states (Crossett et al. 2004). As more humans inhabit the coastal zone, recreational use of beaches, salt marshes, and waterways will continue to rise as well. Many visitors to the coast seek out undeveloped beaches. As coastal islands and beaches are developed, more visitors are concentrated onto the remaining undeveloped areas. Coastal development, recreational activity, and altered predator communities have substantially reduced the amount of suitable nesting and foraging habitat for beach nesting birds in North Carolina. Roads and artificial dunes along nesting beaches can limit access to sound-side marshes and flats that are important foraging habitats for beach nesting species like Piping Plovers (*Charadrius melodus*) and American Oystercatchers. Nesting and roosting sites can also be lost when jetties and revetments alter the normal process of longshore transport of sand and accelerate erosion of adjacent beaches.

Like many long-lived species, Oystercatcher reproductive rates tend to be highly variable but generally low (Evans 1991, Nol and Humphrey 1994, Davis et al. 2001, Wilke et al. 2005, McGowan et al. 2005a, Traut et al. 2006). This means that the species is unable to recover quickly from population declines. These traits also make it difficult to assess the status of a population because populations can persist for many years, even if reproductive success is low. Recent surveys indicate that populations in the Mid-Atlantic States are declining (Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). The breeding population of Virginia's barrier islands, a historical stronghold for Oystercatchers, fell from 619 breeding pairs in 1979 to 255 breeding pairs in 1998 (Davis et al. 2001). A 2004 survey that covered the same region estimated the population at 302 breeding pairs (Wilke et al. 2005). This survey also covered lagoon and marsh habitat and found an additional 223 pairs. These results suggest populations may be moving into non-traditional habitats, and they highlight the need for additional surveys in marsh and upland habitats not normally associated to Oystercatchers. During the period of apparent decline in the mid-Atlantic, the species expanded its breeding range into the northeastern United States (Davis 1999, Mawhinney and Bennedict 1999, Nol et al. 2000, Davis et al. 2001). Understanding the causes of local, regional, and continental population trends will require region-wide studies of the species' population structure and demographics.

A study of breeding American Oystercatchers was initiated on South Core Banks, Cape Lookout National Seashore in 1995 to document nesting success (Novick 1996). The scope of the original study has expanded to include all of the islands of Cape Lookout and Cape Hatteras National Seashores. The study of Oystercatcher breeding success further expanded in the state in 2002 and 2003 when the North Carolina Audubon Society initiated nest monitoring on dredge spoil islands at the mouth of the Cape Fear River, and on Lea and Hutaff Islands. Although the undeveloped barrier islands that comprise the National Seashores were thought to be ideal breeding habitat for American Oystercatchers, nest survival was much lower than expected. Novick (1996) attributed low hatching rates to human disturbance. Davis (1999) continued the work on Cape Lookout and used nest monitoring and predator tracking stations to determine the causes of nest failure. Davis determined that a majority of nests were lost to mammalian predators. Subsequent studies in North Carolina have supported the conclusion that mammals are the primary nest predators, but they also suggested an interaction between human disturbance and nest predation rates (McGowan 2004, McGowan and Simons 2006). McGowan and Simons (2006) found an inverse relationship between the number of visits an Oystercatcher made to the nest and the nest survival rate, suggesting that more disturbed nests are more likely to be found by predators.

Although a considerable amount of research has been conducted on nesting American Oystercatchers, relatively few studies have focused on chick survival. The sources and timing of mortality are very difficult to determine for precocial shorebird chicks (Nol 1989; Ens et al. 1992). Chicks often leave the nest within a few hours of hatching, after which they are cryptic and highly mobile. When chicks are lost to predators, exposure, or other sources, it is often difficult to determine the cause of death. Studies of other shorebird species have identified chick age, mass at hatching, human disturbance, habitat quality, access to foraging sites, rainfall, and an array of predator species as factors affecting chick survival (Dinsmore et al. 2002, Ruhlen et al. 2003, Ruthrauff and McCaffery, 2005, Colwell et al. 2007). Because many breeding attempts fail during the chick-rearing stage, several recent studies have stressed the need for a better understanding of the factors affecting American Oystercatcher chick survival (Davis et al. 2001, McGowan et al. 2005a). In 2004 we initiated a study of American Oystercatcher chick behavior on Cape Hatteras National Seashore. Relatively little was known about how Oystercatcher broods used their habitat and responded to human activity. Anecdotal observations suggested that breeding adult Oystercatchers altered their behavior in the presence of humans and vehicles by hiding their chicks in the dunes and keeping them off the beach. The objectives of this study were to identify patterns of chick behavior and habitat use, quantify the effects of vehicles on Oystercatcher chick behavior, and compare the effects of two management actions (closed beach versus partial beach closures). In 2005, 2006 and 2007 we used radio telemetry to track Oystercatcher chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore to identify the timing and sources of chick mortality. In this report we summarize the results of reproductive success monitoring and mark-recapture analysis on the Outer Banks and take an information theoretic approach to examine variation in nest and chick survival with respect to age, season, year, island, presence of off road vehicles, and habitat quality.

STUDY SITES

We are currently monitoring American Oystercatcher productivity at several locations in North Carolina in cooperation with staff from the National Park Service and the National Audubon Society. Cape Lookout and Cape Hatteras National Seashores (Figure 0.1) comprise over 160 km of barrier island habitat in North Carolina and support a population of approximately 90 breeding Oystercatcher pairs. The islands are characterized by wide barrier beaches backed by a primary and secondary dune complex broken by flats and overwash fans. The dunes fade into wax myrtle (*Myrica cerifera*) scrub and then to spartina saltmarsh bordering the back bays and sounds. This system is subject to periodic washover events, followed by recolonization by dune grasses. Cape Lookout and Cape Hatteras support approximately 90 breeding pairs of Oystercatchers which nest on the sand flats and dunes and forage along the beach and salt marsh. Off road vehicles are permitted on beach and interdune roads in both parks except in designated wilderness areas or sensitive bird or turtle nesting areas. Cape Hatteras has a permanent road system and several small towns along the length of the islands.

The National Audubon Society manages several islands in the Cape Fear region that provide habitat for an additional 32 pairs of breeding Oystercatchers. Ferry Slip and South Pelican Islands are dredge-spoil islands at the mouth of the Cape Fear River where large colonies of Royal Terns (*Sterna maxima*), Sandwich Terns (*Sterna sandvicensis*) and Laughing Gulls (*Larus atricilla*) nest. A third island, Battery, is a natural island that has been armored with large sand bags to prevent erosion and over wash. Battery Island is the site of a large wading bird colony comprised of White Ibis (*Eudocimus albus*), Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*) and Great Blue Herons (*Ardea herodius*). It is also host to substantial population of breeding fish crows (*Corvus ossifragus*). Oystercatcher nesting densities on these islands are much higher than those found on the barrier islands of the Outer Banks. In 2003 the Audubon Society began monitoring nesting success on Lea and Hutaff Islands in Pender County North Carolina. Lea and Hutaff are barrier islands similar to the islands in the national seashores, but they are privately owned and public recreation is limited. The islands recently joined when Topsail Inlet closed to form one island 8 km long (McGowan et al 2005a).

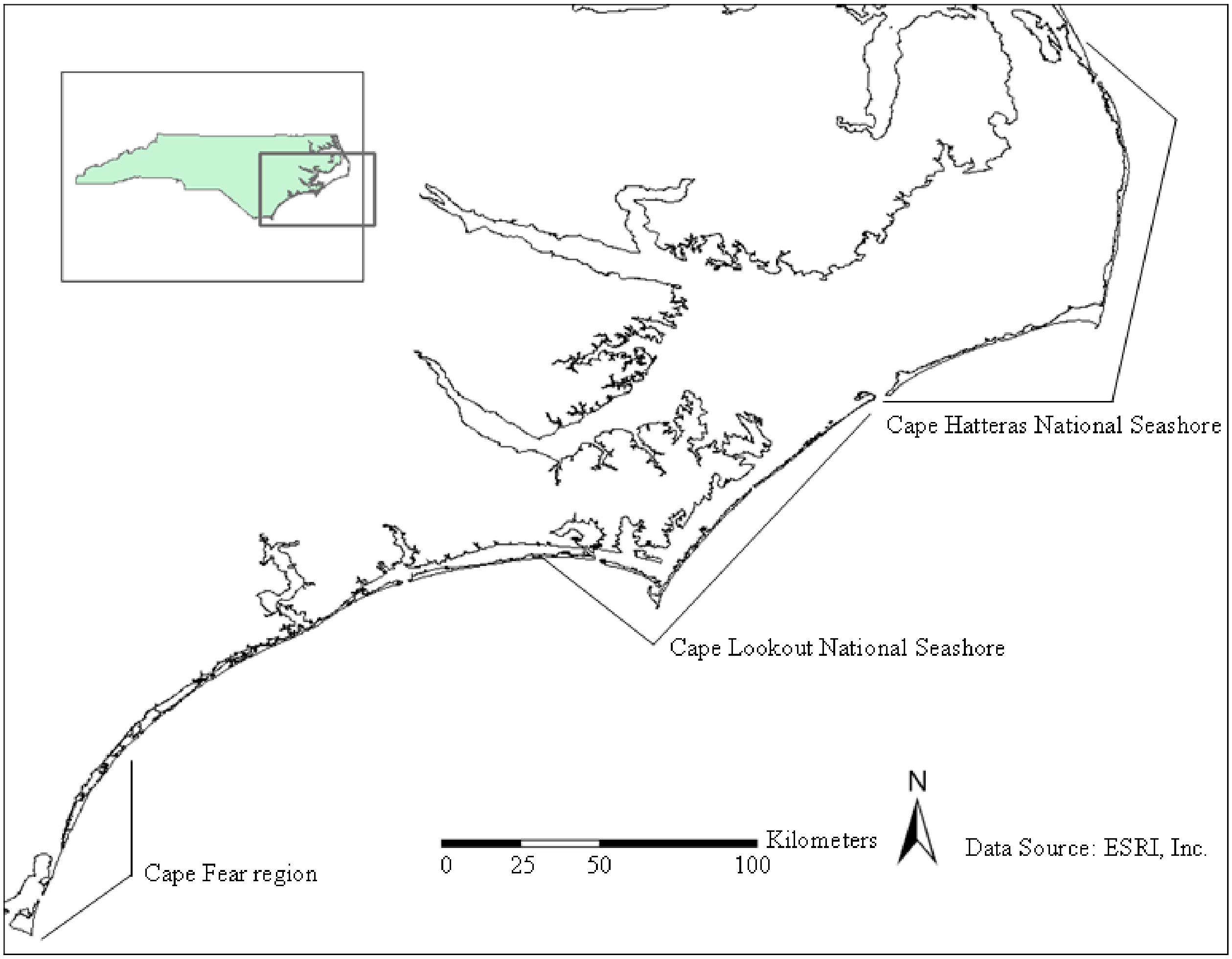

Figure 0.1. American Oystercatcher study sites in North Carolina.

Section 1 - Factors affecting the reproductive success of American Oystercatchers in North Carolina

METHODS

Factors affecting nest survival

Surveys of breeding Oystercatchers on the Outer Banks began in early April each year. Nests were located by walking or slowly driving along the barrier beach and back-road system. When an adult Oystercatcher was located, observers watched for behavioral cues that indicated the bird had a nest. Although nesting Oystercatchers do not usually employ "broken-wing" distraction displays typical of smaller shorebirds, they do exhibit easily identifiable behaviors such as false incubating and alarm calling. When breeding behavior was observed, scrapes were found by following the tracks of the adult birds, or by systematic searches. Once located, nests were marked with a small wooden stick placed near the nest, or by using adjacent natural landmarks like driftwood, shells, etc. as a reference. The location of each nest was recorded with a handheld GPS. Nests were checked every 1-4 days until hatching or failure. We made every effort to minimize disturbance and reduce any effect of our observations on nesting success. If a bird is seen incubating from a distance, the nest was considered active and it was only checked to determine if the chicks had hatched. We avoided walking directly to nest sites, and spent a minimal amount of time in the vicinity of the nest to minimize cues for predators. If a nest failed, we attempted to determine the cause of failure by searching the area for signs of predators, storm overwash, or other sources of nest failure. For example, when a storm event washes out a nest, the nest scrape is usually gone and a debris line is evident above the nest's original location. Unfortunately, such evidence does not last long on a barrier beach, so it was not always possible to determine the causes of nest failure.

We developed a set of hypotheses to explain variation in nest survival on the Outer Banks from 1999 to 2009. The hypotheses described below were incorporated into candidate models as covariates.

1) *Year.* Year to year variation in weather patterns, timing of storms, prey abundance, predator abundance, and numerous other factors that were not explicitly measured could affect Oystercatcher nest survival

2) *Island.* The study area is composed of six islands in two national parks. Human use of the seashores varies considerably from island to island, along with predator composition and abundance. Differences in these and other factors could explain variations in nest survival.

3) *Presence of Off Road Vehicles*. Vehicle activity can affect nesting behavior (McGowan and Simons 2006) and nest survival for beach nesting birds (Buick and Paton, 1989, Novick 1996, Davis 1999, Carney and Sydeman 1999). Although many of the nests in the study area were protected from direct impact by signs and symbolic fencing, we hypothesized that the indirect effects of adjacent vehicle traffic would lower survival for nests on beaches open to vehicles. We considered a beach open for vehicle traffic if vehicles were allowed to pass above or below the nest, even if the nest itself was in a closed area. We did not attempt to include distance from nests to vehicles or the number of vehicles using the beach, as these data were unavailable for most of the nests.

4) *Distance to the high tide line*. Oystercatchers nest anywhere from within a few meters of the high tide line to hundreds of meters away on large sand flats. Overwash from storms and spring tides is a major source of nest failure. In addition, the majority of vehicle traffic is located near the high tide line. We hypothesized that nest survival would increase with distance from the high tide line.

5) *Direct access to foraging habitat.* Oystercatchers will forage on the

ocean beach, but most birds maintain primary foraging territories in the creeks and mudflats on the back side of the barrier islands. If a nesting oystercatcher has to fly a long way to get to their foraging site they are unavailable to help their mate defend the nest from predators. Perhaps more importantly, nest sites adjacent to foraging territories may be very important during chick rearing (Ens et al. 1992, Heg and van der Velde 2001, Kersten and Brenninkmeijer 1995, van de Pol 2007). Older, more experienced birds are likely to occupy these prime territories, so this covariate may be an indirect measure of adult quality. We hypothesized that direct access to primary foraging habitat would increase nest survival.

6) *Time of the nesting season.* The nesting season on the Outer Banks of North Carolina spans approximately five months. We fit linear and quadratic time trend models to the null model of constant survival to evaluate temporal variation in nest survival within the nesting season. For the linear model we predicted that survival would decrease thorough the season. The quadratic model allowed for a non-linear change in nest survival to account for more than one survival peak or valley.

Previous analyses compared estimates of apparent nesting success using the binomial proportion of successful nests to failed nests, with Mayfield nest survival estimates (Mayfield 1961, 1975, Davis, 1999, McGowan 2004). As expected, these results showed that apparent nest success overestimated survival because of nests that failed and were never found. We analyzed our nest survival database from the period 1999-2009 using the nest survival module in Program Mark (White and Burnham 1999, Dinsmore et al., 2002). This method is similar to the Mayfield method in that a daily survival rate is calculated from nest observation days and thus accounts for missed nests. Daily nest survival is defined as the probability of surviving from day i to i + 1. Program Mark uses a maximum likelihood method to estimate the nest failure date when the time between nest checks is greater than 1 day, and it allows for modeling covariates to explain variations in nest success and the comparison of alternative models using Akaike's Information Criteria (AIC) (Akaike 1973, Burnham and Anderson 2002).

Based on our hypotheses and predictions described above, we evaluated seven covariates; Linear time trend, quadratic time trend, year, island, foraging access, distance to the tide line, and presence of off road vehicles. Foraging access was a binary individual covariate based on access to foraging sites for nesting pairs. The covariate was positive if a pair had direct walking access to a primary foraging site. Primary foraging sites were defined as mudflats, saltmarsh creeks, tide pools and intertidal oyster beds. The individual covariate "distance to high tide line" was measured by calculating the distance between nest locations and recorded high tide lines in ArcMap (Esri 2009). Presence of off road vehicles was recorded for each nest based on beach closure records from the National Park Service. Off road vehicles were considered to be present if any part of the beach above or below the nest was open to vehicle traffic, regardless of whether the nest itself was in a vehicle exclosure. We did not account for differences in traffic volume or exclosure size, as these data were not available for the majority of our nests. We used a three-step hierarchical process to evaluate different models. In the first step we created models with linear and quadratic time trends as well as a null model of constant survival. We then added effects of year and island to the best model(s) (ΔAICc ~<2.0). Finally we added the covariates for tide distance, foraging, and ORV access to the new best model(s).

Factors affecting brood survival

When a nest hatched, the young were observed every 1-4 days until fledging, or until all the chicks died or disappeared. We documented habitat use and behavior of Oystercatcher broods on Cape Hatteras National Seashore from 2004 to 2007 using behavioral observations. We did not have the option of experimentally manipulating the disturbance level or closed/open status of the beach (e.g. Simons and Tarr 2008), so this was strictly an observational study. We conducted observations in hour-long intervals, taking instantaneous habitat information at two minute intervals. Broods were observed through scopes from a distance where observer presence did not affect the bird's behavior. Habitats were designated as; below the tide line, open beach, and dunes or grass. Watches continued if the birds went out of sight as long as we could still determine the habitat type. This prevented a negative bias for dune and grass habitats where the birds are less visible. We observed chicks of all ages from hatching through fledging at all times of day and stages of the tide. We were not able to conduct behavior watches at night, but we did periodically check on the location of broods at night to document habitat use. Observation windows were randomly assigned to active Oystercatcher broods throughout the nesting season. We used t-tests to compare habitat use on beaches open and closed to vehicles.

With careful monitoring it was possible to determine annual productivity, or the number of chicks fledged per pair, per year, although usually not the cause or exact timing of chick mortality. Adult Oystercatchers exhibit markedly different behavior patterns when they have chicks. They are much more aggressive toward intruders, and they give distinct alarms calls. It was generally possible to determine whether a pair of adult birds had chicks by observing adult behavior, even if we could not locate the chicks. In most cases chicks were located by observing adults from a distance using a spotting scope, and occasionally a portable blind. On the rare occasion that a chick was found dead, we attempted to determine the cause of death.

In our analysis of factors affecting chicks during the pre-fledging period, we considered chick survival and brood survival separately. Chick survival was defined as the probability of a single chick surviving from hatch to fledging, while brood survival was defined as the probability of at least one chick in a brood surviving to fledging. Because of the difficulty in determining the status of individual chicks during each monitoring check, we developed hypotheses and analyzed covariates associated with brood survival, rather than individual chick survival. We developed models incorporating these hypotheses using the nest survival module in Program Mark. Our hypotheses about factors affecting brood survival were similar to nest survival. We did not include an effect of distance to high tide because Oystercatcher chicks are highly mobile. We also examined the effect of brood age on survival, hypothesizing that daily survival would increase with brood age. Covariates included in the brood survival models were year, island, presence of Off Road Vehicles, direct access to foraging habitat, time of the nesting season (linear and quadratic trends), and age of the brood (linear and quadratic trends).

We used a multi-step approach to model construction, similar to the nest survival analysis. In the first step we ran models with linear and quadratic time and brood age trends as well as a simple null model of constant survival. We then added the effects of year and island to the best model(s). Finally we added the covariates for presence of off road vehicles and foraging access to the best model (inclusive of year and/or island effects) to see if they contributed any useful information to the best model.

Factors affecting chick survival

In addition to the analysis of brood survival from the full dataset, we looked at factors affecting individual chick survival and sources of mortality for a subset of chicks using radio telemetry. From 2005 to 2007 we radio tagged a total of 121 chicks on Hatteras Island, Cape Hatteras National Seashore, and North Core Banks, Cape Lookout National Seashore. Chicks were radio tagged as soon as they were mobile, usually within 24-48 hours of hatching. We attached ATS A2420 transmitters (1.3 grams) to the scapular region of the chick using surgical grade skin glue (Figure 1.1). Chicks were checked every 24 hours for the first week, and every 1-3 days thereafter. Transmitter range was 400-1000 meters depending on terrain. When a chick died, we tried to locate the remains and determine the cause of death. We estimated survival probability for radio tagged chicks using the Kaplan-Meier known fate procedure (Kaplan and Meier 1958). Day zero was defined as the day of hatch regardless of capture date. Multiple chicks from the same brood were tagged and followed, which violates the assumption of independent observations. The result is that the survival estimator was unbiased, but the standard error was likely underestimated (Pollock et al. 1989).

In 2005 and 2006 we exchanged the ATS transmitters for larger PD2 model transmitters from Holohil Systems when the chicks reached four weeks of age. These transmitters were designed to last at least six months and were attached to a permanent leg band (Figure 1.1).

Figure 1.1. Radio tagged American Oystercatcher chicks. Recently hatched American Oystercatcher chicks with glue-on transmitter (right) and post-fledging immature with leg-band transmitter (left).

RESULTS

2009 Field season

One hundred seventy-nine breeding Oystercatcher pairs and 232 nests were monitored in North Carolina in 2009. Monitoring sites in 2009 included Cape Hatteras National Seashore, Cape Lookout National Seashore, Oregon Inlet Islands, Ocracoke Inlet Island, the Cape Fear River Islands, and Lea and Hutaff Island. Overall observed hatching success from the beginning of egg laying to hatching was 0.421 (SE 0.032) (Table 1.1). To adjust for nests that failed and were never found we used Program Mark to estimate the overall daily survival rate (0.962, SE 0.003).The average incubation period for Oystercatcher nests is 27 days (Nol and Humphrey 1994). To obtain the probability of nest survival to hatching (period nest survival) we raised estimates of daily survival rates (DSR) to the 27^{th} power. Adjusted overall nest survival for the full nesting period in 2009 was 0.964^{27} = 0.351 (SE 0.032). Adjusted nest survival varied among locations (Table 1.1, Appendix 1). Oystercatchers nesting on the Oregon Inlet Islands had very high hatching success (0.806, SE 0.123), while those on Lea and Hutaff Island experienced almost complete nest failure (0.085, SE 0.050). The nest survival rate was 0.487 (SE 0.090) on Cape Hatteras National Seashore and 0.242 (SE 0.044) on Cape Lookout National Seashore. Overall productivity, or the number of chicks fledged per nesting pair, was 0.384 (SE 0.044).

Table 1.1. Reproductive success of American Oystercatchers in North Carolina in 2009

Site	Breeding pairs	Nests	Nests hatched	Observed Nest Survival (SE)	Adjusted Nest Survival (SE)	Chicks fledged	Chick survival (SE)	Productivity (SE)
C. Lookout	61	83	20	0.241 (0.047)	0.242 (0.045)	21	0.525 (0.079)	0.344 (0.090)
C. Hatteras	23	31	15	0.484 (0.090)	0.487 (0.090)	13	0.419 (0.088)	0.565 (0.185)
C. Fear	57	62	42	0.677 (0.059)	0.509 (0.075)	27	0.435 (0.063)	0.474 (0.094)
Lea/Hutaff	18	22	4	0.182 (0.082)	0.085 (0.050)	1	0.145 (0.132)	0.056 (0.056)
Oregon Inlet	11	12	10	0.833 (0.108)	0.806 (0.121)	7	0.350 (0.107)	0.636 (0.279)
Ocr. Inlet	15	23	7	0.304 (0.096)	0.356 (0.102)	2	0.167 (0.108)	0.133 (0.091)
Total	185	233	98	0.421 (0.032)	0.372 (0.032)	71	0.413 (0.038)	0.384 (0.044)

Factors affecting nest survival on the Outer Banks

This analysis is based on a sample of 1395 nests monitored on six islands on the Outer Banks of North Carolina (Bodie Island, Hatteras Island, Ocracoke Island, North Core, Middle Core, and South Core Banks) from 1999-2009. Nests were monitored during a 126-day window (April 2 to August 6) during the 11-year period for a total of 17766 exposure days. Overall observed hatching success from the beginning of egg laying to hatching for all years and locations was 0.296 (SE 0.013). The single estimate of daily nest survival from Program Mark (null model) was 0.951 (SE 0.002). The average incubation period for Oystercatcher nests is 27 days (Nol and Humphrey 1994). To obtain the probability of nest survival to hatching (period nest survival) we raised estimates of daily survival rates (DSR) to the 27^{th} power. Adjusted overall nest survival for the full incubation period in $0.951^{27} = 0.258$ (SE 0.011).

Variation in nest survival was best explained by a model with a linear within-season time trend and additive covariates for year and island (Table 1.2). The quadratic time effect was not supported (~ one unit increase in AICc, for a one parameter increase, lower model weights, and 95% CI for the beta coefficient overlapping zero). A linear time effect was supported in all the top models, indicating that nest survival declined over the nesting season (B = -0.005, CL = -0.008, -0.001). The 95% confidence intervals for the beta coefficients of five of the eleven years (2000, 2001, 2003, 2007, and 2008) overlapped zero, indicating no significant difference in survival from the baseline year (1999). In contrast, the entire confidence interval for the coefficient for 2002 was below zero, while the intervals for 2004, 2005, 2006, and 2009 were all above zero. 2004 had the highest beta coefficient of any year (B = 0.882, CL = 0.522, 1.241). Nests on the island of South Core Banks had lower overall survival (B = -0.327, CL = -0.499, -0.156) than North Core Banks, while Ocracoke (B = 0.407, CL = 0.136, 0.677) and Hatteras (B = 0.323, CL = 0.107, 0.538) were higher than North Core Banks over the course of the study. The 95% confidence intervals for the beta coefficients of Middle Core Banks and Bodie Island overlapped zero, indicating no significant difference in survival from North Core Banks.

Table 1.2: Model selection results for factors affecting survival of American Oystercatcher nests on Cape Hatteras and Cape Lookout National Seashores from 1999-2009. Models are ranked by ΔAICc. Wi represents model weight and k is the number of parameters. Model factors include linear and quadratic daily variation over the nesting season (Day and Day^2), year, island, presence of off road vehicles, access to foraging areas, and distance to the high tide line.

Model	ΔAICc[a]	k	W_i	Deviance
Day + Year + Island	0	16	0.294	4807.560
Day + Year + Island + Vehicle	0.015	17	0.291	4805.570
Day + Year + Island + Forage	0.851	17	0.192	4806.406
Day + Year + Island + Tide	1.465	17	0.141	4807.020
Day + Year + Island + Tide + Forage + Vehicle	2.534	19	0.083	4804.080
Day + Year	51.755	11	0	4869.332
Day + Island	56.952	7	0	4882.540
Day	116.954	2	0	4952.548
Day^2	118.750	3	0	4952.342
Constant	121.374	1	0	4958.968

[a]The lowest AICc score in this model set was 4839.594

One of the top two models by AICc rank included a covariate for ORV presence. In this model nests with ORV access had a lower survival rate, but support for the this covariate was inconclusive as the 95% confidence interval for the beta included zero (B = -0.196, 95% CL = -0.472, 0.080) and there was no change in AICc. Models that included covariates for access to foraging habitat, and distance to tide line also received some support (ΔAICc <2), but the confidence interval of the beta coefficient for each of these covariates also included zero.

Mammalian depredation was the major identifiable cause of nest failure at our study sites, accounting for approximately 54% of identified nest failures (Figure 1.1). Over-wash and other weather related causes accounted for 29% of identified failures. The remaining identified failures (17%) were caused by human activity, avian predators, ghost crabs, or unknown reasons (Figure 1.1). Human activity was defined as a human action directly leading to nest failure, such as physical destruction of the eggs, and did not include indirect effects of disturbance. We could not identify the causes of failure for 52% of failed nests. The sources of nest mortality were similar on Cape Hatteras and Cape Lookout, but the relative proportion of nests lost to each source varied by year and location (Figures 1.2 and 1.3).

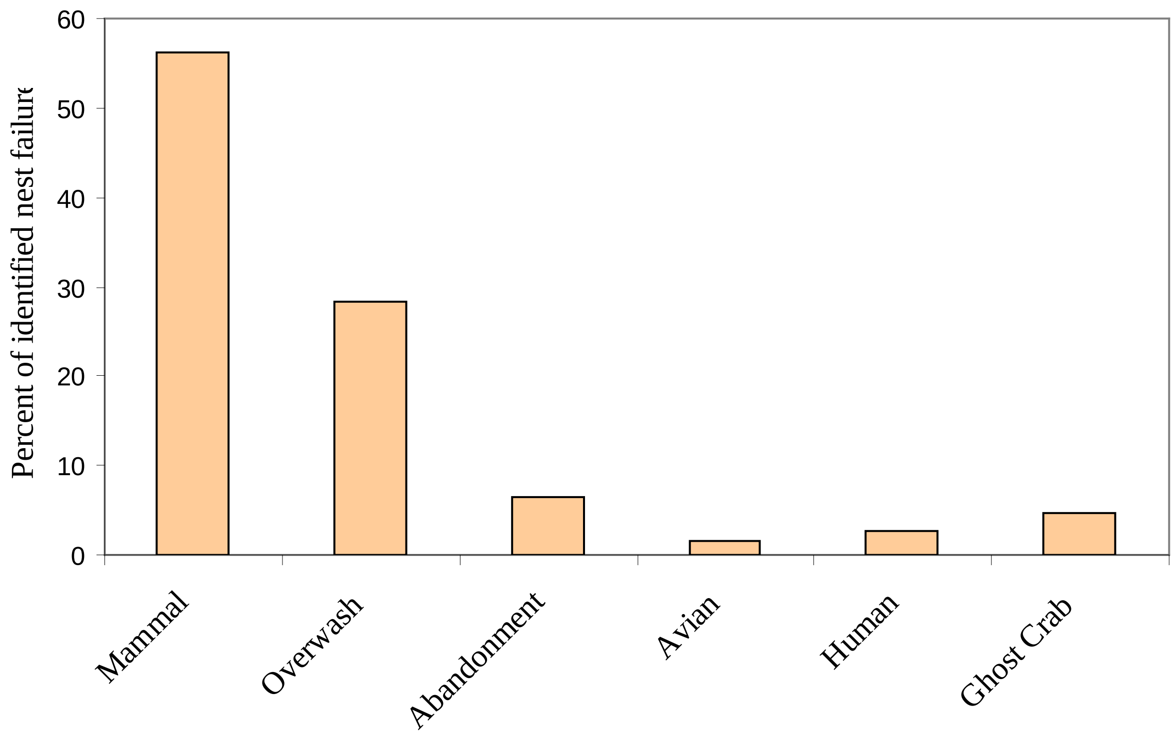

Figure 1.1. Sources of American Oystercatcher nest failure on the Outer Banks of North Carolina from 1998-2009 where cause of failure could be determined (N=502). Cause of failure could not be determined for 50% of nest failures (N=495).

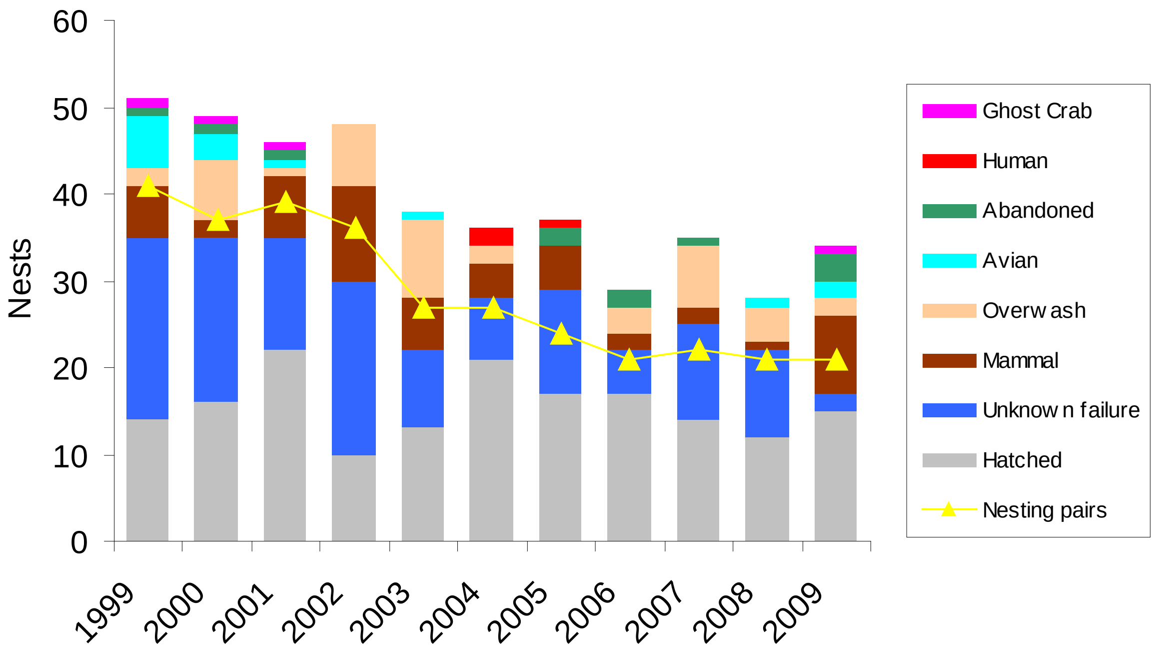

Figure 1.2. Nest fates for American Oystercatcher nests on Cape Hatteras National Seashore from 1999 to 2009. Column segments represent the number of nests in each category.

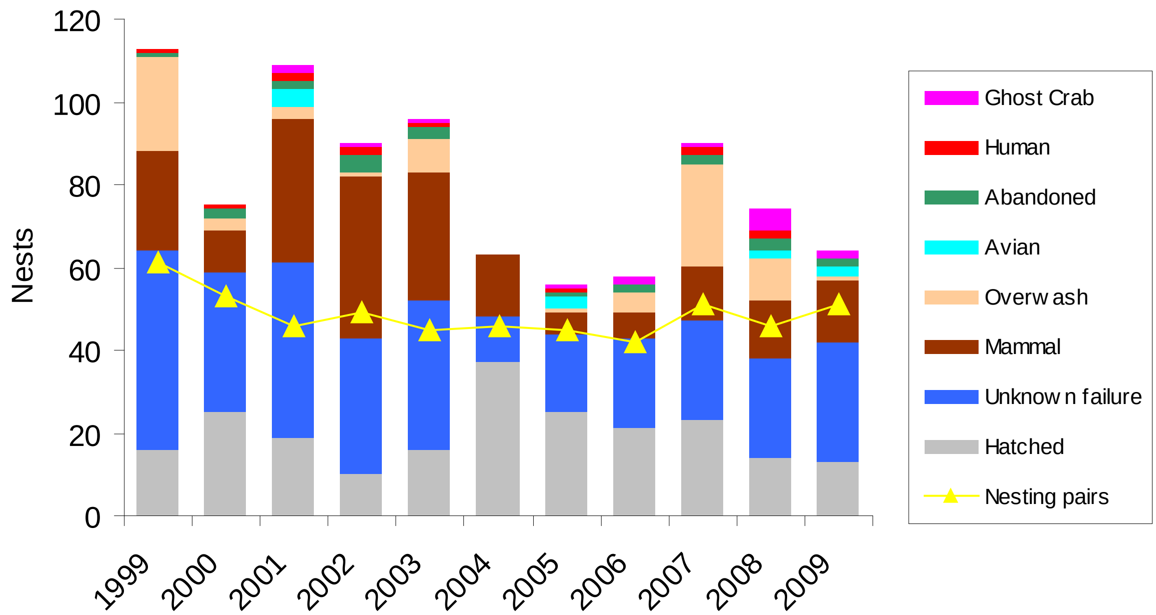

Figure 1.3. Nest fates for American Oystercatcher nests on Cape Lookout National Seashore from 1999 to 2009. Column segments represent the number of nests in each category.

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

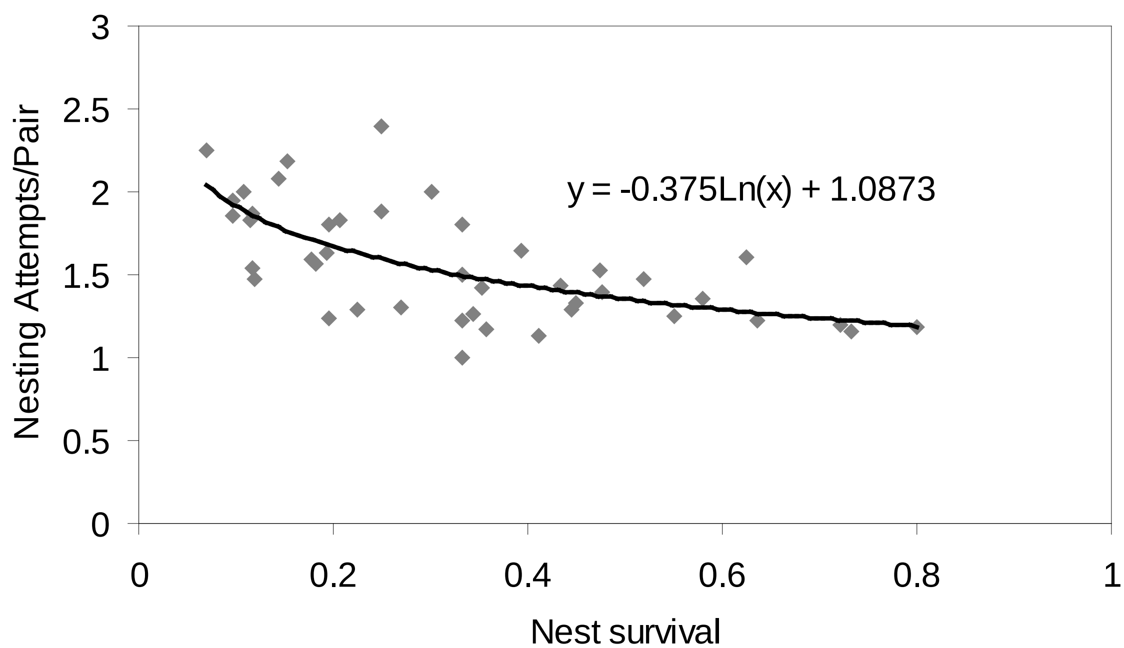

Figure 1.4. The number of nesting attempts per pair as a function of nest survival on Cape Lookout and Cape Hatteras National Seashores. 1999-2009. N=44 location/years, 1234 nesting attempts.

Brood and Chick Survival

Our analysis of factors affecting brood survival is based on a sample of 338 broods on Cape Lookout and Cape Hatteras National Seashores from 1999 to 2009. Mean brood size at hatch was 2.02 chicks (SE 0.042), while the mean daily brood survival was 0.982 (SE 0.001). Mean period survival for the 40 day pre-fledging period was 0.484 (SE 0.030).

Our best model of factors affecting brood survival included covariates for the age of the brood, island, presence of off road vehicles, and access to foraging habitat. This model was the only supported model in our set (model weight = 0.991, ΔAIC of next model = 9.443). Within-season time trends and year effects were not useful in explaining variability in brood survival rates. The best model included a quadratic term for brood age (Table 1.3), with daily survival rates increasing rapidly for the first two weeks, and then leveling off (Figures 8 and 9). Brood survival varied between islands. Survival was highest on Middle Core Banks, Cape Lookout National Seashore (B = 0.722, CL = -0.379, 1.823) and lowest on Bodie Island, Cape Hatteras National Seashore (B = -0.72597, CL = -1.819, 0.367). The within-island variability in survival was very high however, and only South Core Banks had a beta coefficient with a confidence interval that did not include zero (B = -0.688, CL = -0.213, -0.164). Brood survival was lower when off road vehicles were present (Figure 1.5, B = -0.991, CL = -1.381, -0.601) and higher when broods had direct access to foraging areas (Figure 1.6, B = 0.717, CL = 0.277, 1.156).

Table 1.3. Model selection results for factors affecting survival of American Oystercatcher chicks on Cape Hatteras and Cape Lookout National Seashores from 1999-2009. Models are ranked by ΔAICc. W*i* represents model weight and k is the number of parameters. Model factors include linear and quadratic daily variation, linear and quadratic age, year, island, presence of off road vehicles, and access to foraging areas.

Model	ΔAICc[a]	k	W*i*	Deviance
Age^2 + Island + Vehicle + Forage	0.000	10	0.991	1018.194
Age^2 + Island + Vehicle	9.442	9	0.009	1029.641
Age^2 + Island + Forage	24.476	9	0.000	1044.675
Age^2 + Island	32.170	8	0.000	1054.374
Age^2 + Year + Island	34.334	17	0.000	1038.474
Age^2 + Year	40.623	12	0.000	1054.804
Age^2	42.491	3	0.000	1074.711
Day + Age^2	44.139	4	0.000	1074.356
Day^2 + Age^2	45.220	5	0.000	1073.435
Age	47.293	2	0.000	1081.515
Day + Age	48.958	3	0.000	1081.178
Day^2 + Age	50.779	4	0.000	1080.997
Day	77.079	2	0.000	1111.300
Day^2	79.076	3	0.000	1111.296
Constant	91.888	1	0.000	1128.111

[a]The lowest AICc score in this model set was 1038.223

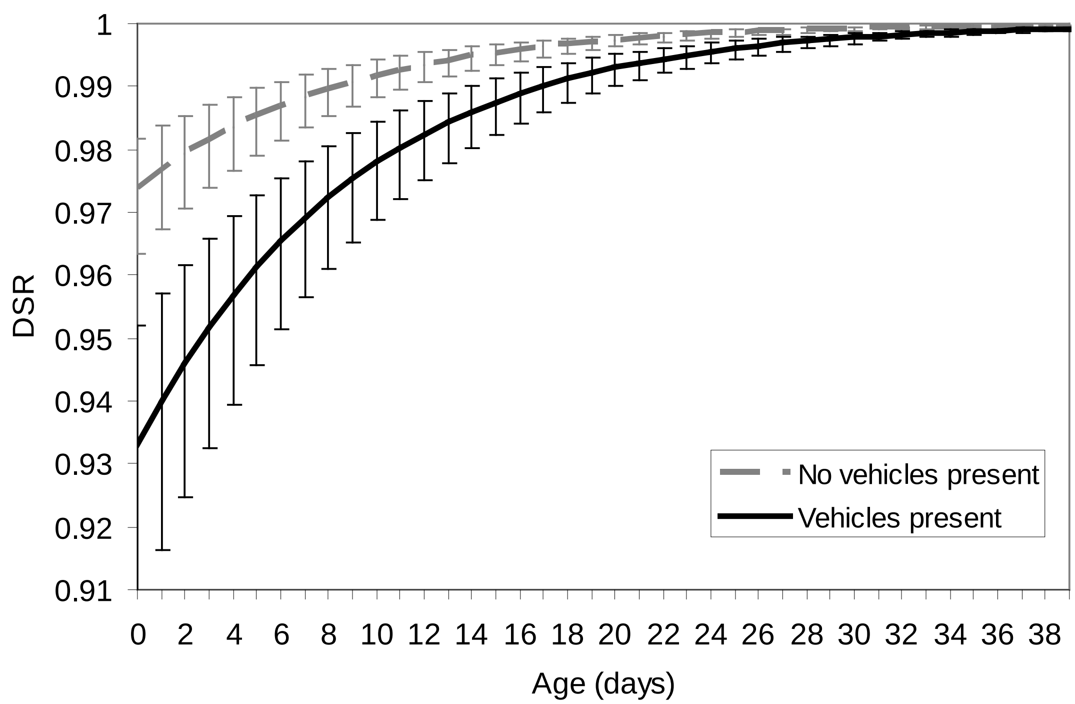

Figure 1.5. Survival curves for American Oystercatcher broods on beaches with and without off road vehicles. Daily survival rates and confidence intervals were estimated from the model with the lowest ΔAICc score (Table 1.3).

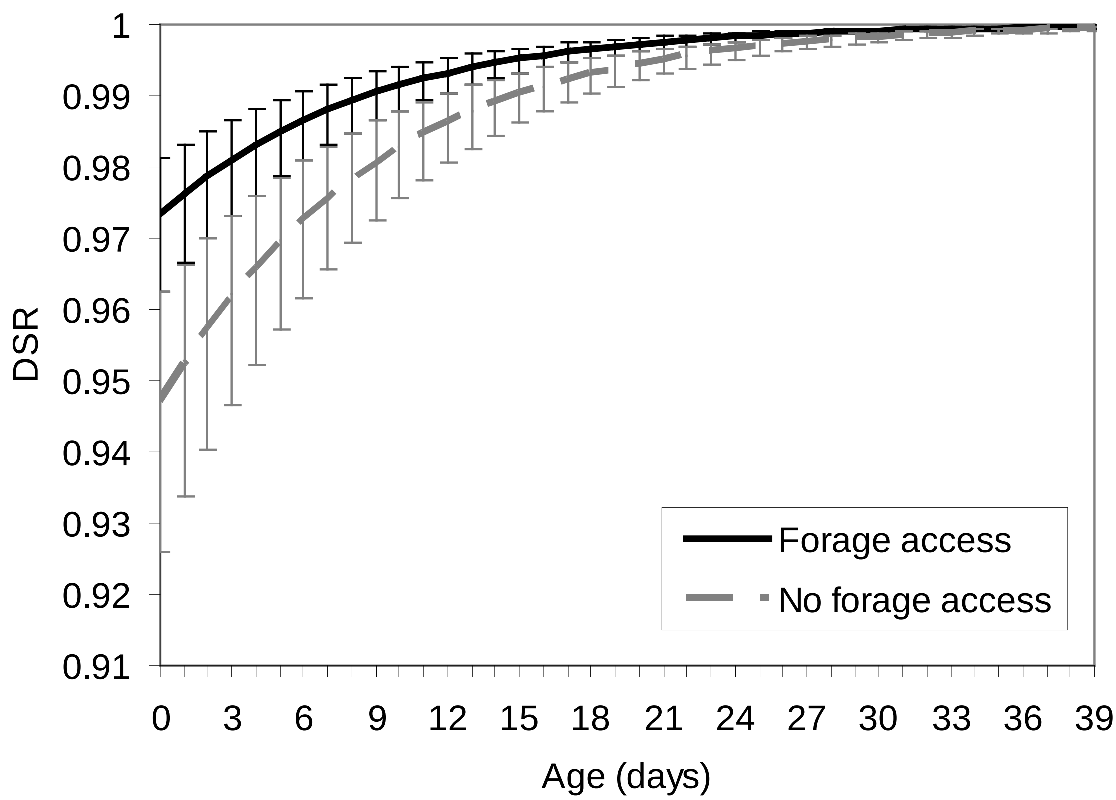

Figure 1.6. Survival curves for American Oystercatcher broods with and without direct access to foraging sites. Daily survival rates and 95% confidence intervals were estimated from the model with the lowest ΔAICc score (Table 1.3).

Individual chick survival and sources of chick mortality were determined from the radio telemetry study. One hundred and twenty-one chicks were tracked from hatching to fledging or death. Chick predators included Great Horned Owls (*Bubo virginianus*), Fish Crows (*Corvus ossifragus*), Feral Cats (*Felis catus*), Raccoons, *(Procyon lotor)*, American Mink (*Mustela vison*), and Ghost Crabs (*Ocypode quadrata*) (Figure 1.7), and accounted for 54.1% of all identified mortalities. Human activity (vehicle collisions and disturbance) was directly responsible for 16% of known chick mortality. Several chicks died of exposure during storm events shortly after hatching. We were unable to determine the cause of mortality in 51% of the chicks monitored (N=39). Typically this occurred if the transmitter was lost when the chick died. Highest chick mortality rates occurred in the first week after hatching, and during the week of fledging (Figure 1.8). The cumulative probability of surviving the pre-fledging period varied with the definition of "fledged". Thirty-five days is the minimum age we observed chicks achieving sustained flight (>100m). Survival to 35 days was estimated at 0.438 (SE 0.0459). A few chicks took up to 46 days to fledge, however, which reduced the survival probability to 0.280 (SE 0.168). The wide confidence interval after 40 days is a result of very few chicks in the sample still alive and unfledged at this age.

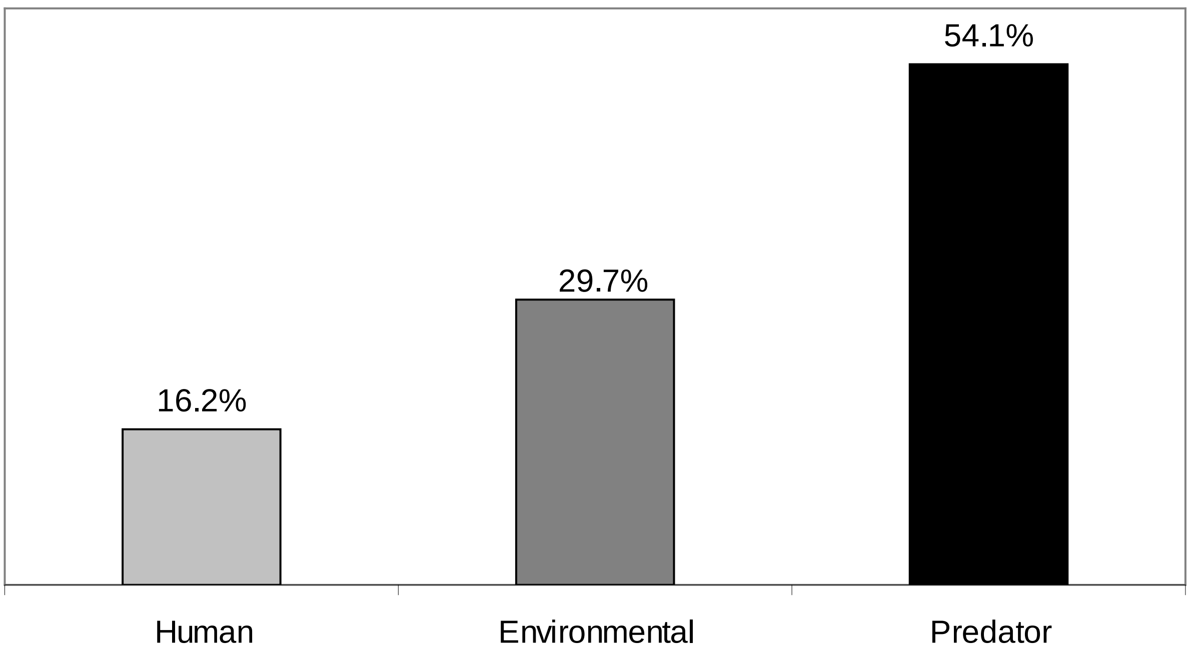

Figure 1.7. Sources of pre-fledging American Oystercatcher chick mortality at Cape Hatteras and Cape Lookout National Seashores from 2005-2007 (N=37). Source of mortality could not be determined for 51% of chick deaths (N=39 chicks).

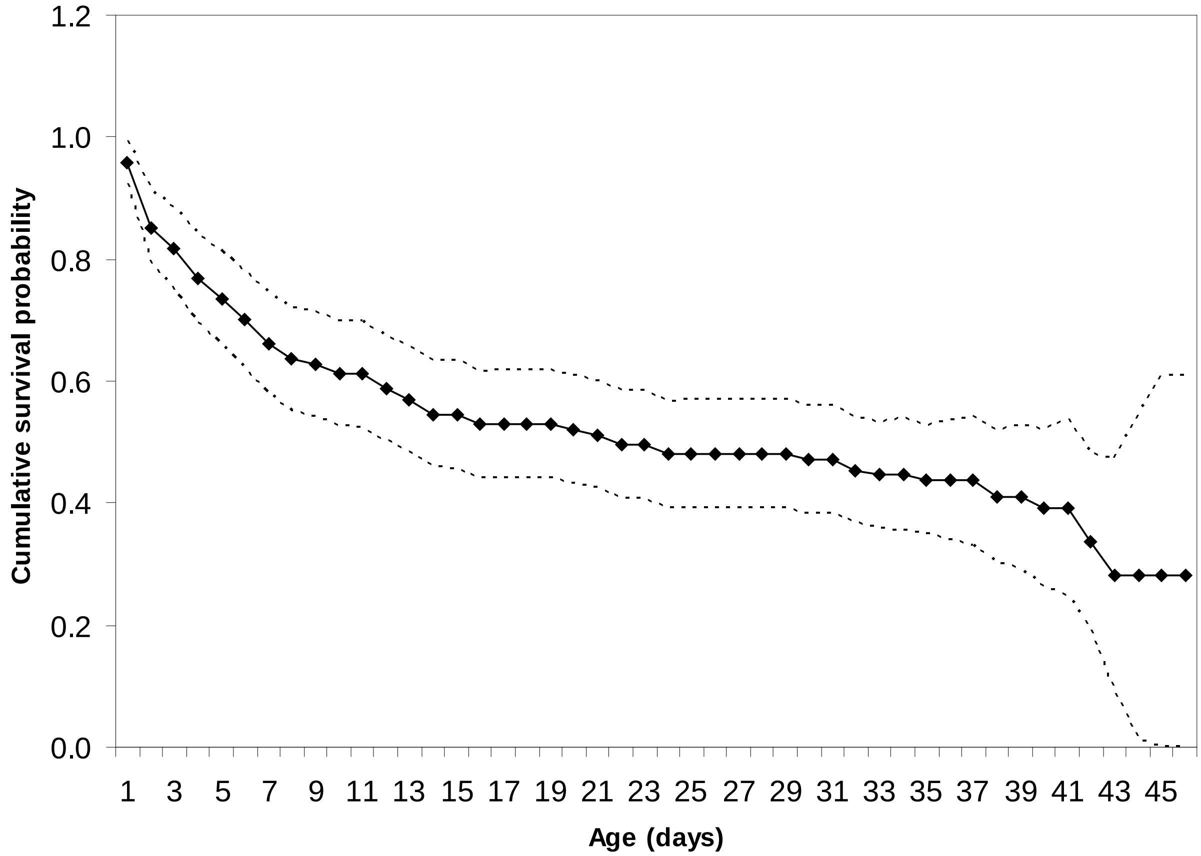

Figure 1.8. Kaplan-Meier survival curve and 95% confidence interval for pre-fledging American Oystercatcher chicks on Cape Hatteras and Cape Lookout National Seashores from 2005 through 2007 (N=121 chicks).

After fledging, radio-marked chicks were tracked daily until mid-August, when field personnel were no longer available. No fledgling mortality was documented during this time. Survey flights in late August and early September in 2005 and 2006 covered the Outer Banks from Nags Head to Morehead City. The oldest chicks began to migrate out of the study area by the end of August, but several still remained at their natal sites on the last survey flight on September 18 2005 and September 25 2006.

We conducted 169 hours of behavioral observation on 63 chicks on Cape Hatteras National Seashore over four years (2004-2007). Over 90% of the observations were of chicks in full-beach closures because most of the locations where chicks hatched were subsequently closed under Park Service policy. Chicks on beaches where vehicles were present spent significantly more time hiding in the dunes and less time at or below the high tide line than chicks on beaches closed to vehicles. (Figure 1.9, $t = 2.00$, $p = 0.047$). Chicks on beaches open to vehicles often ran back and forth from the beach to the dunes in response to vehicles, humans and dogs. Oystercatchers with chicks showed a stronger reaction to humans with dogs than to humans alone. We did not document any dog-related mortality, but dogs were observed chasing adult Oystercatchers on several occasions. Most adults began to bring their chicks to the waterline to forage within 24 hours of hatching. Broods ranged up and down the beach from their nest sites, often moving 500 meters or more each day. This pattern continued throughout the chick-rearing stage. Night observations of chicks invariably found the broods on the open beach or below the tide line on both open and closed sections of beach. During the day chicks spent most of their time hiding in the dunes, particularly in areas open to vehicles. Parents always brought their chicks to the beach around sunset. We observed Oystercatchers of all ages that became disoriented by vehicle headlights at night and walked, ran, or flew toward the light source. We also observed adult Oystercatchers which were startled and apparently disoriented by headlights and abandoned their chicks until the vehicles had passed. In most cases adults returned quickly to their chicks, but in at least one case the adults were kept away by multiple vehicles passing, which resulted in the deaths of their young chicks, presumably due to exposure or lack of food.

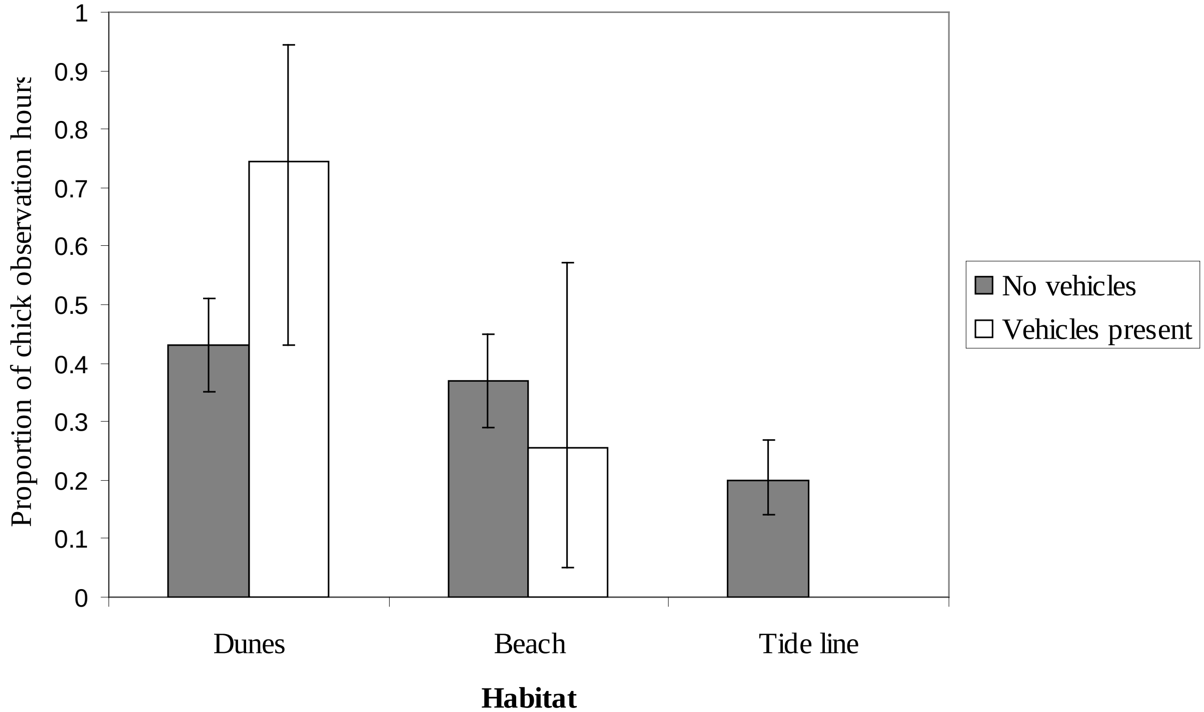

Figure 1.9. Habitat use by American Oystercatcher chicks on Cape Hatteras National Seashore on beaches with and without vehicles present (2004-2007). 54 chicks, 157 observation hours on beaches closed to vehicles , 9 chicks, 12 observation hours on beaches open to vehicles.

We estimated total productivity as the number of chicks fledged per nesting pair, from 1221 pairs and 1812 clutches monitored between 1995 and 2009. Productivity was highly variable among years and among locations (Appendix 1). A total of 391 chicks fledged from all study sites between 1995 and 2009. On average, 0.320 (SE 0.018) chicks fledged per nesting pair. Total productivity (P) is defined as the number of fledged chicks per nesting pair (pair that laid at least one egg). Productivity is a function of nest survival (S_N), chick survival (S_C), chicks hatched per successful nest (H_C), and total nests per breeding pair. As we have seen, the number of nests per pair is a function of nest survival (Figure 1.4), so the equation for productivity can be written as:

Equation 1: $$S_N * S_C * H_C * (-0.375Ln(S_N) + 1.0873) = P$$

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

DISCUSSION

The factors affecting American Oystercatcher reproductive success on the Outer Banks of North Carolina differed for the incubation and chick-rearing stages. This is not particularly surprising given the precocial nature of oystercatcher chicks. One would expect different sources of mortality after the chicks leave the nest and begin to move about their environment. It is instructive from both an ecological and a management standpoint to examine where the differences occur and how different factors influence overall reproductive success. Nest survival through the incubation period was primarily influenced by the date of nest initiation, the nesting island, and year to year variation in nesting conditions. Nest survival showed a linear decline over the nesting season. There was little support for a quadratic model where the rate of change in nest survival could vary across the season. Numerous studies have found trends in daily survival rates when they relax the common assumption of constant survival over the season or the age of the nests (Ainley and Schlatter 1972, Klett and Johnson 1982, Dinsmore et al. 2002). The decline in nest survival over the season could be the result of multiple factors. Heat stress, human activity, and predator abundance and distribution may all change over the course of the season. Predators were directly responsible for the majority of failures (61%) where the source of nest loss could be determined. Differences in nest survival among islands and years may largely be a result of differences in the suite of nest predators and changes in predator abundance. In the absence of comprehensive data on predator populations this explanation is largely hypothetical, but there is some evidence to support the idea. On Hatteras Island, Cape Hatteras National Seashore, the nest survival rate fell from 0.272 (SE 0.048) in the period 1999–2001 to 0.030 (SE 0.023) in 2002, after foxes colonized the island. Predator control measures were initiated in 2003 and the nest survival rate increased to 0.534 (SE 0.047) from 2003-2009. On North Core Banks, Cape Lookout National Seashore, the proportion of nests positively identified as lost to predators dropped from 0.31 to 0.10 after Hurricane Isabel flooded the island in September 2003 and apparently reduced predator populations (Schulte and Simons in prep). Nest survival on South Core Banks, Cape Lookout National Seashore increased from 0.114 to 0.367 from 2008 to 2009 (Appendix 1) after ~50% of the raccoon population was removed from the island over the winter. Productivity jumped from 0.208 to 0.500. The adjacent island of North Core Banks showed no change in survival or productivity during the same period.

Given the importance of depredation as a source of nest failure, Human actions that affect predator populations or the ability of predators to locate nests will have the greatest effect on nest survival. McGowan and Simons (2006) found that oystercatcher nests that were frequently disturbed were more likely to be depredated. Frequent disturbance may make the nest more visible to avian predators and increase the number of scent trails leading to the nest. We hypothesized that nests on beaches open to vehicle traffic would have a lower survival rate as oystercatchers often move away from their nests in response to vehicle traffic. We considered a beach to be open to vehicle traffic if any part of the shoreline was open, even if the upper beach was closed off with symbolic fencing. One of our top two models indicated support for this hypothesis, showing a negative correlation between the presence of off road vehicles and nest survival. This covariate had a large amount of variability and the 95% confidence interval of the beta coefficient just included zero. Much of this variability likely stems from differences in physical conditions, human activity, and oystercatcher behavior across the islands of the Outer Banks. The effect of vehicle traffic on nest survival could be quite different for a nest on a low-traffic, wider beach and a high-traffic narrow beach. Oystercatcher behavioral responses may also vary from pair to pair, with some birds habituating to human activity and others becoming more sensitized. Finally the linkage between disturbance and nest failure should vary with the local predator population. The negative effect of disturbance should be greater in areas with higher predator populations. Our beach closure status covariate is not sensitive to these potentially interacting factors, but it does provide a general measure of the correlation between the presence of vehicles and nest survival. An experimental approach that manipulated disturbance levels and controlled for other factors could effectively reduce the uncertainty in this relationship. Tarr et al (in revision) used this approach to evaluate the effect of vehicle disturbance on shorebird roosting and foraging behavior during fall migration on Cape Lookout National Seashore.

Storms and high tides are another source of nest failure. Breeding season storms can result in significant nest loss as nests are flooded out or sanded over. A strong storm at the wrong time of year can eliminate most of the active nests, which sets back the reproductive cycle by 2-6 weeks. Hurricanes and strong winter storms do not directly affect nest success because they usually occur outside of the breeding season.

These storms can have beneficial effects as they create new nesting habitat and may reduce predators. We predicted that nest survival would increase with distance from the high tide line. This hypothesis was not supported by our data. Models with the tide covariate received less support than the same models without the covariate and the confidence interval of the beta coefficient for the tide covariate encompassed zero. Height above high tide may be a better predictor of success, as some nests on low-lying flats may be hundreds of meters from the high tide line but still flood during storms. Unfortunately, measurements of height above high tide were not available for our nests.

Proximity to foraging area was another factor we considered. We predicted that pairs with adjacent foraging habitat other than the ocean beach would have higher nest survival. Birds with nearby foraging habitat should spend less energy on flight, and both adults would be present to defend the nest and territory as needed. We did not include the ocean beach in this analysis because it is typically not the primary foraging habitat and almost every pair had access to the beach. In addition, oystercatcher pairs that are able to maintain territories near high-quality food resources may be older, more experienced birds. European oystercatchers may wait years for the chance to establish a territory in high-quality habitat adjacent to feeding areas (Ens at al 1995, Heg and van der Velde 2001, van de Pol 2007). In our study we found no effect of forage proximity on nest survival.

We were not able to observe the causes of most nest failures directly. We relied on indirect evidence, such as eggshell fragments, or predator tracks, to infer the causes of nest failures. Nests reported as undetermined generally represent nests where wind or rain erased any clues of the causes of failure. We believe that the vast majority of our unidentified failures are a result of nest predators. Storm losses were usually easy to identify as the tide line following the storm was often evident above the level of the nest, or the nests were completely sanded over. Identification of different nest predators was much more difficult. Avian predators can leave little or no sign at the nest, and the tracks of mammals such as raccoons and cats are quickly blown away. Even during calm weather, predator tracks were often obscured by Oystercatcher tracks as the pair returned and walked around the nest scrape after a predation event. The difficulty of identifying different sources of failure suggests that storm losses may be over-represented in our estimates of identified nest failures (Figure 1.1). It is also possible that avian predators are under-represented in these estimates because these predators often leave little evidence. Losses from avian predators usually result in clutch reductions as often only a single egg is taken. Most nest failures occur overnight with the loss of an entire clutch of eggs, suggesting mammalian depredation.

The cryptic and highly mobile nature of Oystercatcher chicks makes it difficult to obtain estimates of survival and identify sources of mortality. Like many shorebird chicks, Oystercatchers are adept at hiding and are challenging to locate on a regular basis. For this reason we analyzed factors affecting brood survival, rather than chick survival across all years and islands. Brood survival did not change with the date of the nesting season, but survival was affected by the age of the brood. Most brood losses occurred in the first week to ten days after hatching. This pattern resembles that of other species with precocial young (Colwell et al. 2007, Ruthrauff and McCaffery 2005). Young chicks are mobile but cannot fully thermoregulate and are more susceptible to temperature and weather extremes. Smaller chicks are also vulnerable to a wider range of predators. Parental behavior may draw attention to younger chicks that have to be brooded more often and thus stay close to one of the parents. This is particularly true for oystercatcher chicks as they are the only shorebird chicks that are fully dependant on their parents for food (Nols and Humphrey 1994). The Oystercatcher's ability to bring food to their young allows them to exploit nesting sites without local food resources. Broods raised at these sites should be expected to have generally lower survival because parents must bring food from a separate foraging territory. A long-term study of breeding Eurasian Oystercatchers found that pairs with walking access to foraging habitat had significantly higher productivity than pairs that had to fly to their foraging territories (Ens et al. 1992). Our best model predicted lower survival for broods without direct access to foraging habitat (figure 1.6), which is consistent with our a priori hypothesis.

Brood survival was directly and indirectly affected by the presence of off road vehicles. Broods on beaches open to vehicles survived at a lower rate than broods on closed beaches (Figure 1.5). Radio tracking young chicks provided insights into possible mechanisms shaping this pattern. Very young chicks are highly mobile, much more so than previously believed. Movement between the dunes and the waterline places young chicks at considerable risk from beach traffic. We regularly observed chicks hiding in vehicle tracks in response to adult alarm calls and also observed chicks, and even some adults, running or flying directly at the headlights of oncoming vehicles at night. Shortly after we initiated the radio tracking study, we documented the loss of a brood of two-day old chicks to a vehicle on Cape Lookout National Seashore. We radio-tagged the recently hatched brood at the nest on June 16 2005. That same evening the chicks were relocated hiding in seaweed at the tide line with the adult pair. The following morning we tracked the transmitter signals to a nearby location and found two of the chicks crushed in a fresh all terrain vehicle tire track, just above the high tide line (Figure 1.10). After this incident, Cape Lookout National Seashore initiated a policy under which they closed sections of beach with unfledged chicks to vehicle traffic, and re-routed traffic around the birds via a back road. After the beach sections were closed, chicks were regularly observed on the open beach and at the tide line during daylight hours, suggesting that vehicle traffic was altering chick behavior and foraging patterns. Multiple instances of vehicle related mortality have been documented in both parks and highlight the vulnerability of shorebird chicks to vehicle traffic.

Figure 1.10. Radio-marked American Oystercatcher chicks crushed by a vehicle June 16 2005, Cape Lookout National Seashore.

We found that disturbance by vehicles during the chick-rearing phase produces measurable differences in Oystercatcher chick behavior, habitat use, and survival. Despite limitations on our ability to observe chicks on beaches open to vehicles, the differences in habitat use between birds in full and partial beach closures (Figure 1.9) are very apparent. In addition to being at risk from direct mortality from vehicles, chicks in partial closures spend more time in the dunes, which subjects them to greater heat stress, limits feeding opportunities, and may expose them to greater risk from predators such as cats, mink, and raccoons. The increased risk from nocturnal predators probably explains why adults move their chicks from the dunes to the beach every night even if vehicles are present.

Radio tracking individual chicks allowed us to identify a suite of predators responsible for mortality of chicks prior to fledging. Although feral cats and raccoons both preyed on chicks, ghost crabs and avian predators such as Great Horned Owls and Fish Crows, appeared to play a larger role in chick depredation than nest depredation. The Kaplein-Meier survival curve for radio-tagged chicks showed that chicks were most vulnerable during the first week after hatching when they are most susceptible to exposure and ghost crab depredation (Figure 1.8). This result is consistent with the predicted age-related brood survival curve from our best model (Table 1.3, Figures 1.5 and 1.6). This study highlighted the difficulty of documenting the mortality of young Oystercatcher chicks. Without radio telemetry keeping track of broods can be difficult, and locating dead chicks is almost impossible. Even with radio tags we were only able to identify the source of mortality about 50% of the time. Many chicks simply disappeared from one day to the next. We suspect that predators carried these chicks out of range of our receivers or the remains washed away if they died below the high tide line.

Total nesting productivity, or the number of chicks fledged per breeding pair, reflects the ability of an Oystercatcher population to navigate the hazards associated with reproduction from egg-laying through fledging. Predators, storms, habitat quality, and management actions combine to shape the annual success or failure of each breeding pair. Management actions that affect chick survival will generally have the greatest effect on overall productivity. In 2008 Cape Hatteras National Seashore increased predator trapping efforts and expanded disturbance buffer zones for chicks to 300 meters. Chick survival on Cape Hatteras in 2008 and 2009 was the highest recorded during the study period (0.545), which resulted in a final productivity of 0.652 chicks per pair, or twice the average annual productivity in North Carolina. The relative extent to which predator management versus vehicle management contributed to this elevated productivity is not clear, but both actions likely played a role in the increase. Given the importance of predators at all stages of the breeding cycle, a better understanding of predator population dynamics would likely go a long way toward explaining temporal and spatial variability in Oystercatcher productivity.

Section 2 - Migration, fidelity and dispersal of American Oystercatchers

INTRODUCTION

Movement patterns and connectivity in migratory birds influence how events in one season or location will affect populations at other stages of the annual cycle. If a large proportion of a given breeding population migrates to a single wintering area the trajectory of the population will be influenced by anything that affects either site. Conversely, breeding populations that disperse across multiple wintering areas are less affected by events at any single wintering location (Webster et al. 2002, Kelly et al. 2002). Comprehensive conservation strategies for at-risk species should include an understanding of migratory connectivity patterns. In order to predict the effects of habitat loss, environmental damage, or conservation actions on population trajectory we need to know how those events will affect the birds throughout their annual cycle. (Sillett et al 2000, Rubenstein and Hobson 2004, Webster and Marra, 2005). By its very nature migratory connectivity is difficult to study because of the challenges involved in following individual birds throughout the year. American Oystercatchers (*Haematopus palliatus*) are large, conspicuous, long lived, and restricted in range and habitat, and are currently the subject of a broad and coordinated research and monitoring effort. All of these factors combine to make this species an ideal subject for investigating questions about movement and connectivity. Our primary tool for studying Oystercatcher demographics and movement is resighting birds banded with individually marked leg bands. New techniques and technologies, such as stable isotope analysis, smaller satellite transmitters, and geolocators are advancing our understanding of migration strategies, pathways and connectivity for an array of bird species (Marra et al. 1998, Hobson 2005, Croxall et al 2005, Stuchbury et al. 2009, Shaffer et al 2005). Some of these techniques are currently in use studying American Oystercatchers and data from these studies may inform future studies

Migratory strategies for the closely related European Oystercatcher (*Haematopus Ostralagus*) populations vary considerably across the range of the species. Northern breeders have the advantage of high productivity breeding sites with reduced competition, but must undergo the hazards of migration and are at a disadvantage when competing for winter territories with non-migratory birds (Hulscher et al 1992). American Oystercatchers may experience similar choices and challenges. For instance, breeding populations in the Southeast may move very short distances or even remain on breeding territories year-round, while birds in the Northeast may have different migration strategies resulting in a different pattern of connectivity. Here we analyze the database of Oystercatchers banded in North Carolina to elucidate information on Oystercatcher migratory patterns estimate rates of fidelity to breeding and wintering sites.

Site fidelity, or the propensity to return to the same location in subsequent years, is characteristic of many bird species (Greenwood 1980, Greenwood and Harvey 1982, Holmes and Sherry 1992, Haas 1998). Returning to a previously inhabited location must generally confer a strong advantage for the behavior to be so prevalent. Knowledge of food resources, predator community, nesting sites, and neighbors may all be advantages for birds returning to a breeding or wintering site. Against these advantages a bird must weigh the potential to find a better habitat elsewhere. Numerous studies have found that prior breeding success and age of the bird were factors that correlate with the degree of site fidelity (Harvey et al. 1979, Oring and Lank 1982, Gratto et al. 1985, Newton and Marquiss 1982), though is not always true (Haig and Oring 1988, Atwood and Massey 1988). Switzer (1993) proposed a dynamic model that predicted site fidelity should be inversely related to heterogeneity in territory quality, and positively related to the cost of changing territories, age, and probability of mortality in the habitat.

Breeding site fidelity in Eurasian Oystercatchers is related to age, population density, and breeding success (Harris 1967, Ens et al. 1995). Ens et al. modeled the probability of changing status between breeding and non-breeding and high vs low quality habitats as Markovian processes. Birds in high quality habitats were more likely to fledge young and more likely to retain the habitat the following year. The probability of retaining a habitat also increased with the number of seasons an individual was resident on a territory. Subadult birds often waited years for a chance at a high quality territory instead of settling in a more readily available low quality site. Seniority was also the primary factor in establishing dominance on winter foraging territories (Heg et al. 2000).

American Oystercatchers are thought to have fairly high breeding site fidelity. Nol (1985) estimated the annual rate of return for breeding adults at 0.85. The rate of return for nesting Oystercatchers on the Outer Banks of North Carolina was estimated at 0.89 (SE 0.013) (Schulte and Simons in prep). Neither of these studies estimated movement rates between territories in subsequent years. We used 10 years of mark-recapture data from banding efforts in North Carolina and resight records from partners on the Atlantic and Gulf coasts to estimate breeding and winter site fidelity.

METHODS

Resight records are a mix of coordinated resight efforts by researchers, state and federal agencies, and private organizations, as well as reports by interested members of the public. Sightings of banded birds can be reported through the American Oystercatcher Working Group website (http://www.ncsu.edu/project/simonslab/AMOY/Banding.htm). Banding and resighting records for all projects are maintained in a central database.

Adult Oystercatchers on breeding territories are captured using a variety of methods, including a decoy and nose carpet (McGowan and Simons 2005, Figure 2.1 Berger and Mueller 1959, Bub 1991), box traps, and “whoosh” nets. Pre-fledging chicks are captured by hand or with light hand nets.

Figure 2.1. Mechanical decoy and noose carpets.

We successfully trapped 116 breeding adults from 2002 through 2008 using the noose carpet method, and we found that it is an effective way to trap breeding adult birds with minimal disturbance to the nest site. No injuries, aside from minor skin abrasions on the tibiotarsus, have resulted from our trapping efforts. In 2009 we began using “whoosh” nets (miniature versions of canon nets that use an elastic cord to deploy the net), a technique demonstrated as highly efficient at trapping American Oystercatchers at other study sites. We captured 10 adult Oystercatchers using this method and anticipate continued use of whoosh nets in the future. Thirty-four chicks were banded in 2009, bringing the total number of banded birds to 410 over the life of the project (136 adults, 230 chicks, Appendix 2).

Captured adults and chicks were originally marked with steel USFWS bands and combinations of Darvic color bands (Figure 2.2). Under a ooperative banding scheme, adopted by all researchers in the American Oystercatcher working group and approved by the Bird Banding Lab, birds are now marked with two identical bands engraved with a unique two-digit code as well as a metal USFWS band (Figure 2.2). North Carolina bands are green with white lettering. Other states are using yellow with black lettering (Massachusetts), orange with black lettering (New Jersey), black with white lettering (Virginia), blue with white lettering (South Carolina), and red with white lettering (Georgia). All adult Oystercatchers captured in 2009 were fitted with Geolocation devices (geolocators) attached to the leg band. These devices collect data about location of a bird based on the location of the sun and are accurate to within approximately 150km [longitude]. These devices have an average collection life of 2-3 years and will be retrieved opportunistically to download the data.

Figure 2.2. American Oystercatchers banded with old (left) and new (right) banding schemes. Photos by Diana Churchill (left) and Pat Leary (right).

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

We used 89 individually marked birds and eight years of mark-resight data from the Outer Banks of North Carolina to model the probability of an adult oystercatcher returning to the same breeding territory or moving to a new territory in a subsequent year. We used a two state model with states defined as "initial territory" or "new territory". This model was parameterized with survival, spatial transition, and sighting probabilities defined as: $\Phi_{i,j,k}$ = probability that a bird alive and present in state j during year i survives and is present in state k during year i + 1; $P_{i,j}$ = Probability that a bird present in state j during year i is sighted during that period. We followed Joe and Pollock (2002) and used the multi-state recaptures only model in Program Mark (Burnham and White 2003) to separate survival and movement rates. Using this method, we assume that survival from time i to i+1 does not depend on stratum? at time i+1. In this case $\varphi_i^{rs} = S_i^r \psi^{rs}$ where ψ^{rs} is the conditional probability that an animal in stratum r at time i is in stratum s at time i+1, given that the animal is alive at i+1. Oystercatchers on the Outer Banks defended territories up to 1.5 km, so we treated a bird as remaining in the same territory if it nested within 1.5km of the previous year's nest.

Estimating winter site fidelity is somewhat more difficult than estimating fidelity to a breeding territory. Within a season or even a single day, wintering oystercatchers move between multiple roost sites and foraging areas depending on wind, tides and disturbance (Figure 2.3).

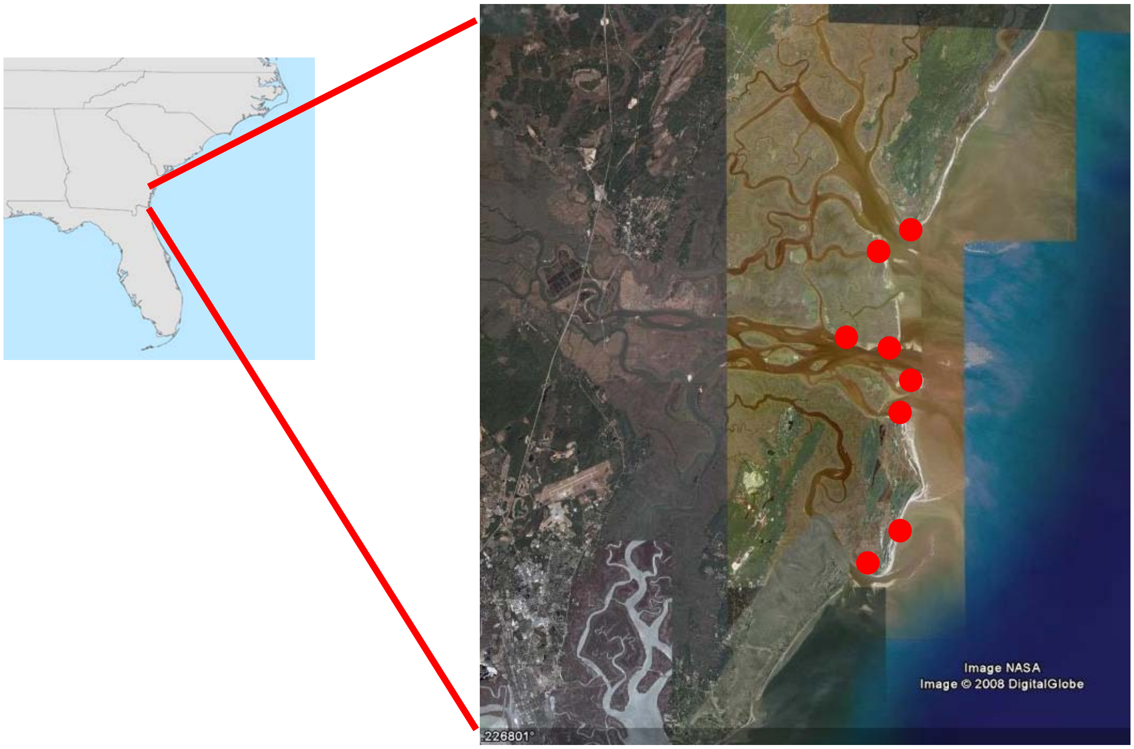

Figure 2.3. Winter resight locations for a banded American Oystercatcher near the Altamaha River Delta in Georgia (Winter 2005-2006).

Winter home ranges could serve as the basis for estimating annual transition rates, but as we described earlier, gaps in spatial and temporal survey coverage at larger scales severely complicate this type of analysis. Instead, we selected a subset of banded cohorts from four wintering areas to compare observed movement distances within seasons and between years. The subsets were chosen based on locations with comprehensive survey efforts for at least three years in a row.

We selected Beaufort, North Carolina, Bulls Bay, South Carolina, Altamaha River delta, Georgia, and Cedar Key, Florida as the focal sites. We measured the average distance between resight locations for each bird in each cohort within season and between years.

RESULTS

Ninety-one individual birds banded in North Carolina were resighted on winter roosts from Virginia to the Gulf Coast of Florida (Figure 2.4). Thirty-two percent were resighted in North Carolina, which contains only 5% of the total wintering population (Figure 2.5). Twenty percent were resighted in South Carolina, and 18% in Northwest Florida, which respectively contain 39% and 10% of the total winter population.

Figure 2.4. Winter resightings of American Oystercatchers banded in North Carolina.

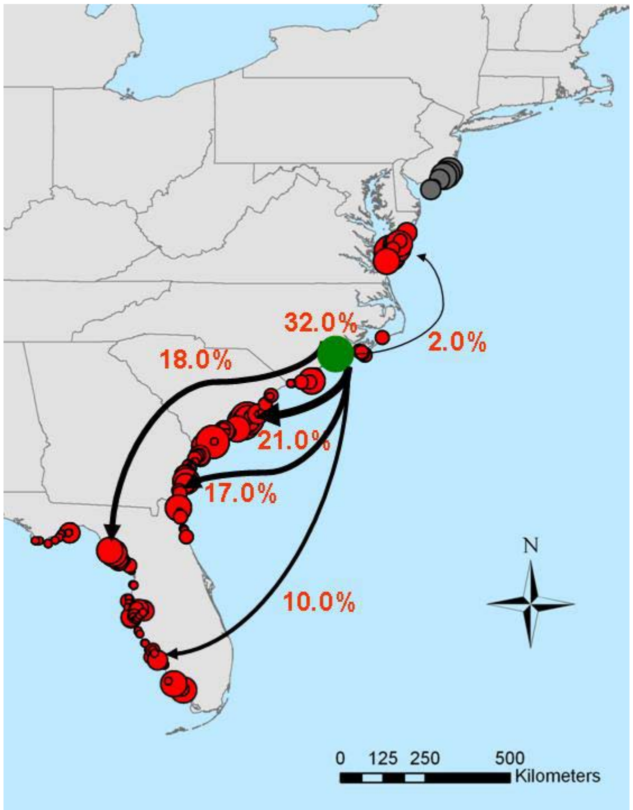

Figure 2.5. Proportion of banded American Oystercatchers observed in six wintering areas in the Southeast United States.

Oystercatchers banded as fledglings spent the first one to two years of life on the wintering grounds. Subadults began to return to their natal area during their second or third year. Twenty-two percent of all banded fledglings were resighted on the breeding grounds during their second year and 33% during their third year. The majority of these birds did not nest, though most were paired by their third year. In 2005 a bird banded as a chick on North Core Banks in 2002 returned to the island, paired successfully, and fledged a chick. This was the first record of a known-age American Oystercatcher chick returning and successfully nesting. Since 2005, 25 banded Oystercatcher chicks have returned to nest. Average age of first breeding is 3.58 years (SE 0.15). Dispersal distance was defined as the distance between an individual's natal site and location of first nest. Dispersal distance averaged 33.1km (SE 7.5) and ranged from 3-120 km.

We found that most nesting oystercatchers showed a high degree of fidelity to nesting territories from year to year. Only 11% moved from the territory where they were initially banded to a new territory on an annual basis (Table 2.1). Average distance for territory transitions was 8.03km (SE 1.05).

Table 2.1. Transition matrix describing the annual probability of an adult Oystercatcher returning to a former territory or moving to a new territory. 2001-2008, N=89, Transition rates are conditional on survival. Parentheses enclose standard errors.

	New State	
Initial State	Original territory	New Territory
Original Territory	0.89 (0.02)	0.11 (0.02)
New Territory	0.24 (0.07)	0.76 (0.07)

Average within season movements during the winter ranged from 1.77km to 6.67km. The maximum observed within-season movement was 38 kilometers. Average between season movements were very similar as most of the birds returned to the same winter roosts in subsequent years. The largest observed between season movement was 63 kilometers (Table 2).

Table 2.2. Average movement rates for banded cohorts of American Oystercatchers at four survey sites. Distances are in kilometers and represent the average distance between subsequent resights of individual birds. Standard errors in parentheses.

Site	Within Season	Between Years	Sample Size
Beaufort, NC	3.42 (2.20)	5.23 (2.84)	14
Bull’s Bay, SC	1.77 (0.33)	2.03 (0.76)	35
Altamaha, GA	5.09 (1.37)	8.33 (1.41)	41
Cedar Key, FL	6.67 (1.11)	7.12 (2.05)	43

DISCUSSION

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

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

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

Most Oystercatchers returned to the same breeding and wintering territory each year. Interestingly, those that did move to a new breeding territory tended to move back to their original territory in subsequent years at a higher rate (24% annually). These may be birds that attempted to move to a higher quality territory and failed to retain it, or birds that were temporarily driven out of their original territory. In the eight years of the study we never observed an Oystercatcher moving among more than two breeding territories. These transition rates assume no permanent emigration from the study site. While the size of the study area (170 km of shoreline) relative to average movement rates does lend credibility to this assumption, it would be naïve to think this is completely accurate. Numerous small marsh and sand islands line the sounds of the Outer Banks and breeding oystercatchers were observed moving from beach habitat to soundside islands on more than one occasion. Permanent emigration would lead us to underestimate survival and overestimate site fidelity.

During winter months most birds tended to be fairly sedentary, only moving a few kilometers between roost sites. A few birds moved tens of kilometers at least once during the non-breeding season, indicating that some birds may employ a different strategy. Factors such as age, weather, food resources, competition, and disturbance may affect the decision to remain in place or shift territories during the winter. Additional research is needed to understand the importance of each of these factors.

The mark-resight effort has already allowed us to estimate adult survival and fidelity rates and start to understand migration and dispersal in different age classes. Partnerships and coordination among researchers and land managers are critical to filling the gaps in our current knowledge of Oystercatcher populations. Improving and standardizing cooperative large-scale banding efforts will be critical to ongoing efforts to estimate survival, dispersal, and migratory patterns in Oystercatchers. These estimates are necessary to understand the effects of natural events and management actions.

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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)
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								
2007	2	3	2	0.667 (0.272)	NA	3	0.750 (0.217)	1.500 (0.500)
2008	2	2	1	0.500 (0.354)	NA	0	0.000 (0.000)	0.000 (0.000)
Island	4	5	3	0.600 (0.219)	NA	3	0.500 (0.204)	0.750 (0.479)
South Core Banks								
1995	20	36	12	0.333 (0.079)	NA	7	NA	0.350 (0.131)
1997	23	34	4	0.118 (0.055)	0.036 (0.022)	2	0.286 (0.171)	0.087 (0.060)
1998	20	26	7	0.269 (0.087)	0.135 (0.062)	3	0.214 (0.110)	0.150 (0.082)

1999	28	52	5	0.096 (0.041)	0.115 (0.036)	1	0.125 (0.117)	0.036 (0.036)
2000	25	38	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)
Island	321	550	114	0.207 (0.017)	0.151 (0.014)	66	0.300 (0.031)	0.206 (0.030)
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)
Island	62	81	9	0.111 (0.035)	0.086 (0.033)	4	0.267 (0.114)	0.065 (0.039)
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)
Island	91	129	53	0.411 (0.043)	0.344 (0.042)	39	0.411 (0.050)	0.429 (0.077)
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)
Island	193	257	107	0.416 (0.031)	0.389 (0.031)	76	0.371 (0.034)	0.390 (0.052)
Bodie Island								
1999	2	3	0	0.000 (0.030)	0.030 (0.035)	0	0.000 (0.000)	0.000 (0.000)
2000	2	3	0	0.000 (0.081)	0.081 (081)	0	0.000 (0.000)	0.000 (0.000)
2001	2	3	1	0.333 (0.272)	0.285 (0.253)	1	0.500 (0.354)	0.500 (0.500)
2002	2	5	1	0.200 (0.179)	0.138 (0.137)	2	1.000 (0.000)	1.000 (1.000)
2003	5	5	1	0.200 (0.179)	0.311 (0.182)	0	0.000 (0.000)	0.000 (0.000)
2004	3	6	0	0.000 (0.000)	0.091 (0.089)	0	0.000 (0.000)	0.000 (0.000)
2005	2	3	1	0.333 (0.272)	0.390 (0.260)	0	0.000 (0.000)	0.000 (0.000)
2006	2	2	1	0.500 (0.354)	0.400 (0.367)	0	0.000 (0.000)	0.000 (0.000)
2007	2	2	1	0.500 (0.354)	0.545 (0.331)	0	0.000 (0.000)	0.000 (0.000)
2008	3	5	2	0.400 (0.219)	0.361 (0.212)	2	0.100 (0.000)	0.667 (0.333)
2009	4	4	1	0.250 (0.217)	0.274 (0.205)	1	0.500 (0.354)	0.250 (0.250)
Island	29	41	9	0.220 (0.065)	0.198 (0.052)	6	0.429 (0.132)	0.207 (0.091)
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)
Island	12	16	9	0.563 (0.124)	NA	11	0.647 (0.116)	0.917 (0.348)
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)
Island	123	159	83	0.522 (0.040)	0.463 (0.041)	41	0.315 (0.041)	0.333 (0.052)
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)
Island	34	38	15	0.395 (0.079)	0.273 (0.074)	10	0.333 (0.086)	0.294 (0.108)
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)
Oregon Inlet Islands								
2009	11	12	10	0.833 (0.108)	0.806 (0.123)	7	0.350 (0.107)	0.636 (0.279)
Summary	**1221**	**1812**	**550**	**0.304 (0.011)**	**0.259 (0.010)**	**391**	**0.379 (0.015)**	**0.320 (0.019)**

Appendix 2. American Oystercatchers banded in North Carolina.

USFWS #	Date	Banding Location	Left Leg	Right Leg	Age
805-60021	5/10/99	CALO - NCB	-;DB(1)/S	-;-	Adult
805-60022	5/11/99	CALO - NCB	-;DG(1)/S	-;-	Adult
805-60024	5/12/99	CALO - NCB Mile 21.3	-;GF/S	-;RD/WH	Adult
805-60026	5/12/99	CALO – NCB	WH;GF/S	WH;DB/RD	Adult
805-60027	5/13/99	CALO – NCB	WH;DG(B)/S	WH;-	Adult
805-60028	5/9/99	CALO - NCB	-;DB(3)/S	-;RD(6)	Chick
805-60029	5/9/99	CALO - NCB	-;DB(3)/S	-;DG(2)	Chick
805-60030	5/9/99	CALO - NCB	-;-	-;YE(3)/S	Chick
805-60034	6/22/99	CALO - NCB	-;-	-;DG(3)/S	Chick
805-60035	6/27/99	CALO - NCB	-;-	-;RD(3)/S	Chick
805-60036	6/28/99	CALO - NCB	-;YE(4)/S	-;RD(4)	Chick
805-60037	6/28/99	CALO - NCB	-;DB(5)/S	-;DG(4)	Chick
805-60038	5/12/00	CALO – NCB	-;S	-;DB(7)/DG(5)	Adult
805-60039	5/16/00	CALO – NCB	-;S	-;DG(6)/RD(5)	Adult
805-60040	5/16/00	CALO – NCB	-;S	-;RD(6)/DB(8)	Adult
805-60041	5/17/00	CALO – NCB	-;S	-;YE(9)/DG(7)	Adult
805-60042	5/19/00	CALO – NCB	-;S	-;DG(8)/RD(7)	Adult
875-98376	5/19/00	CALO - NCB - Mile 4.3	DG(37);-	DG(37);S	Adult
805-60044	6/12/00	CALO – NCB	-;S	-;YE(8)/DB(10)	Adult
805-60049	6/28/00	CALO – NCB	-;S	-;RD(8)/DG(10)	Adult
805-60050	7/5/00	CALO - NCB	-;S	-;DG(14)/YE(10)	Adult
805-60045	6/22/00	CALO - NCB Mile 18.5	-;DG(9)/S	-;-	Chick
805-60046	6/17/00	CALO – SCB	-;DG(11)/S	-;-	Chick
805-60047	6/8/00	CALO – SCB	DB;GF/S	YE;DG/RD	Chick
805-60048	6/8/00	CALO – SCB	-;DG(13)/S	-;-	Chick
805-60051	5/25/01	CALO - NCB Mile 3.7	-;DG/S	-;DB	Adult
805-60052	5/25/01	CALO - NCB Mile 3.5	-;DG/S	-;RD	Adult
805-60053	5/26/01	CALO - NCB Mile 4.7	-;DG/S	-;YE	Adult
805-60054	5/31/01	CALO – NCB Mile 9.6	-;DG/S	-;DG	Chick
805-60055	5/31/01	CALO - NCB Mile 6.6	DG(B);DG/S	-;WH	Adult
805-60056	6/3/01	CALO - NCB Mile 16.3	-;GF/S	-;DB/OR	Adult

805-60057	6/5/01	CALO – NCB Mile 10.3	-;GF/S	-;OR	Chick
805-60058	6/12/01	CALO - NCB Mile 5.9	-;GF/S	-;YE/DG	Adult
805-60059	7/1/01	CALO – NCB Mile 0.0	-;GF/S	-;OR/YE	Chick
805-60060	6/17/01	CALO - NCB Mile 8.4	-;S	-;WH/OR	Adult
805-60061	6/18/01	CALO - NCB Mile 11.7	-;S	-;WH/DB	Adult
805-60062	6/18/01	CALO - NCB Mile 11.7	-;S	RD;DG/RD	Adult
805-60063	6/19/01	CALO – SCB Mile 38	-;DG/S	-;RD/DB	Chick
805-60064	6/19/01	CALO - SCB Mile 38	-;S	-;RD/OR	Adult
805-60065	7/12/01	CALO – NCB Mile 0.2	-;GF/S	-;RD/YE	Chick
805-60066	7/13/01	CALO – NCB Mile 8.9	-;GF/S	-;WH/WH	Chick
805-60067	7/13/01	CALO - NCB Mile 8.9	-;S	-;OR/OR	Adult
805-60068	3/28/02	CALO - NCB Mile 13.8	YE;S	YE;OR/RD	Adult
805-60069	4/1/02	Battery Is.	OR;GF/S	OR;YE/RD	Adult
805-60070	4/1/02	Battery Is.	WH;DG/S	DB;-	Adult
805-60071	5/13/02	Battery Island	-;GF/S	-;WH/RD	Chick
805-60072	5/13/02	Battery Island	-;GF/S	-;OR/DB	Chick
805-60073	5/13/02	Battery Is.	-;GF/S	-;DB/WH	Chick
805-60074	5/17/02	CALO - NCB Mile 0.0	WH;GF/S	WH;RD/RD	Adult
875-98366	5/21/02	CAHA - Hatteras Island Mile 28	DG(28);-	DG(28);S	Adult
805-60076	5/21/02	CAHA - Hatteras Island South Beach	WH;S	WH;DG/DG	Adult
805-60077	5/22/02	CAHA – Ocracoke Island	-;DG/S	-;YE/DB	Chick
805-60078	5/22/02	CAHA - Ocracoke Island	WH;GF/S	WH;DB/DB	Adult
805-60079	5/25/02	CALO – NCB Mile 9.55	WH;DG/S	-;YE/DB	Chick
805-60080	5/27/02	CALO - SCB Mile 38	OR;S	OR;WH/WH	Adult
805-60081	5/28/02	CALO – SCB The Spit	-;GF/S	-;YE/WH	Chick
805-60082	5/28/02	CALO - SCB The Spit	OR;GF/S	OR;OR/OR	Adult
875-98375	5/31/02	CALO - NCB Mile 6.15	OR;DG/S	OR;DB/DB	Adult
805-60084	6/1/02	CALO - NCB Mile 8.4	DB;S	WH;DB/WH	Adult
805-60085	6/1/02	CALO – NCB Mile 5.9	-;GF/S	WH;RD/WH	Chick
805-60086	6/9/02	CAHA - Hatteras Island Buxton	RD;GF/S	DB;RD/RD	Adult
805-60087	6/11/02	CAHA – Hatteras Island Buxton	-;GF/S	-;OR/DG	Chick
805-60088	6/11/02	CAHA – Hatteras Island Buxton	RD;GF/S	DB;OR/DG	Chick
805-60089	6/11/02	CAHA – Hatteras Island Buxton	YE;GF/S	YE;YE/YE	Chick

875-98362	6/13/02	CAHA - Hatteras Island Buxton	DG(24);-	DG(24);S	Adult
805-60091	6/14/02	CAHA – Ocracoke Island	YE;-	-;GF/S	Chick
805-60092	6/14/02	CAHA – Ocracoke Island	RD;GF/S	-;-	Chick
805-60093	6/16/02	CALO – NCB Mile 9.55	-;DG	RD;S	Chick
805-60094	6/17/02	Battery Is.	-;GF/S	RD;OR/WH	Adult
805-60095	6/17/02	South Pelican Is.	WH;GF/S	-;RD/RD	Chick
805-60096	6/17/02	South Pelican Is.	YE;GF/S	DB;OR	Chick
805-60097	6/18/02	Battery Is.	DG;GF/S	-;WH/DG	Adult
805-60098	6/18/02	Battery Is.	-;GF/S	-;RD/RD	Chick
805-60099	6/18/02	South Pelican Is.	YE;GF/S	RD;DB/YE	Adult
805-60100	6/29/02	CALO – NCB Mile 9.55	DB;-	RD;S	Chick
975-85201	7/1/02	CALO – NCB Mile 2.3	-;GF/S	-;DG/YE	Chick
975-85202	7/1/02	CALO – NCB Mile 2.3	RD;S	-;YE	Chick
975-85203	5/27/03	Battery Is.	WH;DG(A)/S	YE;-	Chick
975-85204	5/27/03	South Pelican Is.	RD;DG(A)/S	OR;-	Chick
975-85205	6/1/03	CAHA – Hatteras Island	-;DG(A)/S	-;DB/DB	Chick
975-85206	6/2/03	CAHA – Ocracoke Island	OR;DG(B)/S	OR;-	Adult
975-85207	6/5/03	CALO – SCB mile 24.1	YE;DG(B)/S	WH;-	Adult
975-85208	6/6/03	CALO – SCB mile 39.75	RD;DG(B)/S	YE;-	Adult
875-98335	6/6/03	CALO – SCB, Cape point	DG(16);-	DG(16);S	Adult
975-85291	6/18/03	CALO – NCB mile 3.2	S;-/DG(A)	WH;OR/OR	Chick
975-85210	6/18/03	CALO – NCB mile 3.2	DG(H);-/DG(A)	WH;OR/S	Chick
975-85293	6/23/03	CALO – NCB mile 10.4	S;-/DG(A)	-;DG/WH	Chick
975-85211	6/25/03	CALO – SCB mile 40.55	-;-/DG(A)	RD;RD/RD/S	Chick
875-98321	4/17/04	CAHA – Hatteras Island South Beach	DG(01);-	DG(01);S	Adult
875-98322	4/17/04	CAHA – Hatteras Island Hatteras Inlet	DG(02);-	DG(02);S	Adult
875-98323	5/4/04	CALO – NCB mile 3.0	DG(03);-	DG(03);S	Adult
875-98324	5/6/04	CALO – NCB mile 9.5	DG(04);-	DG(04);S	Adult
875-98325	5/15/04	CAHA – Hatteras Island – North of Buxton	DG(05);-	DG(05);S	Adult
875-98326	5/15/04	CAHA – Hatteras Island – North of Buxton	DG(06);-	DG(06);S	Adult

875-98327	5/16/04	CAHA – Hatteras Island, Cape Point	DG(07);-	DG(07);S	Adult
875-98328	5/17/04	CALO – NCB Mile 0.0	DG(08);S	DG(08);-	Adult
875-98329	5/18/04	CALO - NCB Mile 0.0	DG(09);-	DG(09);S	Adult
875-98330	5/24/04	CAHA - Green Island	DG(10);-	DG(10);S	Adult
875-98331	5/24/04	CAHA - Green Island	DG(11);-	DG(11);S	Adult
875-98332	5/24/04	CAHA - Hatteras Island, South Beach	DG(12);-	DG(12);S	Adult
2406-00411	5/25/04	CAHA - Ocracoke, Pair O08	DG(13);-	DG(13);S	Adult
875-98333	5/25/04	CAHA - Ocracoke, Pair O07	DG(14);-	DG(14);S	Adult
875-98334	5/26/04	CALO – NCB Mile 6.15	DG(15);-	DG(15);S	Adult
875-98336	5/28/04	CALO - SCB Mile 37.3	DG(17);-	DG(17);S	Adult
2406-00412	5/29/04	CALO – NCB Mile 18.5	DG(18);-	DG(18);S	Adult
875-98338	5/31/04	CALO - NCB Mile 0.0	DG(19);-	DG(19);S	Chick
875-98339	5/31/04	CALO - NCB Mile 0.0	DG(20);-	DG(20);S	Chick
875-98340	6/1/04	CAHA - Ocracoke Inlet	DG(21);-	DG(21);S	Adult
875-98361	6/1/04	CAHA – Ocracoke	DG(22);-	DG(22);S	Adult
2406-00413	6/1/04	CAHA – Buxton Washout	DG(23);-	DG(23);S	Adult
875-98363	6/2/04	CAHA - Hatteras Inlet	DG(25);-	DG(25);S	Adult
875-98364	6/3/04	CAHA - 1 Mile North of Ramp 34	DG(26);-	DG(26);S	Adult
875-98365	6/3/04	CAHA - 1 Mile North of Ramp 34	DG(27);-	DG(27);S	Adult
875-98368	6/7/04	CALO - SCB Mile 39.7	DG(29);-	DG(29);S	Chick
875-98367	6/8/04	CALO - NCB Mile 10.3	DG(30);-	DG(30);S	Adult
875-98369	6/9/04	CALO - NCB Mile 0.0	DG(31);-	DG(31);S	Chick
875-98370	6/10/04	CALO - NCB Mile 18.5	DG(32);-	DG(32);S	Chick
875-98371	6/10/04	CALO - NCB Mile 18.5	DG(33);-	DG(33);S	Chick
875-98372	6/10/04	CALO - NCB Mile 6.9	DG(34);-	DG(34);S	Chick
875-98373	6/10/04	CALO - NCB Mile 6.9	DG(35);-	DG(35);S	Chick
875-98374	6/11/04	CALO - NCB Mile 8.9	DG(36);-	DG(36);S	Chick
875-98377	6/16/04	CALO – MCB - Mile 0.6	OR;DG/S	DB;DB	Chick
875-98378	6/16/04	CALO – MCB - Mile 0.6	DB;DG/S	DB;RD	Chick
875-98379	6/16/04	CALO – MCB - Mile 0.6	RD;DG/S	YE;WH	Chick
875-98380	6/17/04	CALO - NCB Mile 6.9	DG(38);-	DG(38);S	Chick
875-98381	6/18/04	CAHA - Ocracoke Inlet.	DB;DG/S	YE;WH	Chick
875-98382	6/18/04	CAHA - Ocracoke Inlet.	OR;DG/S	YE;DB	Chick

875-98383	6/18/04	CAHA - Hatteras Inlet	RD;DG/S	OR;WH	Chick
875-98384	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(56);-	DG(56);S	Chick
875-98385	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(57);-	DG(57);S	Chick
875-98386	6/19/04	CAHA - 1 mile S of Ramp 27	WH;DG/S	DG;WH	Chick
875-98387	6/19/04	CAHA - 0.8 miles south of Ramp 27	DG(58);-	DG(58);S	Chick
875-98388	6/22/04	CALO - NCB Mile 7.15	DG(39);-	DG(39);S	Adult
875-98389	6/22/04	CALO - NCB Mile 6.01	DG(40);-	DG(40);S	Adult
875-98390	6/23/04	CALO - Old Dump Island at Old Drum Inlet	DB;DG/S	RD;RD	Chick
875-98391	6/26/04	Sandbag Island.Pair S02	DG(41);-	DG(41);S	Chick
875-98392	6/26/04	Sandbag Island.Pair S02	DG(42);-	DG(42);S	Chick
875-98393	6/26/04	Sandbag Island.Pair S02	DG(43);-	DG(43);S	Chick
875-98394	6/27/04	CALO - NCB Mile 6.01	DG(44);-	DG(44);S	Chick
875-98395	6/27/04	CALO - NCB Mile 6.01	DG(45);-	DG(45);S	Chick
875-98396	6/27/04	CALO - NCB Mile 2.0	DG(46);-	DG(46);S	Chick
875-98397	6/27/04	CAHA – Ocracoke	DG(47);-	DG(47);S	Chick
875-98398	6/27/04	CAHA – Ocracoke	DG(48);-	DG(48);S	Chick
875-98399	6/27/04	CAHA – Ocracoke	DG(49);-	DG(49);S	Chick
875-98400	6/27/04	CAHA – Ocracoke	DG(50);-	DG(50);S	Chick
875-98421	6/27/04	CAHA – Ocracoke	DG(51);-	DG(51);S	Adult
875-98422	6/28/04	CAHA - Avon - 0.9 Miles North of Ramp 34.	DG(52);-	DG(52);S	Chick
875-98423	6/28/04	CAHA - Avon - 0.9 Miles North of Ramp 34.	DG(53);-	DG(53);S	Chick
875-98424	6/28/04	CAHA - 1.4 miles south of Ramp 27.	DG(54);-	DG(54);S	Chick
875-98425	6/28/04	CAHA - 1.4 miles south of Ramp 27.	DG(55);-	DG(55);S	Chick
875-98426	6/28/04	CAHA - 1.4 miles south of Ramp 27	DG(59);-	DG(59);S	Adult
875-98427	6/29/04	CALO - NCB Mile 6.01	DG(60);-	DG(60);S	Chick
875-98428	6/29/04	CALO - NCB Mile 7.15	DG(61);-	DG(61);S	Chick
875-98429	6/30/04	CALO - NCB Mile 6.3	DG(62);-	DG(62);S	Chick
875-98430	6/30/04	CALO - NCB Mile 9.5	DG(63);-	DG(63);S	Chick
875-98431	6/30/04	CALO - NCB Mile 7.15	DG(64);-	DG(64);S	Chick
875-98432	6/30/04	CALO - NCB Mile 7.15	DG(65);-	DG(65);S	Chick

875-98433	6/30/04	CALO - NCB Mile 10.3	DG(66);-	DG(66);S	Chick
875-98434	6/30/04	CALO - NCB Mile 10.3	DG(67);-	DG(67);S	Chick
875-98435	7/1/04	CALO - NCB Mile 3.9	DG(68);-	DG(68);S	Chick
875-98436	7/1/04	CALO - NCB Mile 3.9	DG(69);-	DG(69);S	Chick
875-98437	7/1/04	CALO - NCB Mile 3.9	DG(70);-	DG(70);S	Chick
875-98348	7/3/04	CALO - NCB Old Drum Inlet	DG(71);-	DG(71);S	Chick
875-98349	7/3/04	CALO - NCB Old Drum Inlet	DG(72);-	DG(72);S	Chick
875-98350	7/3/04	CALO - NCB Mile 9.5	DG(73);-	DG(73);S	Adult
875-98441	7/3/04	CALO - NCB Mile 6.3	DG(74);-	DG(74);S	Chick
875-98442	7/4/04	CALO - NCB Mile 3.4	DG(75);-	DG(75);S	Chick
875-98443	7/4/04	CALO - NCB Mile 3.4	DG(76);-	DG(76);S	Chick
875-98444	7/19/04	Cape Fear - Ferry Slip	DG(77);-	DG(77);S	Chick
875-98445	7/19/04	Cape Fear - Ferry Slip	DG(78);-	DG(78);S	Chick
875-98446	7/19/04	Cape Fear - South Pelican	DG(79);-	DG(79);S	Chick
875-98447	7/19/04	Cape Fear - South Pelican	DG(80);-	DG(80);S	Chick
875-98448	7/22/04	CALO - SCB mile 22.6	DG(81);-	DG(81);S	Chick
875-98449	7/22/04	CALO - SCB mile 22.6	DG(82);-	DG(82);S	Chick
875-98450	7/29/04	CAHA - Ocracoke Pair O03	DG(83);-	DG(83);S	Chick
875-98451	7/29/04	CAHA - Ocracoke Pair O03	DG(84);-	DG(84);S	Chick
875-98452	8/1/04	CALO – NCB Mile 6.15	DG(85);-	DG(85);S	Chick
875-98453	8/5/04	CALO - SCB Mile 23.5	DG(86);-	DG(86);S	Chick
875-98454	8/5/04	CALO - SCB Mile 23.5	DG(87);-	DG(87);S	Chick
875-98455	3/19/05	CAHA - Hatteras Is, Hatteras inlet	DG(88)	DG(88);S	Adult
875-98456	3/20/05	Ocracoke Inlet – Shellcastle/ Ballast rocks Is.	DG(89)	DG(89);S	Adult
875-98457	3/20/05	Ocracoke Inlet -Shellcastle/ Ballast rocks Is.	DG(90)	DG(90);S	Adult
875-98458	3/20/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(91)	DG(91);S	Adult
875-98459	3/21/05	CAHA -Hatteras Is, Hatteras spit, the breach	DG(92)	DG(92);S	Adult
875-98460	4/1/05	CAHA - Bodie Island spit.	DG(A1)	DG(A1);S	Adult
875-98461	4/2/05	CAHA - 1 mile N. of ramp 30	DG(A2)	DG(A2);S	Adult

875-98462	4/3/05	CAHA - 1.8 miles south of ramp 23	DG(A3)	DG(A3);S	Adult
875-98463	4/3/05	CAHA - 1.8 miles south of ramp 23	DG(A4)	DG(A4);S	Adult
875-98464	4/3/05	CAHA - Sandy Bay/Isabel Inlet - sound side	DG(A5)	DG(A5);S	Adult
875-98466	4/17/05	CAHA - Cape Point	DG(A7)	DG(A7);S	Adult
875-98468	4/18/05	CALO - SCB mile 38.5	DG(A9)	DG(A9);S	Adult
875-98469	5/7/05	CALO - NCB mile 9.9	DG(A0)	DG(A0);S	Adult
875-98471	5/7/05	CALO - NCB mile 4.5	DG(C2)	DG(C2);S	Adult
875-98472	5/7/05	CALO - NCB mile 4.5	DG(C3)	DG(C3);S	Adult
875-98473	5/8/05	CALO - NCB mile 10.4	DG(C4)	DG(C4);S	Adult
875-98474	5/9/05	Ocracoke inlet - Shellcastle Islands - with duck blind.	DG(C5)	DG(C5);S	Adult
875-98475	5/9/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(C6)	DG(C6);S	Adult
875-98476	5/9/05	Ocracoke inlet – Shellcastle/ Northernmost marsh Is.	DG(C7)	DG(C7);S	Adult
875-98477	4/10/05	CAHA - Bodie Island spit. North side of bay.	DG(C9)	DG(C9);S	Adult
875-98478	4/10/05	CAHA 0.8 miles S. of ramp 27	DG(C8)	DG(C8);S	Adult
875-98479	5/11/05	Oregon inlet, East waterbird island (near bridge)	DG(C0)	DG(C0);S	Adult
875-98480	5/11/05	Oregon inlet - Island MN (north side)	DG(E1)	DG(E1);S	Adult
785-09571	5/11/05	Oregon inlet - Island MN (north side)	DG(E2)	DG(E2);S	Adult
875-98481	5/11/05	Oregon Inlet - Island L. NW side.	DG(E3)	DG(E3);S	Adult
875-98482	5/11/05	Oregon inlet - Island D (East side)	DG(E4)	DG(E4);S	Adult
875-98483	5/11/05	Oregon Inlet -Wells Island	DG(E5)	DG(E5);S	Adult
875-98484	5/11/05	Oregon Inlet - Wells Island	DG(E6)	DG(E6);S	Adult
875-98485	5/11/05	Oregon Inlet - Island G	DG(E7)	DG(E7);S	Adult
875-98486	5/13/05	CALO - Shackleford Banks - West end	DG(E8)	DG(E8);S	Adult
875-98487	5/13/05	CALO - Shackleford Banks - mile 49.9	DG(E9)	DG(E9);S	Adult
875-98488	5/17/05	CALO - NCB - Mile 15.5	DG(E0)	DG(E0);S	Adult

875-98489	5/17/05	CALO - NCB - Mile 3.8	DG(F1)	DG(F1);S	Adult
875-98492	5/26/05	CALO - NCB - Mile 12.2	DG(F4)	DG(F4);S	Adult
875-98493	5/26/05	CALO - NCB - Mile 6.8	DG(F5)	DG(F5);S	Adult
875-98494	5/26/05	CALO - NCB - Mile 0.2	DG(F6)	DG(F6);S	Adult
875-98495	6/1/05	CAHA - South Beach	DG(F7)	DG(F7);S	Adult
875-98497	6/13/05	Oregon Inlet - Island MN	DG(93)	DG(93);S	Chick
875-98498	6/13/05	Oregon inlet, bridge island	DG(94)	DG(94);S	Chick
875-98499	6/18/05	CAHA - South Beach	DG(H2)	DG(H2);S	Chick
875-98500	6/18/05	CAHA - South Beach	DG(H3)	DG(H3);S	Chick
875-98402	6/18/05	CAHA - North Beach	DG(H4)	DG(H4);S	Chick
875-98403	6/19/05	Ocracoke Island 3.3 miles north of ramp 67	DG(95)	DG(95);S	Chick
875-98404	6/19/05	CALO - SCB - mile 44.8	DG(F9)	DG(F9);S	Chick
875-98405	6/20/05	CALO – SCB - power squadron spit - sound side	DG(F0)	DG(F0);S	Chick
875-98406	6/22/05	CALO - MCB - north end	DG(K1)	DG(K1);S	Chick
875-98407	6/22/05	CALO - MCB - north end	DG(K2)	DG(K2);S	Chick
875-98408	6/25/05	CALO - NCB - Mile 10.5	DG(J1)	DG(J1);S	Chick
875-98409	7/9/05	CALO - NCB - Mile 15.5	DG(J2)	DG(J2);S	Chick
875-98410	7/9/05	CALO - NCB - Mile 15.5	DG(J3)	DG(J3);S	Chick
875-98411	7/10/05	CALO - NCB - Mile 10.8	DG(J5)	DG(J5);S	Chick
875-98413	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K3)	DG(K3);S	Chick
875-98414	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K4)	DG(K4);S	Chick
875-98415	7/12/05	CALO - MCB - 0.5 miles south of Old Drum inlet	DG(K5)	DG(K5);S	Chick
875-98416	7/14/05	CAHA - South Beach	DG(H6)	DG(H6);S	Chick
875-98417	7/14/05	CAHA - South Beach	DG(H7)	DG(H7);S	Chick
875-98418	7/15/05	CAHA - 0.6 Miles north of Ramp 30	DG(H8)	DG(H8);S	Chick
875-98419	7/20/05	CALO - MCB - NW corner at Old Drum inlet	DG(K6)	DG(K6);S	Chick
875-98420	7/20/05	CALO - MCB - NW corner at Old	DG(K7)	DG(K7);S	Chick

		Drum inlet			
1055-04701	7/21/05	CALO - NCB - Mile 7.6	DG(J6)	DG(J6);S	Chick
1055-04702	8/1/05	CALO - NCB - Mile 6.01	DG(J7)	DG(J7);S	Chick
1055-04703	8/2/05	CAHA - Ocracoke, 1.6 miles north of ramp 70	DG(K8)	DG(K8);S	Chick
1055-04704	8/2/05	CAHA - Cape Point	DG(H9)	DG(H9);S	Chick
1055-04705	8/3/05	CALO - MCB - 1.2 miles south of Old Drum inlet	DG(K9)	DG(K9);S	Chick
1055-04706	8/3/05	CALO - MCB - 1.2 miles south of Old Drum inlet	DG(K0)	DG(K0);S	Chick
1055-04708	8/10/05	CAHA - North of Buxton	DG(H0)	DG(H0);S	Chick
1055-04710	4/12/06	CALO - SCB mile 35.2	DG(J0)	DG(J0);S	Adult
1055-04711	4/12/06	CALO - SCB mile 35.2	DG(M1)	DG(M1);S	Adult
1055-04712	4/13/06	CALO - SCB mile 28.3	DG(M2)	DG(M2);S	Adult
1055-04712	5/3/06	CALO - NCB mile 10.6	DG(M3)	DG(M3);S	Adult
1055-04714	6/9/06	Shellcastle Islands - Shellcastle West (Rocky Island)	DG(M4)	DG(M4);S	Chick
1055-04715	6/9/06	Shellcastle Islands - Shellcastle West (Rocky Island)	DG(M5)	DG(M5);S	Chick
1055-04716	6/9/06	Shellcastle Islands - North Rock East	DG(M6)	DG(M6);S	Chick
1055-04717	6/9/06	Shellcastle Islands - North Rock East	DG(M7)	DG(M7);S	Chick
1055-04718	6/10/06	CALO - MCB. 0.5 miles south of Old Drum Inlet.	DG(M8)	DG(M8);S	Adult
1055-04719	6/11/06	Old Dump Island, Old Drum Inlet.	DG(M9)	DG(M9);S	Chick
1055-04720	6/17/06	CAHA - Buxton washout.	DG(P2)	DG(P2);S	Chick
1055-04721	6/17/06	CAHA - Buxton washout.	DG(P1)	DG(P1);S	Chick
1055-04722	6/18/06	CALO - MCB - Old Drum Inlet	DG(M0)	DG(M0);S	Chick
1055-04723	6/19/06	CALO - SCB Mile 38	DG(P3)	DG(P3);S	Chick
1055-04724	6/19/06	CALO - SCB Mile 38	DG(P4)	DG(P4);S	Chick
1055-04725	6/19/06	CALO - SCB Mile 38	DG(P5)	DG(P5);S	Chick
1055-04727	6/29/06	CAHA - South Beach	DG(N1)	DG(N1);S	Chick
1055-04728	6/29/06	CAHA - South Beach	DG(N3)	DG(N3);S	Chick
1055-04730	6/29/06	CALO - NCB - mile 3.6	DG(N6)	DG(N6);S	Chick

1055-04731	6/29/06	CALO - NCB - mile 9.3	DG(N7)	DG(N7);S	Chick
1055-04732	6/29/06	CALO - NCB - mile 10.3	DG(N8)	DG(N8);S	Chick
1055-04734	7/2/06	CALO - NCB - Mile 8.9	DG(T2)	DG(T2);S	Chick
1055-04735	7/7/06	CALO - MCB	DG(N0)	DG(N0);S	Chick
1055-04737	7/8/06	Bigfoot Island Slough	DG(U1)	DG(U1);S	Chick
1055-04738	7/8/06	CAHA - North Beach	DG(U2)	DG(U2);S	Chick
1055-04739	7/9/06	CALO - MCB	DG(U3)	DG(U3);S	Chick
1055-04740	7/9/06	CALO - MCB	DG(U4)	DG(U4);S	Chick
1055-04741	7/14/06	CALO - SCB	DG(U5)	DG(U5);S	Chick
1055-04742	7/14/06	CALO - SCB	DG(U6)	DG(U6);S	Chick
1055-04743	7/20/06	Ocracoke Inlet - Shellcastle Island	DG(U7)	DG(U7);S	Chick
1055-04744	7/20/06	Ocracoke Inlet - Shellcastle Island	DG(P7)	DG(P7);S	Chick
1055-04745	7/20/06	Ocracoke Inlet - Shellcastle Island central (with blind)	DG(U8)	DG(U8);S	Chick
1055-04746	7/20/06	Ocracoke Inlet - Shellcastle Island central (with blind)	DG(P8)	DG(P8);S	Chick
1055-04747	7/21/06	CALO - NCB	DG(U9)	DG(U9);S	Chick
1055-04748	7/21/06	CALO - MCB	DG(U0)	DG(U0);S	Chick
1055-04749	7/21/06	CALO - MCB	DG(P9)	DG(P9);S	Chick
1055-04750	7/27/06	CALO - MCB	DG(P0)	DG(P0);S	Chick
1055-04751	7/27/06	CALO - Ophelia Island - North End	DG(R1)	DG(R1);S	Chick
1055-04752	7/27/06	CALO - Ophelia Island - North End	DG(R2)	DG(R2);S	Chick
1055-04753	7/28/06	CALO - SCB	DG(N2)	DG(N2);S	Chick
1055-04754	7/28/06	CALO - SCB	DG(N4)	DG(N4);S	Chick
1055-04755	7/28/06	CALO - SCB	DG(R3)	DG(R3);S	Chick
1055-04756	5/12/07	CAHA - Buxton/Avon - Canadian Hole	DG(R5)	DG(R5);S	Adult
1055-04757	5/12/07	CAHA - Buxton/Avon - Canadian Hole	DG(R6)	DG(R6);S	Adult
1055-04758	5/16/07	CALO - SCB - Mile 46.7	DG(R7)	DG(R7);S	Adult
1055-04759	5/16/07	CALO - SCB - Mile 37.9	DG(R8)	DG(R8);S	Adult
1055-04760	5/20/07	CAHA - South Beach	DG(R9)	DG(R9);S	Adult
1055-04761	5/27/07	CAHA - South Beach, 0.1 miles east	DG(R0)	DG(R0);S	Adult

		of ramp 45			
1055-04762	5/27/07	CAHA - North Beach, 0.8 m N R30	DG(T4)	DG(T4);S	Adult
1055-04763	6/16/07	CAHA	DG(T5)	DG(T5);S	Chick
1055-04764	6/16/07	CAHA	DG(T6)	DG(T6);S	Chick
1055-04765	6/17/07	CALO - NCB - Mile 9.1	DG(T7)	DG(T7);S	Chick
1055-04766	6/17/07	CALO - NCB - Mile 9.1	DG(T8)	DG(T8);S	Chick
1055-04767	6/17/07	CALO - NCB - Mile 9.1	DG(T9)	DG(T9);S	Chick
1055-04768	6/30/07	CALO - NCB - Mile 8.9	DG(TO)	DG(TO);S	Chick
1055-04769	7/14/07	CAHA - South Beach	DG(X1)	DG(X1);S	Chick
1055-04770	7/14/07	CAHA - South Beach	DG(X2)	DG(X2);S	Chick
1055-04771	7/14/07	CAHA - South Beach	DG(X3)	DG(X3);S	Chick
1055-04772	7/14/07	CAHA - North Beach	DG(X4)	DG(X4);S	Chick
1055-04773	7/15/07	CALO - NCB - Mile 0.0	DG(X5)	DG(X5);S	Chick
1055-04774	7/15/07	CALO - NCB - Mile 0.0	DG(X6)	DG(X6);S	Chick
1055-04775	7/15/07	CALO - NCB - Mile 3.6	DG(X7)	DG(X7);S	Chick
1055-04776	7/15/07	CALO - NCB - Mile 3.8	DG(X8)	DG(X8);S	Chick
1055-04777	7/15/07	CALO - NCB - Mile 3.8	DG(X9)	DG(X9);S	Chick
1055-04778	7/27/07	CAHA - North Beach	DG(Y1)	DG(Y1);S	Chick
1055-04779	7/27/07	CAHA - North Beach	DG(X0)	DG(X0);S	Chick
1055-04780	7/28/07	CALO - NCB - Mile 10.38	DG(Y2)	DG(Y2);S	Chick
1055-04781	7/28/07	CALO - NCB - Mile 3.8	DG(Y3)	DG(Y3);S	Chick
1055-04782	7/29/07	CALO - NCB - Mile 11.5	DG(Y4)	DG(Y4);S	Chick
1055-04783	8/3/07	CALO - MCB - Mile 19.66	DG(Y5)	DG(Y5);S	Chick
1055-04784	8/3/07	CALO - MCB - Mile 19.45	DG(Y6)	DG(Y6);S	Chick
1055-04785	8/3/07	Old Dump Island, Old Drum Inlet.	DG(Y7)	DG(Y7);S	Chick
1055-04786	8/3/07	Old Dump Island, Old Drum Inlet.	DG(Y8)	DG(Y8);S	Chick
1055-04787	8/4/07	CAHA - Ocracoke	DG(Y9)	DG(Y9);S	Chick
2406-00414	4/12/2008	CALO - SCB - Cape Point	DG(L1)	DG(L1);S	Adult
2406-00415	4/14/2008	CALO - SCB - Mile 38.83	DG(L2)	DG(L2);S	Adult
2406-00416	4/14/2008	CALO - SCB - Mile 38.83	DG(L3)	DG(L3);S	Adult
1055-04789	5/3/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(L4)	DG(L4);S	Adult
1055-04790	5/3/2008	CAHA - Hatteras Is. - North of Buxton	DG(L5)	DG(L5);S	Adult
2406-00417	5/3/2008	CAHA - Hatteras Is. - South Beach	DG(L6)	DG(L6);S	Adult

1055-04791	5/5/2008	CAHA - Ocracoke Is. - 1.0 miles south of Ramp 68	DG(L7)	DG(L7);S	Adult
2406-00418	6/10/2008	CAHA - Hatteras Is. - North of ramp 34	DG(L8)	DG(L8);S	Adult
2406-00419	6/10/2008	CAHA - Hatteras Is., 0.7 miles south of ramp 27	DG(L9)	DG(L9);S	Adult
1055-04792	6/22/2008	CAHA - Hatteras Is. - 1.1 miles north or ramp 30	DG(L0)	DG(L0);S	Chick
1055-04793	6/22/2008	CAHA - Hatteras Is. - North of Buxton	DG(W1)	DG(W1);S	Chick
1055-04794	6/22/2008	CAHA - Hatteras Is. - North of Buxton	DG(W2)	DG(W2);S	Chick
1055-04795	6/22/2008	CAHA - Hatteras Is. - Sandy Bay	DG(W3)	DG(W3);S	Chick
1055-04796	6/22/2008	CAHA - Hatteras Is. - Sandy Bay	DG(W4)	DG(W4);S	Chick
1055-04797	6/22/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(W5)	DG(W5);S	Chick
1055-04798	6/22/2008	CAHA - Hatteras Is. - Hatteras Inlet	DG(W6)	DG(W6);S	Chick
2406-00420	6/26/2008	Cape Fear River - Battery Is., South Point	DG(W7)	DG(W7);S	Adult
2406-00421	6/26/2008	Cape Fear River - Battery Is., South Point	DG(W8)	DG(W8);S	Adult
1055-04799	7/3/2008	CALO - NCB, Mile 9.0	DG(W9)	DG(W9);S	Chick
1055-04800	7/3/2008	CALO - NCB, Mile 6.6	DG(W0)	DG(W0);S	Chick
1055-04801	7/3/2008	CALO - MCB - Mile 19.66	DG(EA)	DG(EA);S	Chick
1055-04802	7/3/2008	CALO - MCB - Mile 19.66	DG(EC)	DG(EC);S	Chick
1055-04803	7/3/2008	CALO - MCB - Mile 19.66	DG(EE)	DG(EE);S	Chick
1055-04804	7/3/2008	CALO - MCB - Mile 19.86	DG(EF)	DG(EF);S	Chick
1055-04805	7/12/2008	CALO - SCB - Mile 25.16	DG(EH)	DG(EH);S	Chick
1055-04806	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EJ)	DG(EJ);S	Chick
1055-04807	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EK)	DG(EK);S	Chick
1055-04808	7/23/2008	CAHA - Hatteras Is. - North Beach - 0.7 miles north of ramp 30	DG(EL)	DG(EL);S	Chick
1055-04809	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EM)	DG(EM);S	Chick
1055-04810	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EN)	DG(EN);S	Chick

1055-04811	7/23/2008	Ocracoke Inlet - North Rock (West)	DG(EP)	DG(EP);S	Chick
1055-04812	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(ER)	DG(ER);S	Chick
1055-04813	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(EU)	DG(EU);S	Chick
1055-04814	7/23/2008	Ocracoke Inlet - Shellcastle (South)	DG(ET)	DG(ET);S	Chick
1055-04815	8/1/2008	Oregon Inlet - Green Is. - NE side	DG(EW)	DG(EW);S	Chick
1055-04816	8/1/2008	CAHA - Bodie Is. Spit, Northeast side	DG(EX)	DG(EX);S	Chick
1055-04817	8/1/2008	CAHA - Bodie Is. Spit, Southwest side	DG(EY)	DG(EY);S	Chick
1055-04818	8/7/2008	CALO - SCB - Mile 38.06	DG(AA)	DG(AA);S	Chick
1055-04819	8/7/2008	CALO - SCB - Mile 38.06	DG(AC)	DG(AC);S	Chick
1055-04820	8/7/2008	CALO - SCB - Mile 31.78	DG(AF)	DG(AF);S	Chick
1055-04821	8/7/2008	CALO - SCB - Mile 31.78	DG(AE)	DG(AE);S	Chick
1055-04822	8/8/2008	CALO - NCB - Mile 8.9	DG(AH)	DG(AH);S	Chick
1055-00823	4/26/2009	CALO - South Core Banks - Mile 28.3	DG(AJ)	DG(AJ);S	Adult
1055-04824	4/28/2009	CALO - South Core Banks - Mile 23.46	DG(AK)	DG(AK);S	Adult
915-32663	4/28/2009	CALO - South Core	DG(AL)	DG(AL);S	Adult
2406-00423	4/29/2009	CALO - South Core Banks - Mile 32.75	DG(AM)	DG(AM);S	Adult
2406-00424	4/29/2009	CALO - South Core Banks - Mile 32.75	DG(AN)	DG(AN);S	Adult
2406-00425	4/29/2009	CALO - South Core Banks - Mile 33.93	DG(AP)	DG(AP);S	Adult
2406-00426	4/29/2009	CALO - South Core Banks - Mile 33.93	DG(AR)	DG(AR);S	Adult
1055-04757	5/14/2009	CAHA - Hatteras Island	DG(AT)	DG(AT);S	Adult
2406-00422	5/24/2009	CALO - North Core Banks - Mile 11.4	DG(AU)	DG(AU);S	Adult
2406-00430	5/28/2009	CALO - Hatteras Island - Ramp 44	DG(AW)	DG(AW);S	Adult
1055-04825	6/8/2009	CALO - South Core Banks - Cape Point	DG(CP)	DG(CP);S	Chick
2406-00441	6/12/2009	Oregon Inlet - East Island	DG(CR)	DG(CR);S	Chick
2406-00442	6/13/2009	Oregon Inlet - East Island	DG(CU)	DG(CU);S	Chick
2406-00443	6/12/2009	Oregon Inlet - East Island	DG(CT)	DG(CT);S	Chick
2406-00444	6/19/2009	CALO - Shackleford Banks, approx. mile 53	DG(CW)	DG(CW);S	Chick
2406-00445	6/19/2009	CALO - Shackleford Banks, approx. mile 53	DG(CX)	DG(CX);S	Chick
2406-00446	6/20/2009	CALO - South Core Banks - mile 38.09	DG(CY)	DG(CY);S	Chick

2406-00447	6/24/2009	CALO - South Core Banks - mile 40.03	DG(HP)	DG(HP);S	Chick
2406-00448	6/24/2009	CALO - South Core Banks - mile 40.03	DG(HR)	DG(HR);S	Chick
2406-00449	6/28/2009	CAHA - Hatteras Island - Sandy Bay	DG(HT)	DG(HT);S	Chick
2406-00450	6/28/2009	CAHA - Bodie-Hatteras - N of Ramp 27	DG(HU)	DG(HU);S	Chick
2406-00451	6/29/2009	CAHA - Hatteras Island	-	DG(HC);S	Chick
2406-00452	6/29/2009	CAHA - Hatteras Island	-	DG(HE);S	Chick
2406-00453	6/29/2009	CAHA - Hatteras Island	-	DG(HW);S	Chick
2406-00454	6/29/2009	Oregon Inlet - Island D	DG(HF)	DG(HF);S	Chick
2406-00455	6/30/2009	Ocracoke Inlet - Shellcastle Island	DG(HX)	DG(HX);S	Chick
2406-00456	7/2/2009	CALO - North Core Banks - mile 9.81	DG(CC)	DG(CC);S	Chick
2406-00458	7/2/2009	CALO - North Core Banks - mile 5.96	DG(CE)	DG(CE);S	Chick
2406-00457	7/2/2009	CALO - North Core Banks - mile 9.81	DG(CF)	DG(CF);S	Chick
2406-00460	7/2/2009	CALO - North Core Banks - mile 5.96	DG(CH)	DG(CH);S	Chick
2406-00461	7/6/2009	CAHA - Hatteras Island	DG(HY)	DG(HY);S	Chick
2406-00462	7/6/2009	CAHA - Hatteras Island	DG(AX)	DG(AX);S	Chick
2406-00463	7/6/2009	CAHA - Hatteras Island	DG(AY)	DG(AY);S	Chick
2406-00464	7/6/2009	CAHA - Bodie-Hatteras	DG(CN)	DG(CN);S	Chick
2406-00465	7/6/2009	CAHA - Bodie-Hatteras	DG(CM)	DG(CM);S	Chick
2406-00466	7/7/2009	CALO - North Core Banks - mile 6.06	DG(CJ)	DG(CJ);S	Chick
2406-00467	7/8/2009	CALO - South Core Banks - mile 35.34	DG(UA)	DG(UA);S	Chick
2406-00468	7/8/2009	CALO - South Core Banks - mile 35.35	DG(UC)	DG(UC);S	Chick
2406-00469	7/9/2009	CALO - South Core Banks - mile 38.51	DG(UE)	DG(UE);S	Chick
2406-00470	7/17/2009	CALO - South Core Banks - mile 31.08	DG(UF)	DG(UF);S	Chick
2406-00471	7/24/2009	Oregon Inlet - Island MN	DG(UH)	DG(UH);S	Chick
2406-00472	7/25/2009	CALO - South Core Banks - mile 35.9	DG(UJ)	DG(UJ);S	Chick
2406-00473	7/25/2009	CALO - South Core Banks - mile 35.9	DG(UK)	DG(UK);S	Chick
2406-00474	7/25/2009	CALO - South Core Banks - mile 39.73	DG(UL)	DG(UL);S	Chick

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

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