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NEGOTIATED RULEMAKING COMMITTEE

Revised: 12th → **~~11~~th Regulatory Negotiation Meeting**

Wright Brothers Memorial, Kill Devil Hills, NC

February 3, 2009

Information Open Houses on Work of Joint Committees

- There will be an "open house" for available Committee principals and alternates to review the options and ideas generated by the joint subcommittee. This will be (pending availability) at the Outer Banks Visitors Bureau, Manteo, from 3:00 to 5:00 on Monday, February 2nd, and from 7:30 until 8:30 AM, February 3rd, Wright Brothers Memorial.

Draft Final Agenda

Objectives

- Updates since last meeting
- Review status of routes and areas and natural resources work and proposals
- Reach conditional consensus on, or narrow, as many issues as possible
- Form integration subcommittee to bring back proposal(s) at the last meeting
- Provide opportunity for public comment

8:00 Gathering and Coffee

8:30 Welcome to All and Opening of the Meeting, *Mike Murray, NPS, DFO*

8:35 Review Meeting Objectives and Agenda, *Facilitators and Agenda Planning Subcommittee*

- Approach for the Day
- Be thinking about the idea of an integration group between now and final meeting to craft final package

8:45 Brief Updates Since the Last Meeting and Approval of Meeting Summaries

9:00 Briefing on Routes and Areas and Natural Resources Work and Options

10:30 Break

10:45 Deliberations to Narrow Options and Reach Consensus

12:00 Public Comment
(up to 4 minutes per person, with 5 minutes total at the end of the public session for a brief response from Committee members to the public comments)

Specific comments are requested on the following -- Routes and Areas proposals

12:45 Lunch *(provided for principals and alternates)*

1:30 (with break) Deliberations to Narrow Options and Reach Consensus

4:00 Planning for February 26-27 Meeting

- Integration Subcommittee – goal, composition, meetings
- Materials for Committee review – due February 23

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4:45	Break
5:00	Additional Public Comment Session *(if not completed before lunch)* *(up to 4 minutes per person, with 5 minutes total at the end of the public session for a brief response from Committee members to the public comments)*
Following Public Comment	Adjourn for the Day

SUBCOMMITTEE DOCUMENT
FROM 12/12/08 COMMITTEE MEETING

CAHA NEGOTIATED RULEMAKING COMMITTEE
WORKING DOCUMENT

NOTE: THE VILLAGE SUBCOMMITTEE MAY DEVELOP ADDITIONAL RECOMMENDATIONS CONCERNING THE VILLAGES.

ORV SAFETY CLOSURE

PURPOSE: Ensuring the safety of the public when natural conditions within a specific area of CAHA present a clear and imminent threat of (a) significant bodily injury or death to the driving public or other CAHA users or (b) significant damage to personal property, primarily vehicles and their contents.

SCOPE: May be applied within any routes, trails, and areas designated for ORV driving.

TRIGGERS FOR CLOSURE: Conditions listed below may trigger an ORV Safety Closure in the event of a clear and imminent threat of significant bodily injury or death; and/or damage to personal property, primarily vehicles and their contents. Examples of hazards that could justify a closure include, but are not limited to:

- deep beach cuts which block the beach from dune to surf with no obvious way around;
- obstacles, such as exposed stumps, shipwrecks, or debris that cannot be safely by-passed or that block the entire width of the beach and cannot be easily removed;
- severe beach slope that puts vehicles in an unsafe gradient position that increases the chances of the loss of vehicular control.
- A high concentration of pedestrian users coupled with a narrow beach

Triggers do not include:

- a narrow beach, by itself;
- tides which block access through portions of beaches occur periodically and predictably and are an obvious, easily avoidable hazard;
- hazards blocking only a portion of the beach, where safe passage is available around the hazard.

While the above criteria provide the rationale for what does or does not constitute an "safety closure," the Superintendent retains the authority under 36 CFR §1.5 (a) to close all or a portion of a park area to all public use or to a specific use or activity, based upon a determination that such action is necessary for the maintenance of public health and safety, protection of environmental or scenic values, protection of natural or cultural resources, aid to scientific research, implementation of management responsibilities, equitable allocation and use of facilities, or the avoidance of conflict among visitor use activities. For any such closures implemented, the public will be notified in accordance with the public notice requirements identified in 36 CFR § 1.7.

CAHA PERSONNEL ACTION: Providing for the public safety is the responsibility of all CAHA employees. The following is expected of CAHA personnel.

- Law enforcement (LE) rangers should have the authority to enact closures consistent with the triggers noted above.
- Non-emergency service staff, when encountering safety hazards, should establish initial safety precautions and contact the LE ranger staff to evaluate the situation and establish any necessary ORV Safety Closures.
- Where hazards block only a portion of the beach, staff will mark and post the hazard to direct ORV traffic safely around the hazard.

MONITORING: ORV Safety Closures shall be monitored on a weekly basis.

DEMARCATION: ORV Safety Closures shall be clearly marked by carsonite posts and signs indicating the area is closed to ORV use. The signs used for this purpose shall indicate that safety is the reason for the closure.

ORV SAFETY CLOSURE NOTIFICATION AND CONTINUANCE: Any employee initiating an emergency ORV safety closure will notify their supervisor immediately. The Superintendent and Division Chief will be notified as soon as possible of any such emergency ORV safety closure. As soon as possible after the initial closure has been established, but no later than one week, the employee will complete a "Closure Request Form" and submit the form for final approval through the chain of command. Such form should include the coordinates of the closure, the specific reasons for the closure, the dates of action, and the employee taking action. Completion of a "Closure Request Form" will only be required when a complete beach closure is established and does not apply to any modification of the ORV corridor width that does not preclude access. As long as the area is closed, the form shall be updated weekly to include a brief description of the condition of the area based on the weekly monitoring.

TRIGGERS FOR RE-OPENING: Sufficient diminishment, reduction or elimination of the conditions and hazards described under *TRIGGERS FOR CLOSURE* would constitute the trigger for re-opening a closure. ORV safety closures are intended to be in effect only as long as visitor safety or personal property is clearly and imminently threatened.

STAKEHOLDER INPUT: The Park shall establish and maintain a standing stakeholder advisory [FACA] committee with representatives from various sections/geographies of the Park representing diverse and balanced interests to provide input to the Park on, among other things, safety closures and openings.

SUBCOMMITTEE DOCUMENT
FROM 12/12/08 COMMITTEE MEETING

PEDESTRIAN SAFETY

Due to ambient level of natural sounds on the beach (from surf, wind, etc.), and other inherent distractions in the beach setting, pedestrians may not be attentive to or aware of moving vehicles (ORVs) on the beach, especially those vehicles approaching from the sides or from behind. It is the legal responsibility of the ORV operator to always give pedestrians the right of way on the beach. The following federal regulations currently apply to motor vehicle operation in the vicinity of pedestrians:

36 CFR § 4.20 *RIGHT OF WAY*
An operator of a motor vehicle shall yield the right of way to pedestrians, (saddle and pack animals, and vehicles drawn by animals). Failure to yield the right of way is prohibited.

36 CFR § 4.22 *UNSAFE OPERATION*
(b) The following are prohibited:
(3) Failing to maintain that degree of control of a motor vehicle necessary to avoid danger to persons, property or wildlife.

In addition, the following (new) measures apply *(assuming a parkwide ORV speed limit of 15 mph)*:

1) When approaching or passing a pedestrian(s) on the beach, ORVs shall move to the landward side of the available ORV driving corridor to the extent practicable without driving on the toe of the dune or the dune itself in order to yield the wider portion of the beach corridor to the pedestrian(s).

2) ORVs shall slow to 5 mph (or the slowest possible speed to maintain traction without exceeding the overall speed limit) when traveling within 10 meters (30 ft) or less of pedestrians at any location on the beach at any time of year.

3) Pedestrians should not block access ramps and should use pedestrian ramps/boardwalks where available. If a pedestrian walkover is not available, pedestrians should walk to the side of ORV ramps, not in the tire tracks.

SUBCOMMITTEE DOCUMENT
FROM 12/12/08 COMMITTEE MEETING

CAHA NEGOTIATED RULEMAKING COMMITTEE
WORKING DOCUMENT

Vehicle Characteristics, Equipment and Operations

I. GENERAL

ENFORCEMENT: Such regulation shall be enforced by the NPS according to graduated law enforcement principles.

STAKEHOLDER INPUT: The Park shall establish and maintain a standing stakeholder advisory [FACA] committee with representatives from various sections/geographies of the Park representing diverse and balanced interests to provide input to the Park on, among other things, ORV-related issues via a standing ORV subcommittee.

ESSENTIAL VEHICLES: Essential vehicles are allowed in non-ORV areas, and within resource closures subject to guidelines in Essential Vehicles section of Appendix G of the U.S. Fish and Wildlife Service Piping Plover (Charadrius melodus), Atlantic Coast Population, Revised Recovery Plan (USFWS 1996a, as cited in the strategy/EA). To the extent practicable, emergency response vehicle operators will consult with trained resources management staff regarding protected species before driving into or through resource closures; however, prior consultation may not always be practical.

In the event of an emergency, the protection of human life takes precedence over all other management activities.

Essential vehicles will avoid driving within turtle nest closures.

COMMERCIAL FISHING: ORV operations by commercial fishermen will be addressed in the Commercial Fishing CFR (CFR 7.58) and any associated permits.

II. VEHICLE CHARACTERISTICS

PURPOSE: Manage and regulate the type of vehicle allowed to drive on CAHA beaches.

SCOPE: Applied for all driving on all routes, trails, and areas designated for ORV driving.

VEHICLE CHARACTERISTICS: All vehicles must exhibit the following characteristics to drive on the Park's beaches. Drivers are responsible for ensuring their vehicles meet these characteristics.

1. All vehicles must be registered, licensed, and insured and comply with inspection

regulations within the state, country or province where the vehicle is registered.
2. Four-wheel drive vehicles are allowed.
3. Two wheel drive vehicles are allowed after the operator obtains a special use permit.
4. Motorcycles are prohibited on the ocean beachfront.
5. All-Terrain Vehicles (ATVs) are prohibited. ATVs are defined as a type of off-highway vehicle that travels on three or more low-pressure tires; has handle-bar steering; is less than or equal to 50 inches in width; and has a seat designed to be straddled by the Operator.
6. The Park Superintendent will determine the acceptability of new or state of the art vehicles (those that are not listed in items 2-5) for driving on CAHA as needed, with input from the standing advisory group and/or state law.
7. There is a three axle maximum for vehicles (this is the axle maximum for the powered vehicle only and does not include the additional number of axles on towed trailers).
8. Any trailers are limited to no more than two axles.
9. The maximum vehicle length is thirty (30') feet (this is the maximum length for the powered vehicle and does not include the additional length of a towed trailer).
10. Tires must be U.S. Department of Transportation listed and/or approved tires only.

III. REQUIRED AND RECOMMENDED EQUIPMENT

PURPOSE: To identify special equipment required and recommended to safely operate a vehicle on the beach

REQUIRED EQUIPMENT: All vehicles operated on the beach shall contain the following required equipment.
1. A low-pressure tire gauge effective down to 5 psi.
2. A shovel
3. A jack
4. A jack support
5. Trash bag or container
6. A flashlight
7. Copy of the current ORV regulations and map.

HIGHLY RECOMMENDED EQUIPMENT: The following equipment is recommended but not required.
1. A full size spare tire
2. First aid kit
3. Fire extinguisher
4. Tow strap with loop ends, no hooks, with a rating capacity at or above the GVW of item being recovered or moved unless vehicle is equipped with an operable electric or hand winch

IV. VEHICLE OPERATIONS

PURPOSE: Ensuring the safety of all public users of the Park and protection of Park resources.

SCOPE: Applied for all driving on all routes, trails, and areas designated for ORV driving.

DRIVER'S LICENSE: All drivers must carry a valid driver's license.

SPEED LIMITS: The speed limit on CAHA beaches is 15 mph year-round, unless otherwise posted.

TIRE PRESSURE: When driving on designated routes, tire pressure must be lowered sufficiently to maintain adequate traction within the posted speed limit. Twenty (20) psi is recommended for most vehicles. The softer the sand, the lower the pressure needed. When you return to paved roads, inflate the tires to normal as soon as possible.

RIGHT OF WAY: Right of way shall be as follows:

1. A vehicle exiting the beach via a Ramp or Interdunal Road has the right of way until reaching state-regulated roads.
2. When traveling parallel to the ocean or sound, the vehicle with the water to its right side has the right of way.
3. Vehicles must yield to pedestrians on beaches and ramps.

SELF-CONTAINED VEHICLE CAMPING: Self contained vehicle camping is allowed in CAHA and will be managed under a special use permit system. The special use permit will be an addition to any other broad beach access permit or pass system required.

The special use permit will include a fee whose price will be determined under NPS rules, regulations, and policies regarding a value of service determination.

Self-contained vehicle camping is limited to designated areas in the beach environment only. At all designated times there will be at least one designated area on each of the three islands (Bodie, Hatteras & Ocracoke) contained within CAHA. These areas include Oregon Inlet Campground, Cape Point Campground, and Ocracoke Campground.

For the purpose of this CAHA-specific regulation, a self-contained vehicle camper is defined as follows:

- Self-contained vehicle campers must meet the ORV characteristics and requirements.
- Self-contained vehicles must be 4WD only. 2WD campers are prohibited.
- Self-contained vehicles are limited to a maximum length of thirty feet (30') including

front racks and rear decks.
- Self-contained vehicles must have a self-contained water or chemical toilet and a separate permanently installed holding tank for both black and grey water, each with a minimum capacity of 3 days waste.
- Tents and camping trailers are prohibited.

There will be no limit to the total number of available self-contained vehicle permits.

The number of self-contained vehicle campers allowed to camp in CAHA at any one time will be limited by the space available in the designated self-contained vehicle camping areas. The camping space limits are as follows:

- Oregon Inlet Campground: not more than100 spaces
- Cape Point Campground: not more than 100 spaces
- Ocracoke Campground: not more than 50 spaces

Other than the parking space for self-contained vehicles, the NPS will provide no additional services other than garbage and septage dumping services. The experience is intended to be a primitive, beach camping experience within appropriate self-contained vehicles. When possible, the only access to the camping will be via a four-wheel drive only path or road (i.e., access to Cape Point Campground only via the interdunal road).

Self-contained camping will be allowed from November 1 until March 31.

Self-contained camping permits will be offered either weekly or annually.

There will be a self-contained camping limit of no more than seven consecutive days/six nights) in any one visit.

There will be a self-contained camping limit of no more than one visit per month.

All self-contained beach camping spaces are available on a first-come, first-served basis.

All self-contained vehicles arriving for an overnight stay must check in/register via a system to be determined before entering the self-contained camping area. An overnight authorization must be displayed at all times the vehicle is in the designated self-contained camping area.

Self-contained vehicles MUST exit the self-contained camping area after no longer than 72 consecutive hours in order to empty holding tanks and gray water at an established septage dumping facility.

Any permittee who violates the terms and conditions of the self-contained vehicle (SCV) permit is subject to being cited for the violation, will have his/her SCV permit revoked, and may be denied from obtaining any ORV related permit at CAHA for a period of at least one year.

Generally, the NPS will work to discourage illegal camping on any and all NPS properties via signage, education, information, and/or other appropriate and effective means

OTHER RELEVANT REGULATIONS: Other pertinent and relevant federal or state regulations include:

- Camping is only allowed at designated areas. (36 CFR 2.10)
- Obstructing traffic on park roads is prohibited. (36 CFR 4.13)
- Driving under the influence of alcohol or drugs is prohibited. (36 CFR
- 4.23)
- All drivers and passengers are required to wear seatbelts. (36 CFR 4.15)
- A valid state driver's license is required for all operators of motor vehicles on park roads. (36 CFR 4.2)
- Operating a motor vehicle without due care or at a speed greater than which is reasonable and prudent considering wildlife, traffic, weather, road and light conditions and road character is prohibited. (36 CFR 4.22)
- Operators of motor vehicles involved in accidents resulting in property damage, personal injury, or death shall immediately report the accident to park rangers. (36 CFR 4.4)
- The operators of authorized emergency vehicles, when responding to an emergency or when pursuing or apprehending an actual or suspected violator of the law may disregard traffic control divides, exceed the speed limit, and obstrSuct traffic. (36 CFR 4.3)

SUBCOMMITTEE DOCUMENT
Draft 12/1/08

PERMIT/PASS/FEE CONCEPTUAL FRAMEWORK

Conceptual Approach

The Cape Hatteras National Seashore (CAHA) Beach Permit/Pass system will be established under the following principles:

- Share responsibility across users for natural resource protection;

Equitable and reasonable fees across motor vehicles users who access the beach via the vehicle via driving and/or parking;

- Multi-point, broad, effective education;
- Equitable and easy access to the system;
- A tailored solution to CAHA meeting all legal requirements.

The goals of the CAHA Beach Permit/Pass system will be to:

- Encourage and support appropriate beach behavior;
- Provide education to as many users of the beach as possible;
- Collect fees for compliance and enforcement, operations, maintenance and improvements, related to ORV and pedestrian use of beaches and associated facilities;
- Provide an enforcement mechanism for individual acts and behavior that threatens people, resources, and general enjoyment of the beach by all.

Summary

Any vehicle utilized for beach access via a National Park Service parking lot or ramp shall be required to have a permit/pass.

Key Characteristics

Permits/passes would be available on a *daily, weekly or annual* basis. There would be no numerical limit on the number of permits/passes issued.

OPTION #1: The intent is to permit/pass those *individuals* with a valid drivers license and vehicle registration who access the beach via federal parking lots and/or ramps. The permit/pass will be issued to individuals because the purpose of the system is to encourage education and appropriate action and behavior. The point of control will be the vehicle (the permit/pass will be displayed on or in the vehicle).

OPTION #2: The intent is to permit/pass all adults ("individuals"), on behalf of themselves and their minor children, if any, only when such individuals access the beach (1) via federal developed parking lots; and/or (2) via ramps for the purpose of driving onto the beach. The permit/pass will be issued to individuals because the purpose of the system is to encourage education and appropriate action and behavior. Each individual will be required to obtain a permit/pass. Individuals on the beach need not carry the permit on their person, however they must have easy and quick access to their permit within their personal belongings located on the beach. For example, users entering the beach on foot after parking in a developed parking lot must leave the permit/pass page marked "vehicle" clearly displayed on or near the dashboard of the parked vehicle and must carry the permit/pass page marked "individual" amongst or within their personal belongings on the beach. Users that are, or have, operated the off-road vehicle onto the beach must leave the permit/pass page marked "vehicle" clearly displayed on or near the dashboard of the off-road vehicle. Users entering onto the beach via an off-road vehicle must carry the permit/pass page marked "individual" amongst or within their personal belongings on the beach. [NOTE: consider language on the circumstances under which law enforcement may check for a permit on a person; as a first offense, only with probable cause, etc.]. Permits/passes for vehicles and individuals are obtained as a part of a multiple page printout via the Internet or as part of a multiple part system obtained at NPS distribution stations, as discussed below.

For vehicles driving onto the beach, they will be required to carry the *required minimum equipment* detailed elsewhere.

There will be a *fee* charged for the permit/pass, differentiated only by day, week, or annual pass. No fee differentiation will be made for the purposes of whether the vehicle is used for parking and walking to and/or driving on the beach. The fee will be set to ensure reasonable access for both residents and non-residents and across diverse socio-economic users.

Permits/passes would be *available* via the Internet . They would also be available in-person at a limited number of NPS distribution stations that could be established at various locations throughout the Outer Banks. Local in-person NPS distribution locations could include: the Whalebone Junction Welcome Center, NPS Buxton Ranger Station or Lighthouse Visitor Center, and the NPS Ocracoke Ranger Station or Visitor Center. In any case, they should be available in at least one physical location each on Bodie, Hatteras, and Ocracoke Islands.

Permits/passes will be obtained via a "single access portal" so that regardless of whether just parking or parking and driving on the beach, all permittees will be required to read all educational material for the greatest informed beach user as possible. Local governments, welcome centers, and/or interested businesses such as area hotels, bait and tackle shops, outfitters, and tour operators sell permits/passes will be encouraged to sell permits/passes via the internet for members of the public as a convenience to their respective customers. Such non-NPS permit stations are not intended to become vendors by collecting any fees that may be associated with the pass/permit (if any) but rather will solely provide computer and Internet connections for the convenience of the public.

Law enforcement will periodically patrol the beach and beach parking lots to ensure vehicles have the appropriate permit/pass clearly visible and their drivers are acting responsibly. Law enforcement may issue tickets for failure to be authorized, excessive speeding, and so forth.

OPTION #1: The point of control is the vehicle: individuals outside of their vehicle will in no way be required to carry any kind of permit, pass, tag or other indication of authorization.

OPTION #2: The point of control is the vehicle and/or the person.

Law enforcement will retain all other police powers authorizing them to issue tickets, for example, for excessive speeding, failure to have dog on leash, and so forth. Permits/passes for vehicles and individuals are obtained as a part of a multiple page printout via the Internet or as part of a multiple part system distributed at NPS distribution stations. The permit/pass can be revoked for a "major violation" (needs to be defined) and/or a number of "minor " violations. Violations that endanger people or damage wildlife may result in loss of obtaining access, pending approval by the court. A standard system of fines and penalties is approved by the U.S. District Court, announced by NPS, and listed in required educational information.

The Park will keep *accurate records* of the number and types of permits/passes issued each time period, and keep cumulative totals as the year progresses, by week, month, season, and annually. NPS will retain basic, appropriate registration data on each individual when they apply the first time, and annually add any record of violations.

The park should prepare and distribute an *annual report* to document the number and type(s) of permits/passes issued, the amount of fee revenue received, a summary of how the fee revenue was expended, any significant issues or changes that were implemented in the program, and the number and types of violations committed by (or the number of violation notices issued to) both permitted and unpermitted beach users.

Education

Education and awareness is key to protecting beach resources. Therefore, the following reinforcing and multiple actions are necessary to ensure the greatest number of educated beach users as possible.

- Education is required in order to obtain a beach driving/parking permit/pass. The applicant is required to read information and/or watch an educational video that provides education on park regulations, natural resource protection, vehicle characteristics, vehicle operation and instruction on how to access information on the current status of beach access. The applicant is required to sign the brochure or a form noting they had watched the video. The brochure shall include the terms and conditions of the permit/pass. It is expected that the driver/permittee will both educate passengers with the appropriate information who access the beach via the permittee's vehicle as well will be responsible, to the extent possible, with the behavior of their passengers while on the beach.

- There will be a more general, expansive, and effective education and outreach program through the printing/form of the permit itself, the web, brochures, signs, NPS staff, and other means, to ensure the highest percentage of educated beach users as possible. Tailored education for Cape Hatteras National Seashore may be developed in partnership with such groups as Tread Lightly and Leave No Trace.
- All education will include significant information focused on natural resource protection/mitigation.
- Educational materials will make clear that the Superintendent shall have authority to close ad hoc any part of the beach for safety, resource purposes (chiefly birds, turtles, and certain endangered grasses), and when conditions of crowding or undue stress on the resource show that reasonable limits have been reached.

What is not Intended

This Park/Pass system is not intended to:

- Be a general entrance permit/pass for the Park as a whole.
- Require a permit/pass for each individual enjoying the beach via driving, walking, or other means.
- Require all legal parking to be solely on federally-developed parking lots [that are in compliance with FLREA?]
- Include additional special park uses or additional activities that otherwise require an additional or separate special use permit and/or fees (i.e., beach weddings, self-contained vehicle camping, etc.)

Legal Authorities

The following are statutes and policies that may apply to the permit/pass system put in place.

The special use permit is authorized and guided by:

- 16 USC 3a - (PL 103-1138, Title I, November 11, 1993, 107 Stat. 1387)
- *NPS Management Policies 2006* Section 8.6

The entrance pass is authorized and guided by:

- Federal Lands Recreation Enhancement Act (FLREA) – (16 USC 6801-6814; PL108-447, Division J, Title VIII)

- *NPS Management Policies 2006* § 8.2.6
- NPS Director's Order 22 (DO-22) and Reference Manual 22 (RM-22): Recreation Fees

Implementation

There are three potential mechanisms for implementing the above system as described. Given the complexities of federal regulations, policies, and guidance, the subcommittee has explored all three. These three mechanisms evaluated are outlined below. A single special use permit system is preferred by the subcommittee and the supported heartily by the [sub?]committee as a whole.

- A special use permit
  - This system implements a requirement for all beach users to obtain a special use permit however such permit does not equate to a pass for the general public. Each user to the beach at this particular unit within the National Park Service system places a unique and special demand upon resources within the unit. Each user, by the very nature of their activity(ies), is a special class of use with the need of an activity to be regulated, including but not limited to the class of kite flyers, swimmers, beach sport users, fishermen, bird watchers, and use for spiritual practices or enjoyment.
- A "combined" system that includes:
  - A special use permit for off-road vehicle driving; and
    - Those visitors using an off-road vehicle on the beaches of the unit would be required to obtain a special use permit prior to driving on the beach.
  - An entrance pass implemented at parking facilities for pedestrian access to the beach.
    - Those visitors utilizing a developed NPS-managed parking facility for the purpose of beach access would be required to obtain an entrance pass prior to utilizing said parking facility.
- An entrance pass
  - This system implements a requirement for every visitor to the unit to obtain an entrance pass.

A *special use permit* for beach users of NPS ramps and beach access parking lots would be preferred because: 1) it would be one kind of permit tailored under special use permit authority to the unique needs of Cape Hatteras National Seashore; 2) allow the Park to retain 100% of the revenue to enhance and support the principles and goals of the system. Such a special use permit is justified because: 1) the beach, as opposed to the Park as a whole, requires special on-going management in terms of public safety and natural resource protection; 2) the beach requires special facilities for use including ramps, boardwalks, restrooms, and so forth; 3) education is essential for on-going natural resource protection; 4) the majority of users of the beach fall into a class of special uses putting unique and identifiable demands upon resources distinguishable from the general public.

A *combined system* would include a special use permit for beach drivers and an entrance pass system for beach pedestrians accessing the beach via federal parking facilities. The system would charge the same fee for both the permit and the pass. Since the entrance pass fees are set nationally, they would need to reflect this consistency across NPS units. This bifurcated approach is more awkward and complex to administer than a single special use permit. However, it would ensure beach users accessing the beach via federal property (ramps or lots), have education and shared responsibility for beach and natural resource protection.

An *entrance pass*, obtained via the Internet or in-person, with the point of compliance at federal parking lots, ramps, and the beach (NOT on Highway 12), could provide some of the same benefits as the above approaches. However, such an approach does not have the tailoring possible under special use permits and under current federal law, CAHA can only retain 80% of revenue and the use of that revenue is significantly restricted.

Commercial Fishing

Commercial fishing permittees regulated pursuant to 36 CFR 7.58(b)(2) are not subject to the provisions of this ORV permit regulation during times or periods when beach use occurs while engaged in commercial fishing from seashore beaches.

Draft Subcommittee Document for Discussion Purposes Only
Does not Represent Agreement
Rev. 1/5/09

Reducing or Removing Natural Resource Bird Breeding Closures prior to August 31

Summary

- Natural resource closures for breeding birds within specific areas of the Park can be opened for recreational activities prior to August 31 and as early as 31 July as long as breeding and nesting activities have ended for the season.

Details

- Natural resource closures for bird breeding and nesting protections may be reduced or removed as early as July 31 in the locations designated below where they are already designated as ORV routes and areas.
- Areas designated include Cape Point, Bodie Island Spit, Hatteras Inlet, North Ocracoke, South Ocracoke, and South Beach.
- These designated areas will be periodically reviewed due to the dynamic nature of the beach and the possibility that such areas may increase or decrease in habitat value over time.
- The area shall be open if no breeding activity, unfledged chicks (i.e. definition of fledged chicks as determined by NPS policy), or black skimmer breeding and nesting activity is identified within the previous two weeks. Breeding and nesting activity is further defined in the NPS alternatives Resource Tables.
- Monitoring shall occur daily for the seven (7) days prior to reducing or removing closures to detect the presence of unfledged chicks or other nesting activity.
- Interior areas suitable for breeding and nesting habitat may remain closed until August 31 (i.e, part of the route or area will be open, but not necessarily the full extent of that route or area).
- Surveys for seabeach amaranth from the high tide line to the toe of the dune must be conducted prior to reopening these areas to ORV use. A general Park-wide seabeach amaranth survey may also be conducted at a later date.
- Migratory bird foraging, resting, and roosting closures will be addressed as a related but separate document (i.e., some geographic areas and dates may overlap).

Draft Document for Discussion Purposes Only
Does not Represent Agreement

Adaptive Management Proposal for Night Access during Sea Turtle Nesting and Hatchling Season

Acknowledgement

Numerous factors may affect sea turtles, turtle behavior, and turtle habitat including natural factors (ocean water quality, water temperature, storm events, predators, etc.), general human activity on beaches, artificial lighting (stationary in particular), and ORVs. Though the scope and focus of this plan is ORV management, this is not to imply numerous other management actions are not necessary and important to maintain and improve turtle populations on CAHA.

General Goals of Night Driving, Seasonal Restrictions, and Turtle Management

- Protect the sea turtles and contribute to the recovery of the species. More specific goals include:
  - Reduce the potential for false crawls due to night activity on the beach;
  - Reduce the potential for female turtles not emerging onto the beach due to night activity on the beach;
  - Reduce the potential for hatchling disorientation, when attempting to return to the sea, due to night activity on the beach;
  - Reduce potential direct impact to hatchlings seeking to reach the ocean, especially those hatchlings emerging from undiscovered/unmarked nests.
- Protect the opportunity for access.

General Concepts

This overall plan includes robust education, a permit system, a related but separate predator control plan, NPS facility lighting controls, and a related but separate effort to reduce and manage lights from villages adjacent to the Seashore. Specific measures are as follows.

- In general, night driving would be prohibited from 22 May, until 14 September, from 1 hour after sunset until 30 minutes after sunrise, unless otherwise noted below.
- Night driving on specific designated routes to spits and points that are not otherwise closed due to bird breeding activity would occur with nighttime restrictions from 1 May to 21 May, with sufficient NPS monitoring.
- Specifically, in four areas of the Park (Bodie Island Spit, Cape Point, Hatteras Spit and South Point Ocracoke), limited access for appropriate nighttime parking and appropriate stationary recreational activity, with significant restrictions, would be permitted from 21 May until 14 September provided those areas are not otherwise closed due to bird breeding activity. At the designated location(s), drivers would have to park and stay parked at night, with lighting restrictions, fishing or other appropriate recreation (i.e., stargazing), and remain stationary until the area reopens to ORV access in the morning.

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- From 15 September until 14 November night driving on all routes and areas (not otherwise subject to bird closures) would occur with nighttime restrictions with appropriate NPS monitoring. Geographic ORV access openings would be dictated by the location of turtle nests and at the discretion of the NPS.
- Night driving on all routes and areas would occur without any nighttime restrictions from November 15 until April 30.

Monitoring

- Daily sea turtle patrols begin on May 1, unless leatherback nests have been reported within the state, in which case CAHA will follow the direction of NCWRC. Patrol will continue until September 15, or two weeks after the last sea turtle nest or crawl is found, whichever is later.
- Conduct daily morning surveys by ATV/UTVs and possibly ORVs for crawls and nests on all beaches before onset of heavy public ORV use. Daily surveys for nests end September 15, or two weeks after the last sea turtle nest or crawl was found, whichever is later. Periodic monitoring (e.g., every two to three days) for unknown nesting and emerging hatchlings will continue, especially in areas of high visitation from that date until November 15.
- Monitoring will also occur for post-hatchling washbacks during periods when there are large quantities of seaweed washed ashore or following severe storm events. Nest observations stop when all nests have hatched or excavation indicates that the nest was not viable.
- At approximately 50-55 days into incubation, NPS will expand the closure around a nest to the surf line, establish the filter fencing, and monitor the nest daily for signs of hatchling emergence.
- More intensive night monitoring focused on the appropriate turtle will occur from 1 May until 21 May (nesting) and again from 15 September until 15 November (hatching).

Management

- In general, NPS will follow the guidance found in the NCWRC Handbook for Sea Turtle Volunteers.
- November 16 - April 30: Designated ORV routes and areas are open to ORV use 24 hours a day subject to other natural resource and sea beach amaranth closures.
- May 1 – September 15: The general (parkwide) approach to sea turtle management during these dates includes the following:
  - All potential sea turtle nesting habitat (ocean intertidal zone, ocean backshore, and dunes) will be closed to non-essential ORV use from 1 hour after sunset until the beach is cleared by the turtle patrol, which shall be ½ hour after sunrise.

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- Areas of beach shall be cleared by turtle patrol prior to allowing ORV morning access. NPS shall provide sufficient personnel to meet the ½ hour after sunrise standard.
- Early morning monitoring will be done in the most effective and efficient fashion possible. This may include: an initial sweep for marking of new nests and false crawls followed by a second sweep for detailed fencing, more permanent protections, etc.; beginning patrols at first twilight on the beach; and so forth.
- The turtle patrols will prioritize for first patrols those areas that are currently open to ORV access, and as necessary, further prioritize those open areas within the spits and points.
- Signaling of some kind should be established at ORV access ramps to indicate if the beach is closed. This may be signage, traffic-light lights, or so forth.
- The Park shall seek, in partnership with the NCWC, Dare County, and a volunteers program to provide for at least 8 separate turtle patrols per day during the turtle-nesting season.
- The Park shall provide for sufficient and necessary enforcement to ensure the beach is cleared at night by the night closure time, and that any violators are found and receive appropriate penalties.
- Resource Protection Tables, dated 11/15/08 (see page 9 of Table).
- Nest closures and buffers will be established as described in the CAHA ORV Resource Protection Tables, dated 11/15/08 (see page 9 of Table).
- Pedestrian access to the ocean beaches after dark is allowed at any location(s) adjacent to the villages or established parking, subject to site specific resource closures as needed for bird breeding activity or sea turtle nests.

- <u>Site Specific Management 1 May to 21 May</u>: Designated ORV routes and areas to Bodie Island Spit, Cape Point, Hatteras Inlet and South Point Ocracoke, if not otherwise closed due to bird breeding activity, are open to ORV use in the nighttime with the following additional restrictions within those ORV routes/areas:
  - All ORVs must be permitted for driving.
  - Permits will be accompanied by education about sea turtles, their protection, the rules of night driving, and a phone number to report any specific turtle behavior (nesting, false crawls, etc.).
  - In areas open to night driving, campfires, use of vehicle headlights (other than as below), auxiliary lights, vehicle battery powered spotlights, or lanterns that cast light in a 360 degree direction are prohibited, except as needed in a true emergency situation, from 1 hour after sunset until 6 AM or sunrise, whichever comes first. Intermittent use of lighting (5 minutes or less) is limited to handheld flashlights, headlamps or other battery powered lighting devices that cast a one-directional beam of light.
  - Headlights may only be used when in transit and will be turned off when the vehicle is parked.
  - No flash or fixed light photography is allowed.
  - Drivers and pedestrian should not approach turtles or turtle nests closer than 75 feet.

- Flashlights, headlamps, and other low light sources may be used on an intermittent basis.
- NPS will conduct night monitoring of the specific ORV routes and areas open to night driving, with at least one monitor per ranger district, to identify, record, and monitor nesting females and record false crawls.
- Incentives should be established for beach users to report any turtle activity.

- From 22 May – 14 September, Specific: Limited ORV Access for Appropriate Night Recreation during Turtle Nesting Season (i.e., park and stay). The following areas are designated as open to limited ORV access for appropriate and stationary night recreation from May 22 to September 15, subject to site specific resource closures as needed for bird breeding activity or sea turtle nests; and subject to the terms and conditions of a permit (see next section) and to the overnight vehicle limit indicated in (parentheses):
  - Bodie Island Spit limit – 25 (if not otherwise closed)
  - Cape Point: Vehicle limit – 50 (Access via eastern corridor, if not otherwise closed.)
  - Hatteras Inlet Vehicle limit – 25 (Access via Spur Road, if not otherwise closed.)
  - Ocracoke South Point limit – 25 (Access via designated corridor, if not otherwise closed.)
- The above limits will be established in the Superintendent's Compendium under the authority of 36 CFR § 1.5, subject to periodic review by NPS, and adjusted as appropriate (could be increased if no negative impacts to resources are determined or decreased if needed to protect park resources).
- The above areas will be accessible by ORV only during daylight hours, subject to resource closures for bird breeding activity or turtle nests, and subject to terms and conditions of a special use permit, which include the following:
  - Such vehicles must have a special use permit that is in addition to any standard beach access permit or pass.
  - Appropriate recreation would include fishing, stargazing, or other relatively stationary activities.
  - Permitted vehicles must arrive at the site no later than one hour after sunset and remain parked within the designated area with headlights off until the beach is cleared by turtle patrol, which shall be ½ hour after sunrise.
  - Under rare circumstances, should a "park and stay" permittee need to leave the beach during the night due to a serious emergency, they must make a call to Dare County central dispatch (473-3444) or 911. Dispatch information will be listed on the nightly permit.
  - Parking areas at the respective night access sites will be designated by NPS law enforcement staff and marked with signage (e.g., carsonite or barricades) that will be maintained by the LE staff. Permittees must park their vehicles only in the designated area. Such areas will be contained and shall prevent vehicles from being spread up or down large sections of beach.
  - Pets are prohibited
  - Campfires, use of vehicle headlights, vehicle battery powered spotlights, or lanterns that cast light in a 360 degree direction are prohibited, except as needed in a true

emergency situation. Intermittent use of lighting is limited to handheld flashlights, headlamps or other battery powered lighting devices that cast a one-directional beam of light.

- Special use permits will be issued one night at a time and must be obtained in person at a designated NPS permit issuing station (locations TBD).
- Each vehicle must have a functional portable toilet.
- NPS may impose a limit on the number of nights in a row an individual may obtain a night fishing permit, if it appears that there is routinely more demand for permits than the vehicle limit allows.
- NPS retains the right to not issue night parking permits when weather forecasts dangerous conditions.
- NPS may utilize volunteer park-and-stay site hosts as a management tool to monitor compliance with the permit requirements.

- If a permittee or individual accompanying a permittee violates the terms and conditions of the permit, including any of the above provisions, the violator is subject to a citation and the person's privilege to obtain a night-access permit will be revoked for the remainder of the season. If there are three (3) or more documented violations of these requirements at a particular site within a 30-day period, all night access to that site will be suspended for a 30 day period. If night access is suspended at a location due to repeated violations, NPS will evaluate apparent causes of non-compliance (is it training? signing? something else?) and take proactive steps to address manageable causes prior to reopening. If, in the judgment of NPS, causes of non-compliance cannot be effectively managed, NPS will not reopen an area to night access until all turtle nests in the area have hatched.
- *ADDITIONAL OPTION:* The NPS may provide an escort for a one-time leaving of the park and stay area each night in one or more of the four points and spits' designated areas at midnight. Such an escort would be a one- time action per night, would not involve escorting <u>any</u> vehicles on the beach after night as defined as one hour after sunset, and would follow appropriate procedures to minimize all light, speed, noise and other measures that might adversely influence turtle nesting behavior.

- <u>September 15 – November 14</u>: Based on the location(s) of remaining unhatched sea turtle nests, NPS will designate routes/areas that are reopened to night driving (i.e., night driving will be reopened on routes/areas that do not have unhatched turtle nests). NPS will publish the list of routes/areas open to night driving in the weekly beach access report and will update the list weekly until all turtle nests have hatched. The Park will ensure an appropriate width of filter fencing for managing light and will provide for an appropriate buffer around turtle nests to ensure hatchlings may make their way to the sea, especially after Day 55 of incubation.
    - o All ORVs must be permitted for night driving (either a special use permit or part of the overall general beach use permit/pass).
    - o Permits will be accompanied by education about sea turtles, their protection, the rules of night driving, and a number to report any specific turtle behavior (nesting, false crawls, etc.).

  - In areas open to night driving, campfires, use of vehicle headlights (other than as below), auxiliary lights, vehicle battery powered spotlights, or lanterns that cast light in a 360 degree direction are prohibited, except as needed in a true emergency situation, from 1 hour after sunset until 6:00 AM. Intermittent use of lighting (less than 5 minutes) is limited to handheld flashlights, headlamps or other battery powered lighting devices that cast a one-directional beam of light.
  - Headlights may only be used when in transit and will be turned off when the vehicle is parked.
  - No flash or fixed light photography is allowed.
  - Drivers and pedestrian should not approach turtles or turtle nests closer than 75 feet.
  - Flashlights, headlamps, and other low light sources may be used on an intermittent basis.
- As of September 16 if unhatched sea turtle nests remain that block night access to Bodie Island Spit, Cape Point, Hatteras Spit or South Point Ocracoke, NPS may continue to utilize the ORV limited night access special use permit for night procedures described above to allow night access to those locations until all such turtle nests have hatched.
- NPS will conduct night nest monitoring/watch during expected hatching to ensure the safety of hatchlings in any areas open to ORV use with turtle nests present. The NPS will work to establish a nest watch program with volunteers under appropriate supervision.
- Resources Management staff will examine all sea turtle nests after hatching to determine productivity rates. Excavate nests in the evening a minimum of 72 hours after hatching event. In cases where hatching events or dates were unknown, unearth nest cavities 80–90 days after the lay date, or later if eggs are still viable. Any live hatchlings found during excavations will be released at dusk or after dark on the same day as excavation. Provided no other unhatched nests remain in the area, areas will reopen to nighttime driving in accordance with what is published in the weekly beach access report.
- The Superintendent retains the authority under 36 CFR § 1.5 (a) to close all or a portion of a park area to all public use or to a specific use or activity, as needed to protect park resources.

Education and Outreach

The NPS will develop an appropriate, robust and effective turtle education and outreach program to help inform all beach users, regardless of the means they use to access the beach, regarding turtle species, their behavior, and all appropriate human behavior to ensure the success of nesting and hatching of turtles on Cape Hatteras National Seashore.

Research and Knowledge Base

The NPS will commit sufficient resources to the monitoring, science and adaptive management approach to build a detailed, thorough knowledge of turtle management on Cape Hatteras National Seashore and to share that knowledge with others within the state, other Parks, and up and down the Atlantic Seashore.

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Volunteer Program

The NPS will develop an appropriate and effective volunteer program to increase its access to resources, to inform and educate interested members of the public, and to help advance the recovery of turtle species. To the greatest extent possible, the NPS will also partner with such state agencies as the North Carolina Wildlife Resources Commission (NCWRC) to maximize resources and abilities to achieve the goals noted above. Volunteers may assist with turtle patrols and may also serve as nest watchers during hatching.

Stationary Lighting within the Control of the NPS

The NPS will work with FWS, the NCWRC, and appropriate others to develop turtle-friendly lighting at all NPS facilities that might affect lighting on or near the beach, as well as require all concessionaires with potential impact to utilize the same lighting through their special use permits.

Village Lighting

In addition, the NPS, with technical assistance from the FWS and the NCWRC, will work with Dare and Hyde Counties, and the villages to develop a lighting ordinance to promote and encourage the installation of turtle-friendly lighting. The ordinance might include requirements for new construction, timelines for retrofits or renovations, grants, technical assistance, and other means to achieve the end goal. Other efforts might include homeowner education, homeowner stickers or emblems designating “turtle friendly households,” reminder light switches, and other outreach efforts to ensure broad education and participation in lighting reduction efforts.

Predator Control

Under a separate process, NPS will develop and implement a predator control plan for predators of turtles, particularly hatchlings, in order to reduce harm and death to hatchlings.

Adaptive Management

Caveat: **This section needs to be reviewed by someone with expertise in adaptive management methodology in order to confirm or improve the technical sufficiency of the following proposal. The information that is collected by the Resources Management staff is anecdotal in nature. It can reasonably be used to inform management decisions or to support the need for additional formal research studies. The anecdotal information alone should not be used as the**

sole basis for making significant changes in management practices. Any significant changes in management should include consultation with recognized experts in the field.

Objective: To determine the effect of management on nesting rate, hatching success, sea-finding by hatchlings (prevalence of misorientation/disorientation and trapping by obstacles), and proportion of false crawls.

Proposal: Identify the "management category" of each ocean beach segment as one of the following:

1. ORV areas (ORV/pedestrian segments, open to ORV use during daylight hours)
2. Non-ORV areas (pedestrian only segments)
3. Resource Areas that are closed from (date) to (date) to all ORV and pedestrian use (control segments)
4. Other resource closures (i.e., a category # 1 or # 2 segment that is closed during the season for resource protection and then it become a category # 3 segment at that time)

Monitor and Document the following information:

1. Turtle species
2. Nest vs. false crawl
3. Dates and times of activities (nest, false crawls, hatching)
4. Location (physical description and GPS location)
5. Management category (ORV, Non-ORV, Resource Area, other Resource Closures, or Experimental) of the nest site at the time it was laid
6. If nest needs to be relocated and, if so, why and where (new physical description and GPS location), number of eggs relocated, and time of day
7. Necessary protective measures for nest and hatchlings
8. Information regarding any resource closure violations, predation, hatchling misorientation, trapping by obstacles, or possible "take" incidents
9. Information regarding any post hatching nest excavation and analysis
10. Visitor use in terms of number of visitors using the beach from May 1 to November 15, kinds of use, night use, kinds of night activities, and other appropriate socio-economic data.
11. Examine all nests after hatching to determine productivity rates. Excavate nests in the evening a minimum of 72 hours after hatching event. In cases where hatching events or dates were unknown, unearth nest cavities 80–90 days after the lay date, or later if the eggs are still viable (i.e., late season nests). Any live hatchlings found during excavations will be released after dark on the same day as excavation.

Evaluate:

1. Compare the number and proportion of nests, false crawls, hatchling misorientation/disorientation incidents, predation incidents, and hatchling emergence rate that occur in the respective management categories. Document in annual sea turtle report.

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2. Evaluate data over multiple years to help determine management actions chosen in terms of dates, times, and restrictions, to the extent possible, against such criteria as nests, false crawls, and others noted above, generally related to risk management, overall impact, etc.
3. Conduct periodic review and evaluate trends every 5 years and include a summary of that analysis in the annual sea turtle report for the respective year. Review results with USFWS and NCWRC. (Note: Loggerhead and green turtles typically nest every 2-3 years, so this would allow for a minimum of two nesting cycles to be considered.)

Adapt:

1. If a significant effect of recreation at a particular site is found, recreational restrictions can be varied systematically to distinguish the effects of type and level of activity. This might include changing dates, times, and locations. On the other hand, if no effect is detected, then the next round of experiments could entail allowing similar night access to other selected sites. Any change in management would require consultation with USFWS and NCWRC, prior to implementation.

Further Studies to Consider:

1. Design a systematic research study to monitor and determine the effects of night access on sea turtle nesting

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Nat Res Subcommittee Document w/Track Changes ~~v01/19/09~~

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Survey Time and Frequency	Piping Plover	American Oystercatcher	Colonial Waterbirds
All Bird Species	**Species Management 1 (SM1): Will use larger, longer lasting buffers with less monitoring to alleviate the need for constant monitoring and frequent fencing changes. Will be used at locations which would likely be closed anyway if SM2 buffers were used. Estimated staffing requirements TBD by NPS.** **Species Management 2 (SM2): Will use smaller buffers and require more frequent monitoring and fencing changes. Will be used at selected inlets and Cape Point, and, at the discretion of NPS, at other locations in which more labor intensive management would provide access. Estimated staffing requirements TBD by NPS.** **Pass-through Corridors: At a limited number of locations (TBD), a smaller buffer may be used as part of a controlled study with adequate monitoring (daily?) to determine if a smaller buffer for an ORV pass-through corridor is adequate to prevent disturbance.**		
Pre-Nesting Surveys	By March 1, all potential habitats will have been evaluated. PIPL prenesting closures will be recommended based upon that habitat evaluation. Those closures will installed by March 15. March 15 – July 15: Survey prenesting areas at least 3 times per week. Outside of prenesting areas and existing closures, survey suitable habitat 3 times per week; more often if breeding PIPL are observed in the area. Survey for Wilson's plover during piping plover surveys. Prenesting buffers will not be modified in cases where the beach erodes into the buffered habitat.	March 15 – July 15 survey historic breeding areas (last ten years) 2 times per week. If/when AMOY pairs are observed in an area, survey site 3 times per week. As of May 1 turtle staff will observe for AMOYs during daily patrols. Turtle patrol will take over monitoring after July 15th.	April 1 – July 15 survey historic breeding areas (last ten years) 2 times per week. If/when CWB are observed in an area, survey site 3 times per week. As of May 1 turtle staff will observe for CWBs during daily patrols (i.e., survey for CWB while observing for AMOY.) Turtle patrol will take over monitoring after July 15th.
Pre-Nesting Buffers	SM1: Areas designated as SM1 Resource Areas will not allow ORV or pedestrian access during the prenesting period. SM2: Areas designated as SM2 may have a designated ORV and/or pedestrian access corridor, provided prescribed buffers for the respective species are maintained. In areas open to ORV use, delineate the ORV corridor with posts placed up to 100 feet above the high tide line, or as designated in a site specific plan (e.g., Bodie Island Spit, Cape Point, and South Point). During the breeding season, pets are prohibited in pass-through corridors or at the points and spits. As breeding season progresses, SM2 prenesting closures may be modified as needed to maintain adequate buffers around breeding birds of all species.		

	In February or March of each year, NPS natural resource staff will conduct an annual assessment of piping plover breeding habitat to plan pre-nesting closures in recent breeding areas that are adapted to current habitat and physiographic conditions. Recent breeding areas will be closed by posting symbolic fencing by **March 15.** Closures will be removed if no breeding activity is seen in the area by July 15,or 2 weeks after chicks in the area have fledged, whichever comes later.	SM1 and SM2: Prenesting closures will be installed by **March 15** in areas that had nest(s) in the past 3 years, if habitat is still suitable**.** Closures will be removed if no breeding activity is seen in the area by July 15, or 2 weeks after the site is abandoned by AMOY, whichever comes later.	SM1 & SM2: Prenesting closures will be established for CWB by April 1 in areas that had a colony (or colonies) of at least ___ (#) nests in the past 3 years, if habitat is still suitable. Closures will be removed if no breeding activity is seen in the area by July 15, or two weeks after the site has been abandoned by CWB, whichever comes later.
Courtship/Mating Surveys:	If PIPL, AMOY, or CWB are observed exhibiting territorial or courtship behavior in suitable habitat, or if scrapes are observed in the absence of courtship behavior, observe 3 times per week. Survey potential new habitat 2 times per week; increase to 3 times week once birds are observed in the area.		
Courtship/Mating Buffers:	If courtship or copulation is observed outside of existing prenesting closures, establish or expand buffer to ensure 50 m buffer for the observed birds. Buffer will be increased in 50 m increments if disturbance occurs.	SM1: Outside of existing prenesting closures, if one observation of scraping or territorial behavior has been documented or if a scrape is being maintained, a 300 meter buffer will be established around the bird activity. Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Outside of existing prenesting closures, if one observation of scraping or territorial behavior has been documented or if a scrape is being maintained, a 150 meter pedestrian/ORV buffer will be established around the bird activity. If, in the judgment of NPS	SM1: Outside of existing prenesting closures, if one observation of scraping or territorial behavior has been documented or if scrapes are being maintained, a 300 meter buffer will be established around the scrape locations. Closure establishment will be based on the locations of scrapes and not locations for copulation or "fish flashing". Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Outside of existing prenesting closures, if one observation of scraping or territorial behavior has been documented or if scrapes are being maintained, establish a buffer around the scrape location. Buffer will be 100 meters for least terns and 200 meters if the colony contains common terns, gull-billed terns

		Resources Management staff, a pair has abandoned a territory and established a new territory at another location, the buffer may be removed at the abandoned territory.	or black skimmers If, in the judgment of NPS Resources Management staff, a colony has abandoned a territory and established a new territory at another location, the buffer may be removed at the abandoned territory.
Nesting Surveys:	Nesting survey (walk-through to looks for nests) conducted every 3 days.	Nesting survey (walk-through to looks for nests) conducted when observations suggest a nest is present.	Colonies will be surveyed by foot during the "peak" nesting period which is during the last week of May and the first week of June.
Nest Observation:	Observe nests daily from a distance that does not disturb the birds, based on professional judgment. Approach nests once per week to observe and record data. If nest buffer is less than ___ m observe nest at least 1 hour per day to determine if disturbance is occurring.	SM1: Observe nests at least 3 times per week from a distance. For incubating birds that cannot be observed from a distance, check nests on a weekly basis (or as staff is available). SM2: Observe nests daily from a distance that does not disturb the birds, based on professional judgment. For incubating birds that cannot be observed from a distance, check nests every 3 days.	SM1: Observe colonies at least three times per week from a distance. For incubating birds that cannot be observed from a distance, check colonies on a weekly basis. SM2: Observe nests daily from a distance that does not disturb the birds, based on professional judgment. For incubating birds that cannot be observed from a distance, check colonies every three days.
Nesting Buffers:	All species: The park retains the discretion to expand buffers under SM1 and SM2 depending on staffing and bird behavior. In unprotected areas, a closure will be established immediately when a nest with egg(s) is found. When nesting occurs in the immediate vicinity of paved roads, parking lots, campgrounds, buildings and other facilities, NPS retains the discretion to provide resource protection to the maximum extent possible while still allowing those sites to remain operational. Buffers will remain in place for 2 weeks after a nest is lost to determine if pair will re-nest, if no other species nesting in area. After July 15, closures will be removed outside of prenesting closures two weeks after all nesting is complete or all chicks in area have fledged, whichever is later. After August 1 the 2-week removal period will no longer be required for closure removal.		
	SM1 & SM2: Establish 50 m buffer around piping plover nests occurring outside existing closures. If bird leaves nest due to human disturbance, buffer will be increased in 50 m increments until disturbance is abated. If the nest buffer falls within the intertidal zone a	SM1: Use buffer of 300 m. Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Use buffer of 150 m around	SM1: Use buffer of 300 m. Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Use buffer of 100 m for least terns and 200 m if the colony contains common terns, gull-billed

	full-beach closure will result. If buffer is adequate to prevent human disturbance, a designated ORV or pedestrian access corridor can be maintained during incubation. During breeding season, pets are prohibited in pass-through corridors or at the points and spits.	nests occurring outside of existing closures. All: Establish buffer immediately when nest is located. Increase buffer in flexible increments if necessary to prevent human disturbance. If the buffer falls within the intertidal zone a full-beach closure will result. For AMOY nests that occur inside a prenesting closure at one of the points or spits and requires a buffer expansion of the prenesting area, if the nest is lost due to overwash or predation, the buffer expansion shall be removed to the original prenesting closure. During breeding season, pets are prohibited in pass-through corridors or at the points and spits.	terns or black skimmers. All: Establish buffer immediately when nest/colony is located. Increase buffer in flexible increments if necessary to prevent human disturbance. If the buffer falls within the intertidal zone a full-beach closure will result. For a colony that occurs inside a prenesting closure at one of the points or spits and requires buffer expansion of the prenesting area, if the colony is over-washed or predated, the buffer expansion shall be removed to the original prenesting closure. During breeding season, pets are prohibited in pass-through corridors or at the points and spits.
Pass-through Corridors during Courtship/Mating and Incubation	n/a	At a limited number of locations (TBD), a smaller buffer (less than 150 m) may be used as part of a controlled study with adequate monitoring (daily?) to determine if a smaller buffer for an ORV pass-through corridor is adequate to prevent disturbance.	At a limited number of locations (TBD), for the respective CWB species, a smaller buffer (100 m for LETE; 200 m when other species present) may be used as part of a controlled study with adequate monitoring (daily?) to determine if a smaller buffer for an ORV pass-through corridor is adequate to prevent disturbance.
Adult Foraging Surveys & Buffer:	Survey suitable piping plover breeding habitat 3 times per week to monitor for breeding adults (with an associated scrape or nest territory) foraging outside of an existing closure. If observe foraging outside of existing closure, survey site daily. If observe foraging outside of buffer on two consecutive surveys, establish or expand the buffer using flexible increments based on	No additional buffers/closures.	No additional buffers/closures.

	observed bird behavior to include foraging site if the foraging area is associated with a prenesting closure. These closures are intended to provide foraging opportunities close to breeding sites. Remove closure if no foraging observed for a 2-week period during the breeding season, or when associated breeding activity has concluded.		
Unfledged Chicks Surveys:	SM1: Observe brood once daily. SM2: Observe brood at least 1 hour each in am and pm daily. Have monitor(s) present during periods of ORV or pedestrian access. Observations end once chicks have fledged. Chicks are considered fledged at 35 days or are observed in sustained flight of >15 m.	SM1: Observe brood at a minimum every other day. SM2: Observe brood once daily. Observations end once the chicks have fledged. Chicks are considered fledged if they have been observed to be proficient in flying or observed in sustained flight of >30 m.	Colonies will be surveyed by foot during the "peak" hatching period which should fall 21 days after initial nest counts. A follow-up survey by foot should be conducted during the "peak" fledge which should fall 20 days after hatch counts. SM1: Observe colony weekly. SM2: Observe colony at two-three day intervals; or daily if shoreline is open to ORV use. Observations end after no unfledged chicks have been observed on two consecutive occasions. Closure can be removed after all chicks have fledged.
Unfledged Chick Buffers:	SM1: Establish a minimum 1000 meter buffer on either side of brood based on observation of bird behavior and terrain conditions at site. No ORV or pedestrian access until all chicks have fledged. SM2: For the first 2 weeks after hatching, establish a 1000 m buffer for ORVs and pedestrians on either side of the brood. Based on mobility of the brood, at the discretion of park management, the buffer can be reduced after the first two	SM1: Establish a 300 meter buffer when unfledged chicks are present. Include foraging and roosting habitat from the ocean intertidal zone to the dune (or sound shoreline, if applicable), if accessible. Closure would be removed 2 weeks after fledging. Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Establish a 200 meter buffer	SM1: Use 300 m buffer. If chicks move outside of the buffer, it will be adjusted to include an additional 200 meters from the chick(s) location outside of the closure. Consider using SM2 buffer and survey frequency at sites in which the smaller buffer would still allow access. SM2: Establish a 200 meter buffer around the chick(s) location. Adjust buffer as needed when chicks are mobile. Monitor daily if shoreline in front of colony open to ORV use.

	weeks to 500 m for ORVs and 200 m for pedestrians. (If ORV buffer is less than 500 m, then constant monitoring is required.) Points and spits would only be accessible from 7 a.m. to 7 p.m. as long as unfledged PIPL chicks are in the area and only if prescribed buffers can be maintained. The 7 a.m. opening may be delayed until the chicks have been located. If chicks are highly mobile, the 1000 m buffer may need to be maintained. Buffer moves with chicks. Vehicles may be allowed to pass through portions of the protected area that are considered inaccessible to PIPL chicks because of steep topography, dense vegetation, or other naturally occurring obstacles.	around the unfledged chick(s) location. Include foraging and roosting habitat from the ocean intertidal zone to the dune (or sound shoreline), if accessible. Adjust/increase buffer as needed when chicks are mobile. ORV access would not be allowed until 2 weeks after AMOY chicks have fledged (observed flight of 30 meters); a pedestrian corridor may be established prior to 2 week requirement for access to the points and spits.	
	Reopen access corridor outside of prenesting area after chicks fledge (except for AMOYs where the area will remain closed to ORVs for an additional 2 weeks). During breeding season, pets are prohibited in pass-through corridors or at the points and spits. Remove prenesting closure 2 weeks after all chicks in the area have fledged.		
Non-breeding / Wintering Survey	NPS will monitor presence, abundance and behavior of migrating and wintering PIPL, AMOY, WIPL, and REKN 3 times per month at the points and spits July 1 through May 31 following the existing NPS winter monitoring protocol. In addition, the International Shorebird Survey (ISS) protocol will be used to document other migrating/wintering species.		
Non-breeding / Wintering Areas	An annual migrating/wintering habitat assessment will be conducted of the points and spits by NPS after all chicks have fledged in the area. Migrating/wintering resource closures will be established at designated points and spits in conjunction with the removal of prenesting closures at the respective sites, and will be based on habitat used by migrating/wintering PIPLs in the past 3 years, the presence of birds at the beginning of the migratory season, and suitable habitat types based on the results of the annual survey. Access to inlet shoreline will be maintained via a corridor TBD by NPS Resources Management staff based on an annual habitat assessment. To benefit all species of migrating shorebirds, at other locations (TBD), designated non-ORV areas (open to pedestrians) will also provide relatively less disturbed foraging areas for migrating/wintering birds. Actual locations of suitable foraging and resting habitat may change periodically due to natural processes.		

Data Collected	Collect data as recommended by USGS (*list*) and use GPS to document nest locations. Record locations where territorial/ courtship behavior occurs, including scrape locations. Estimate where adult and chick foraging occurs. Chicks should never be disturbed to obtain this information. Record presence and abundance of birds. Assess productivity and reasons for nest failure.	Collect data as recommended by USGS (*list*) and use GPS to document nest locations. Record presence and abundance of birds. Assess productivity and reasons for nest failure.	Collect data as recommended by USGS (*list*) and use GPS to document colony locations. Record presence and abundance of birds.
Sea Turtles (a minimum of 7 field personnel is required to meet the daily monitoring requirements on the Park's 67 miles of shoreline)			
Survey Time and Frequency	Sea turtle patrol will begin on May 1, unless leatherback nests have been reported within the state, in which case CAHA will follow the direction of NCWRC. Patrol will continue until September 15, or two weeks after the last sea turtle nest or crawl is found, whichever is later. Conduct daily morning surveys by ATV/UTVs and possibly ORVs for crawls and nests on all beaches before onset of heavy public ORV use. Daily surveys for nests end September 15, or two weeks after the last sea turtle nest or crawl was found, whichever is later. Periodic monitoring (e.g., every two to three days) for unknown nesting and emerging hatchlings will continue, especially in areas of high visitation from that date until November 15. Monitoring will also occur for post-hatchling washbacks during periods when there are large quantities of seaweed washed ashore or following severe storm events. Nest observations stop when all nests have hatched or excavation indicates that the nest was not viable. Once a light filter fence is installed, monitor nests daily for signs of hatchling emergence.		
Data Collected	Follow the North Carolina Wildlife Resources Commission Handbook and record: -Turtle species -Nest vs. false crawl -Location (physical description and GPS location) -If nest needs to be relocated and, if so, why and where (new physical description and GPS location), number of eggs relocated, and time of day -Necessary protective measures for nest and hatchlings -Information regarding any post hatching nest excavation and analysis Examine all nests after hatching to determine productivity rates. Excavate nests in the evening a minimum of 72 hours after hatching event. In cases where hatching events or dates were unknown, unearth nest cavities 80–90 days after the lay date. Any live		

	hatchlings found during excavations will be released after dark on the same day as excavation. For strandings the following will be recorded: species, location, measurements, and signs of human interactions. Samples and photos will be collected when necessary. Necropsies will be conducted when possible.
Nest Closures/ Buffers	Establish a buffer approximately 10 meters by 10 meters with symbolic fencing and signage around nest. Closure size may be modified due to environmental conditions at the nest site. Approximately 50– 55 days into incubation, closures expanded to the surf line. The width of the closure based on the type and level of use in the area of the beach where the nest was laid: a. Vehicle-free areas with little or no pedestrian traffic – 25 meters wide (total width); b. Villages or other areas with high levels of day use –50 meters wide (total width); c. Areas with ORV traffic –105 meters wide (total width). Opposite the surf line on the landward side of the closure, expand the closed area to 15 meters where possible, but no less than 10 meters landward from the nest. Traffic detours behind the nest area clearly marked with signs and reflective arrows. Where present within closure, vehicle tracks manually smoothed with rakes or a steel mat attached to an ATV, so as not to impede hatchlings attempting to reach the surf. Use light filtering fence behind nests nearing hatch dates to block light pollution from the villages and vehicles operating on the beach after dark. If multiple nests are located near each other (within 150 feet), and have similar hatch dates (14 days), then closures will encompass all nests in the area, and will not be removed until all nests within the closure have hatched.
Nest Relocation	By April 15th, areas deemed unsuitable for turtle nests (i.e. high erosion rate) will be identified by Park staff. Maps and descriptions of these areas will be analyzed by NCWRC prior to nesting season. When a nest is found, staff assesses need for nest relocation and follows relocation guidance identified in the NCWRC handbook. If it is determined the nest will not be relocated, it will be immediately protected with a symbolic fencing and signs and will measure approximately 10 meters by 10 meters in size. Closure size may vary at the discretion of staff due to the environmental factors at a nest location. If a nest is threatened by an imminent storm event, NPS will consult with NCWRC to determine appropriate action.
Light Management	Establish turtle friendly lighting standards and/or reduce light for all Seashore (NPS) structures. Encourage concessioners to install turtle friendly lighting. Develop educational material to inform visitors about their impact on the success of sea turtle nests.

Research	Support research efforts looking at the sex ratios of sea turtles. Respond to sea turtle strandings in a timely manner, and report all information, pictures, and signs of human interaction to NCWRC. Necropsies of strandings will be done when possible.
Seabeach Amaranth	
Survey Time and Frequency	August An annual survey of potential habitat will be conducted. Some bird closure areas may not be surveyed due to the potential to disturb nesting birds. Some areas may not be surveyed until just prior to re-opening an area to ORV traffic. July– September Before opening any species closure or identifying alternate ORV corridors, survey for seedlings/plants. End observations when all plants have died back.
Data Collected	Record location of all individual plants or plant clusters using a GPS and note if the plant is located in an area open or closed to recreational use.
Buffers	April 15 – November 30 If a plant/seedling is found outside of an existing closure, the Seashore will erect symbolic fencing with signage creating a 10 meter by 10 meter buffer around the plant. If plants are located next to each other, the area will be expanded to create one enclosure protecting several plants. If a SBA is found during the survey prior to reopening a bird closure to ORV and pedestrian use, the Seashore will protect the SBA as described above and reopen the areas of the bird closure where no plants exist. Areas reopened if no plants are present by September 1. Where plants occur, the closed areas will be reopened after the plants have died.

See Shorebird/Waterbird Buffer Summary on next page.

Shorebird / Waterbird Buffer Summary

Species	Breeding Behavior/ Nest Buffer	ORV Pass-through	Unfledged Chicks
	SM1 / SM2	**SM2 only**	**SM1 / SM2**
Piping Plover	50 m / 50 m	50 m	1000 m / 200-1000 m
American Oystercatcher	300 m / 150 m	Use SM1 or SM2 buffer, based on level of monitoring assigned. Conduct study to determine if a smaller SM2 buffer is adequate for ORV pass-through corridor.	300 m / 200 m
Least Terns	300 m / 100 m	Use SM1 or SM2 buffer, based on level of monitoring assigned. Conduct study to determine if a smaller SM2 buffer is adequate for ORV pass-through corridor.	300 m / 200 m
Other Species CWB	300 m / 200 m	Use SM1 or SM2 buffer, based on level of monitoring assigned. Conduct study to determine if a smaller SM2 buffer is adequate for ORV pass-through corridor.	300 m / 200 m

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CAHA ORV Routes & Areas Table (1-22-09) (Sheet 4)				
Oceanside Location	Approx Mileage	Map Color Code	Alternative F	NOTES
ORV Use Areas (YR = ORV permitted Year Round) All areas subject to temporary resource/safety closures				
Bodie Island (approx 6.1 miles)				
Ramp 1 (Town of Nags Head/NPS boundry)	2	red	Closed to ORV	Add 25 parking places @ Ramp 1 & expand parking @ Coquina Beach Ped access
south 2 miles (includes Coquina Beaach)	or less			
Ramps			Move Ramps 2 & 4	Ramp 2 moves So. For ped safety, Ramp 4 moves No.
				due to bridge construction
From 2 miles so of NPS bondry to Ramp 4	1.5	green	ORV Route -YR	
Ramp 4 to "Bait Pond" , (Bodie Island Spit,	2.6	purple	ORV Route -subject to conditional seasonal closures	Open July 15 - March 15
a Traditional & Cultural Recreational Area)				Open (restricted*) March 16 - July 14 *see specific plan for Bodie
				Island Spit access during Breeding season. (**SM2**)
				Establish Ped/ORV access corridor which may include a pass thru
				to Bodie Island spit. Delineate the corridor with posts placed
				150 ft.above the high tide line.
Bodie Island - Soundside Access				
				Add at least 1 soundside access (ORV & Ped combined)
				somewhere between North boundry of CAHA and Oregon Inlet
Pea Island NWR (approx 15 miles)				
Pea Island NWR	15	red	Closed to ORV & Open YR to Pedestrians	PINWR & NCDOT should cooperate to provide roadside & other parking with walkovers
				wherever practicle to provide public with access to beaches.
Hatteras Island (approx 42.6 miles)				
South Boundry PINWR to South boundry	5.3	blue	Open to Ped YR & open to ORV seasonally	season to be determined by Committee
Village of Salvo				(suggested Sept 16 thru May 14 open to ORV)
South boundry Salvo to Ramp 27	4.4	green	ORV Route - YR	Add ramps @ "24" & "26" (Ramp 23 as is)
Ramp 27 to new Ramp "28"	1	red	Closed to ORV	Add new Ramp "28" with Ped facilities & parking
Ramp 28 to North boundry of Avon	5.5	green	ORV Route - YR	Add new Ramp "32" opp Little Kinnekeet Light Station (Ramps 30 & 36 as is).
North boundry Avon to South boundry Avon	3.8	blue	Open to Ped YR & open to ORV seasonally	season to be determined by Committee (Ramp 38 as is).
South boundry Avon to new ramp "39"	2	green	ORV Route - YR	Add new Ramp 39 within 100 ft North of Haulover access road

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Ramp "39" to Buxton North Boundry	**1.7**		Closed to ORV	
North Boundry to South Boundry Buxton	**0.6**		Open to Ped YR & open to ORV seasonally	Add new Ramp "41" @ Coast Guard Station
South Boundry Buxton to 0.7 mile North of	**1**		Closd to ORV	
Ramp 43				
0.7 mile North of Ramp 43 to 44	**1.1**		ORV Route YR	
Ramp 44 to Ramp 45 (Cape Point, a	**2.4**		ORV Route -subject to conditional seasonal closures	Open July 15 - March 15
Traditional & Cultural Recreational Area)				Open (restricted*) March 16 - July 14 *see specific plan for Cape
				Point access during Breeding season. (**SM2**)
				Establish Ped/ORV access corridor which may include a pass thru
				to Cape Point. Delineate the corridor with posts placed up to 150 ft
				above the high tide line.
Ramp 45 to North Boundry Frisco, (South	**4.6**		ORV Route YR	(Ramp 49 as is)
Beach, a Traditional & Cultural Rec Area)				
No. Boundry Frisco to So. Boundry Frisco	**1**		Open to Ped YR & open to ORV seasonally	Add new Ramp "51" @ So. Boundry Frisco
Ramp "51" to Hatteras Village No. Boundry	**2**		Closed to ORV	
No. Boundry Hatteras Vil. to So. Boundry	**1.3**		Open to Ped YR & open to ORV seasonally	
So. Boundry Hatteras Vil. To So. Exit of	**2.2**		ORV Route YR	
Pole Road				
Pole Road aroud Inlet beach to Cable	**2.7**		ORV Route -subject to conditional seasonal closures	Open July 15 - March 15
Crossing				Open (restricted*) March 16 - July 14 *see specific plan for Hatteras
(A Traditional & Cultural Recreational Area)				Inlet access during Breeding season. (**SM2**)
				Establish Ped/ORV access corridor which may include a pass thru
	42.6			to Hatteras Inlet. Delineate the corridor with posts placed 150 ft
				above the high tide line.
Hatteras Island - Soundside Access & Interdunal road				
				All current soundside access routes (including Pole Road, Spur Road, Bone Road,
				Little Kinnakeet & others are to be kept open with reasonable maintainence to allow
				safe,year round, access to both ORV & Ped. Boat launching to be allowed @ Sound
				access # 48 & #58, behind Coastguard station & at Cable Crossing.
				An interdunal road to be created from Ramp 43 to Ramp 49 with
				at least 2 cross overs to oceanfront beach.
Ocracoke Island (approx 19.8 miles)				
Borrow Road to Mid point of Spit	**2**		Closed to ORV	

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Mid Point of Spit to Ramp "59"	**1.2**		ORV Route YR	Relocate Ramp 59 (westerly) and add parking & Ped Access
Ramp "59" to new Ramp "62"	**2.7**		Closed to ORV	Add Ramp "66" with parking & Ped Access
Ramp "62" to 1 mi. No of Poney Pens	**2**		ORV Route YR	
1 Mi. No. Of Poney Pens to I Mi. So. of Poney Pens	**2**		Closed to ORV	
1 Mi. So of Poney Pens to Campground	**1.5**		ORV Route YR	
Campground to Ramp 70	**3.1**		Open to Ped YR & open to ORV when campground is closed	
Ramp 70 to 0.5 mi. So. Of Ramp 72	**2.7**		ORV Route YR	
0.5 mi. So of Ramp 72 around Ock. Inlet	**2.6**		ORV Route -subject to conditional seasonal closures	Open July 15 - March 15
(A traditional & Cultural Recreational Area)				Open (restricted*) March 16 - July 14 *see specific plan for
				Ocracoke Inlet (South Point) access during Breeding season.
	19.8			**SM2**
				Establish Ped/ORV access corridor which may include a pass
				thru to Ocracoke Inlet. Delineate the corridor with posts placed 150 ft
				above the high tide line.
Ocracoke Island - Soundside access & Interdunal roads				
				All current soundside access routes are to be kept open with
				reasonable maintainence to allow safe access to both
				ORV & Ped.
				Reopen soundside access @ So. Boundry of Ocracoke Village
				from Ramp 72 road bed for both ORV & Ped.
				Reopen soundside access from Ramp 72 road bed south of spur
				to Ramp 72 (around SW end of dunes in non breeding season).
Milage Summary (approx)				
Closed to ORV's		14.4 = 21%	+ 15(Pea Island) = 29.4 or 35.2%	
ORV open with seasonal restrictions		10.3 = 15%		
Open YR		28.7 = 41.9%		
Villages (Ped YR & ORV seasonally)		15.1 = 22%		
		68.5	**+ 15 (Pea Island NWR) = 83.5**	

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ORV Management Alternatives Matrix with Alternate F (Presented by ACCESS Group 1/3/09)

Management Activity	Alternative A—No Action, Continuation of Management under IPSMS	Alternative B – No Action, Continuation of Management Under Consent Decree	Alternative C	Alternative D	Alternative E	Alternative F
	General					
ORV Access	Visitors accessing the Seashore by ORV must use only designated beach access ramps and soundside access roads to enter designated ORV routes.	Same as alternative A	Same as alternative A	Same as alternative A	Same as alternative A	Visitors accessing the Seashore by ORV must use only designated beach access ramps and soundside access roads to enter designated ORV routes.
	Oceanside Access					
	ORV access is provided via 18 oceanside ramps and access points located off NC-12.					ORV access is provided via oceanside ramps and access points (18 Min) located off NC-12.
			Oceanside Ramps	**Oceanside Ramps**	**Oceanside Ramps**	**Oceanside Ramps**
	Ramps are numbered and identified on the Seashore's ORV route map as official vehicle access routes.	Same as alternative A	[See ORV Use Areas Table for details.]	[See ORV Use Areas Table for details.]	[See ORV Use Areas Table for details.]	[See ORV Use Areas Table for details.]
	Seashore staff maintains ramps and signage.					Seashore staff maintains ramps and signage.
	Soundside Access		**Soundside Access**	**Soundside Access**	**Soundside Access**	**Soundside Access**
	ORV access is provided via 21 soundside access points located off NC-12.	Same as alternative A	Existing soundside ramps would remain . open	Same as alternative A.	Soundside ramps to designated boat launch areas and Pole Road access to Cable Crossing and Spur Road would remain open. The remaining soundside ramps would be closed to ORV use and small parking areas would be constructed to provide pedestrian access to the water.	Existing soundside ramps would remain . open
	Seashore staff maintains ramps and signage.		Signage/posts would be installed at the primitive parking areas and boat launch areas to prevent damage to vegetation and other soundside resources.			Signage/posts would be installed at the primitive parking areas and boat launch areas to prevent damage to vegetation and other soundside resources.
					Signage/posts would be installed at the parking areas and boat launch areas to prevent damage to vegetation and other soundside resources.	Add 1 soundside ORV access on Bodie Island. Plus all ramps would be constructed/maintained with a clay & shell surface. All ramps would be maintained at 2 lanes wide for the safety of visitors.
	Interdunal Roads		**Interdunal Roads**	**Interdunal Roads**	**Interdunal Roads**	**Interdunal Roads**
	One lane, interdunal routes have been designated as follows:	Same as alternative A	Same as alternative A, plus: Existing interdunal roads would be maintained as needed to provide access to ORV areas. Pull-outs or road widening would be provided where appropriate to provide safe passage.	Same as alternative A	Same as alternative A, plus:	One lane, interdunal routes have been designated as follows: (see Alt A) Plus all ramps would be constructed/maintained with a clay & shell surface. All ramps would be maintained at 2 lanes wide for the safety of visitors.

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	Bodie Island Ranger District				*Bodie Island Ranger District*	*Bodie Island Ranger District*
	None. Same as alternative A	Same as alternative A	Same as alternative A	Same as alternative A	Same as alternative A	To be determined with design/access of
						new ramp 2 & 3. (replacing current ramps 2 & 4)
	Hatteras Island Ranger District					*Hatteras Island Ranger District*
	Cape Point between Ramp 44 to Ramp 45		Same as alternative A, plus		Same as alternative A, plus	Cape Point between Ramp 44 to Ramp 45
		Same as alternative A		Same as alternative A	Extend interdunal road west of Ramp 45	Extend interdunal road west of Ramp 45
	Hatteras Inlet from Ramp 55 to the inlet		Extend interdunal road west of Ramp 45		to Ramp 49. Establish new Ramp 47	to Ramp 49. Establish new Ramp 47
	(includes Pole Road and Spur Road).		to new Ramp 47		off of interdunal road.	off of interdunal road.
						Maintain Pole Road, Bone Road & Spur Road to allow
						for safe 2 way passage.
	Ocracoke Island Ranger District					
	None.	Same as alternative A	Same as alternative A	Same as alternative A	Same as alternative A	All current soundside access routes to be kept open
						with maintainence to allow safe access for ORV & PED
						Reopen soundside access @ So boundry of Village.
						Reopen soundside access from ramp 72 south of spur
						around SW end of dune in non-breeding seasn.
	A	**B**	**C**	**D**	**E**	**F**
Hours of Allowable ORV		November 16 – April 30: All beaches open	November 16 through April 30:	November 16 through April 30:	November 16 - April 30: Designated ORV	November 16 - March 24: Designated ORV
Operation on Beach	All areas of the seashore open 24 hours a	to ORV use 24 hours a day.	Designated ORV routes and areas open to	Designated ORV routes and areas open to	routes and areas open to ORV use 24	routes & areas open to ORV use 24 hours a day.
	day year round.	May 1 – November 15: Beaches open	ORV use 24 hours a day.	ORV use 24 hours a day.	hours a day.	
		from 6:00 a.m. to 10:00 p.m. and closed	May 1 – November 15:	May 1 – November 15: All potential sea	May 1 – September 15: All potential sea	May 25- August 31: All potential sea turtle nesting
		from 10:00 p.m. – 6:00 a.m.; except that	All potential sea turtle nesting habitat	turtle nesting habitat (ocean intertidal	turtle nesting habitat (ocean intertidal	habitat (ocean intertidal zone, ocean backshore
		from September 16 to November 15 ORV	(ocean intertidal zone, ocean backshore,	zone, ocean backshore, and dunes)	zone, ocean backshore, and dunes)	& dunes) closed to non-essential ORV use from
		use is allowed from 10:00 p.m. – 6:00 a.m.	and dunes) closed to non-essential ORV	closed to non-essential ORV use from	closed to non-essential ORV use from	10:00 pm until 6:00 am.
		subject to terms and conditions of a	use from 7:00 p.m. to 7:00 a.m.	7:00 p.m. to 7:00 a.m.	10:00 p.m. until 6:00 a.m.	
		permit.			September 16 – November 15: ORV	September 2 - November 15: ORV route & areas
					routes and areas with no or low density of	with no or low density of remaining turtle nests
					turtle nests remaining (as determined by	(as determined by NPS) open between 10:00 pm
					NPS) open between 10:00 p.m. and 6:00	& 6:00 am subject to terms of free educational permit.
					a.m. subject to terms and conditions of	Stationary vehicles (for nighttime enjoyment) are
					permit.	allowed up to a maximum number to be determined.
	A	**B**	**C**	**D**	**E**	**F**
ORV Routes	Visitors accessing the Seashore by ORV	Same as alternative A.	Same as alternative A.	Same as alternative A.	Same as alternative A.	Visitors accessing the Seashore by ORV
	must drive only on marked ORV routes and					must drive only on marked ORV routes and
	comply with posted restrictions.					comply with posted restrictions.
	The ORV corridor will be marked by posts	Same as alternative A, except:	ORV beach routes would be a designated	Same as alternative C.	September 1 – March 14: ORV beach	ORV beach routes would be a designated
	placed approximately 150 feet landward from	In all locations not in front of the villages	area seaward from the toe of dune or		routes would be a designated area	area seaward from the toe of dune or
	the average, normal high tide line, or if less than	that are open to ORV use, NPS shall	vegetation line to high tide line.		seaward from the toe of dune or	vegetation line to high tide line.
	150 feet of space is available, at the vegetation	provide an ORV-free zone in the ocean			vegetation line to high tide line.	
	or the toe of the remnant dune line; except as	backshore at least 10 m wide, wherever			March 15 – August 31: ORV beach routes	
	noted in the Interim Protected Species	there is sufficient beach width to all an			would be a designated area from 10	
	Management Strategy. The corridor width will	ORV corridor of at least 20 m above the			meters from the toe of the dune to the	
	fluctuate over time due to the dynamic nature of	mean high tide line, from March 15 to			existing tide line in areas open to ORV	
	beach and surf. (Superintendent's Order #7)	November 30.			use. Such backshore closures would be	
					implemented only when there is sufficient	
					beach width to allow an ORV corridor of at	
					least 20 meters above the mean high tide	
					line.	
ORV Use Areas	All areas of the Seashore are open to ORV	Same as alternative A.	ORV access would be prohibited in all	Same as alternative C.	Same as alternative C	ORV access would be prohibited in all
	access.		areas of the Seashore except where			areas of the Seashore except where
			routes and areas are specifically			routes and areas are specifically
	Refer to Use Areas Table.		designated.			designated.
			Refer to Use Areas Table.			Refer to Use Areas Table.

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	A	B	C	D	E	F
Safety Closures	Safety closures apply only to ORV safety. ORV safety closures established as needed to address safety conditions such as debris on the beach or narrow beaches. Narrow beaches are reopened as the beach widens. Safety closures applicable only to ORV access; pedestrian access is maintained. Existing ORV safety closures include: Ramp 1 to Ramp 2 1.8 miles south of Ramp 38 to 0.4 mile north . of Ramp 43 Buxton to Lighthouse Beach Northern boundary of Frisco to Hatteras Village September 16 – May 14: Hatteras Village 1.5 miles north of Ramp 67 to 1 mile south of Ramp 59	Same as alternative A.	Safety closures established in areas open to ORV use as needed to address ORV and pedestrian safety considerations, including debris on the beach, narrow beaches, and congested areas. Safety closures would preclude ORV access, while pedestrian access would be maintained through all safety closures. Safety closures would be reopened when/if conditions improve as determined by monitoring every two weeks by Seashore law enforcement.	Safety closures would not be established. ORV drivers would need to determine conditions and safety and would drive at own risk.	Same as alternative C, plus: For village beaches that are open to ORV use during the winter season, the village beaches must be at least 30 m (100 ft) wide from the toe of the dune seaward to mean high tide line in order to be open to ORV use.	See safety closure as developed by subcommittee/approved by committee (12/12/08)
	A	**B**	**C**	**D**	**E**	**F**
Administrative ORV Closures	Beach in front of Cape Hatteras Lighthouse closed to ORV access. Buxton Woods road closed to ORV access.	Same as alternative A.	No administrative closures would be established. (Buxton Woods road is a non-ORV area.)	Same as alternative C.	Same as alternative C.	No administrative closures would be established. (Buxton Woods road is a non-ORV area.)
	A	**B**	**C**	**D**	**E**	**F**
Ramp Characteristics			2-lanes wide with shell/clay base Standard regulatory signs and information boards at all ramps Gates at all ramps and access points Designated air down area with hardened surface (e.g., shell/clay base)	Same as alternative C.	Same as alternative C, plus for “high-use” ramps (to be determined); add toilet facility	Same as alternative C, plus for "high-use" ramps (to be determined); add, toilet facilities, preditor proof dumpsters and fish cleaning statiuons. 2-lanes wide with shell/clay base Standard regulatory signs and information boards at all ramps Gates at all ramps and access points Designated air down area with hardened surface (e.g., shell/clay base)
	A	**B**	**C**	**D**	**E**	**F**
Wintering Closures	Suitable interior habitats at spits and at Cape Point closed year-round to all recreational users to provide for resting and foraging for all species. For example, at present, such suitable habitats include ephemeral ponds and moist flats at Cape Point, Hatteras Spit, Ocracoke, and Bodie Island Spit. Actual locations of suitable foraging and resting habitat may change periodically due to natural processes.	Same as alternative A	Based on an annual wintering habitat assessment of the RAs conducted after the breeding season, wintering areas are established within the respective RAs, while allowing an access corridor (pedestrian or pedestrian/ORV) as identified in ORV Use Areas Table. At spits, access will be maintained to inlet shoreline via ocean shoreline.	Same as alternative C	Same as alternative C	Based on an annual wintering habitat assessment of the RA's conducted after the breeding season, wintering areas are established within the respective RA's, while allowing an access corridor (pedestrian and pedestrian/ORV) as identified in the Use Areas Table. At the spits and Cape Point acess will be maintained via ocean shoreline and interdunal roads.
	A	**B**	**C**	**D**	**E**	**F**
Resource Protection Buffers	As identified in the Interim Strategy	As identified in the Interim Strategy, as modified by the Consent Decree.	SM1 and SM2 as described in the Resources Protection Measures Table. Implement SM1 at all locations, except implement SM2 at areas designated in Use Areas Table.	SM1 as described in the Resources Protection Measures Table. Implement alternative SM1 at all locations.	Same as Alternative C.	To be determined and agreed to by the subcommittee and commttee.
	ORV buffers are established for observed breeding behavior. See Resources Protection Measures table for SM1 and SM2 alternatives.					
	A	**B**	**C**	**D**	**E**	**F**
Permit Requirements	No permits required.	10p.m. – 6:00 a.m. September 16 – November 15.	permit req'd	permt req'd	permit req'd	As agreed to by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit Distribution	n/a	To follow Seashore guidelines to be developed	Available in-person at various locations and on-line.	Same as alternative C.	Same as alternative C.	As agreed to by the committee.

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	A	B	C	D	E	F
Permit Issuance Requirements	n/a	Night driving permit application process has an educational component and the permit contains restriction on light use.	ORV owners must read the rules and regulations governing ORV use at the seashore and complete a written or online exam. The owner would sign for their permit in acknowledgement that they understand the rules and that all drivers will abide by the rules and regulations governing ORV use at the seashore, including beach driving safety, and resource closure requirements	ORV owners must sign for the permit in acknowledgement that they understand the rules and that all drivers will abide by the rules and regulations governing ORV use at the seashore, including beach driving safety, and resource closure requirements	Same as alternative C.	as agreed to by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit number limits	n/a	No limit on night driving permits	No limit	Same as alternative C.	Same as alternative C.	As agreed by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit types	n/a	Night driving permit for Sept 16 – Nov 15	Annual permits would be available that would be valid for 12 months from date of purchase so as to span seasonal use.	Annual permits would be available. Valid for calendar year.	Annual and short-term permits (e.g., weekly) available. Night driving permits required under this alternative.	As agreed by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit fees	n/a	None	Fees subject to cost recovery	Same as alternative C (although fee would be lower than alternative C due to decreased management costs under this alternative)	Fees subject to cost recovery, with lower price for short-term or off-season permit (although fee would be higher than alternative C due to increased management costs under this alternative)	As agreed to by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit form	n/a	Night driving permit to follow Seashore guidelines	Permit affixed to vehicle in a manner approved by the NPS.	Same as alternative C.	Same as alternative C.	As agreed to by the committee.
	A	**B**	**C**	**D**	**E**	**F**
Permit Revocation	n/a	Night driving permit to follow Seashore guidelines	A permit may be revoked for violation of applicable park regulations or terms and conditions of the permit.	Same as alternative C.	Same as alternative C.	A permit may be revoked for violation of applicable park regulations or terms and conditions of the permit.
	A	**B**	**C**	**D**	**E**	**F**
Beach Parking	Parking within routes is allowed in any configuration.	Same as alternative A.	Same as alternative A.	Parking within ORV routes is allowed, but only one vehicle deep. Stacking of vehicles in more than one row would be prohibited.	Same as alternative A.	Parkng is allowed in any configuration so long as parked vehicles do not interfer with the clear and safe passage of 2 lanes of traffic.
	A	**B**	**C**	**D**	**E**	**F**
Vehicle Carrying Capacity Determination	Vehicle carrying capacity would not be determined.	Same as alternative A.	Carrying capacity would be established for all areas (to be determined) based on their linear feet of beachfront and the following physical space requirements ("miles" refers to miles of beach open to ORV use): *Bodie Island Ranger District* 260 vehicles/mile (20 feet per vehicle) *Hatteras Island Ranger District* 260 vehicles/mile (20 feet per vehicle) *Ocracoke Island Ranger District* 100 vehicles/mile (54 feet per vehicle) Exceptions to carrying capacity limits may be approved for events operating under a special use permit.	Same as alternative A.	Carrying capacity would be established for all areas based on their linear feet of beachfront and the following physical space requirements: *Bodie Island Ranger District* 260 vehicles/mile (20 feet per vehicle) *Hatteras Island Ranger District* 260 vehicles/mile (20 feet per vehicle) except: Cape Point – 400 vehicles allowed within a 1 mile area centered on Cape Point. *Ocracoke Island Ranger District* 175 vehicles/mile (30 feet /vehicle) Exceptions to carrying capacity limits may be approved for events operating under a special use permit.	To be determined!

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	A	B	C	D	E	F
Temporary Emergency Beach Closures	Temporary emergency closures established per Superintendent's Compendium and NPS policy.	In addition to beach closure restrictions under the Consent Decree, NPS retains the authority to implement a temporary emergency beach closure if any of the following conditions are observed: * ORV traffic backing up on the beach access ramps, either on- or off-beach bound, which threatens to impede traffic flow * ORV traffic on the beach is parked in such a way that 2-way traffic is impeded * Multiple incidents of disorderly behavior are observed or reported	The NPS retains the authority to implement a temporary emergency beach closure if any of the following conditions are observed: * ORV traffic backing up on the beach access ramps, either on- or off-beach bound, which threatens to impede traffic flow * ORV traffic on the beach is parked in such a way that 2-way traffic is impeded * Multiple incidents of disorderly behavior are observed or reported	Same as alternative C.	Same as alternative C.	As agreed to by the committee (12/12/08).

	A	B	C	D	E	F
Seasonal Element related to Carrying Capacity	n/a	n/a	Applicable March 15 – October 14.	n/a	Focus is on peak use periods during breeding season, but may be implemented any time need arises.	

	A	B	C	D	E	F
Periodic Review of Carrying Capacity	n/a	n/a	Visitation, crowding, and safety monitored periodically to determine if implementation of carrying capacity is warranted. Once implemented, carrying capacity limits would be reviewed every 2 years.	n/a	Same as alternative C.	Visitation, crowding, and safety monitored periodically to determine if implementation of carrying capacity is warranted. Once implemented, carrying capacity limits would be reviewed every 2 years. Revew to include NPS and the appointed FACA committee at least every 2 years and more often if requested.

	A	B	C	D	E	F
Areas of Implementation	n/a	n/a	Would apply to all areas in the seashore. Carrying capacity requirements only implemented if increased visitation results in crowding threshold being met.	n/a	Same as alternative C.	

	A	B	C	D	E	F
Off-Road Vehicle Requirements	All vehicles operating in area of the Seashore must: * Have a valid vehicle registration, insurance, and license plate. Vehicles must be street legal. ATVs prohibited from beach driving. Recommend “air down” of tires prior to driving on beach.	Same as alternative A.	Vehicle Characteristics: 1. All vehicles must be registered, licensed, and insured for highway use and comply with state inspection regulations within the state, country or province where the vehicle is registered. 2. Four-wheel drive vehicles are recommended 3. Two wheel drive vehicles are allowed. 4. Motorcycles are prohibited on the ocean beachfront. 5. ATVs are prohibited. 6. There is a three axle maximum for vehicles (this is the axle maximum for the powered vehicle only and does not include the additional number of axles on towed trailers). 7. Any trailers are limited to no more than two axles. 8. The maximum vehicle length is thirty (30') . feet (this is the maximum length for the powered vehicle and does not include the additional length of a towed trailer) 9. Tires must be U.S. Department of Transportation listed and/or approved tires only.	Same as alternative C.	Same as alternative C.	As agreed to by the committee(12/12/08).

SUBCOMMITTEE DOCUMENT

	A	B	C	D	E	F
Equipment Requirements	n/a	n/a	Equipment Requirements: * All vehicles shall contain a low pressure . tire gauge, shovel, jack, and jack stand * A full sized spare tire, first aid kit, fire extinguisher, trash bag or container, flashlight (if night driving), and tow strap are recommended. * When driving on designated routes, tire pressure must be lowered sufficiently to maintain adequate traction within posted speed limit. 20 psi recommended for most vehicles.	Same as alternative C.	Same as alternative C.	As agreed to by committee (12-12-08).
	A	**B**	**C**	**D**	**E**	**F**
Speed Limits	25 mph (unless otherwise posted) on park beaches for public and private vehicles. Speed limit in front of villages during off season (September 16 – May 14) on park beaches posted at 10 mph. Emergency vehicles exempt when responding to a call.	Same as alternative A.	15 mph (unless otherwise posted). Emergency vehicles exempt when responding to a call.	Same as alternative C.	Same as alternative C.	15 mph (unless otherwise posted). Emergency vehicles exempt when responding to a call.
	A	**B**	**C**	**D**	**E**	**F**
Non-ORV Areas	None designated. Temporary non-ORV areas occur as a result of seasonal (village) closures, safety closures, and resource closures.	Same as alternative A.	Non-ORV areas as designated in the ORV Use Areas Table.	Same as alternative C.	Same as alternative C.	Non-ORV areas as designated in the ORV Use Areas Table.
	A	**B**	**C**	**D**	**E**	**F**
Parking Areas for Non-ORV Access	Parking is currently provided in 64 park-maintained park lots throughout the Seashore, totaling approximately 1,000 spaces.	Same as alternative A.	Any new parking areas to be located near Non-ORV Areas and located away from eroding areas or potential inlet areas. New parking areas will implement environmentally appropriate design standards to minimize stormwater runoff. New or expanded parking areas for oceanside locations are identified in ORV Use Areas Table.	Same as alternative C.	Same as alternative C.	Any new parking areas to be located near Non-ORV Areas and located away from eroding areas or potential inlet areas. New parking areas will implement environmentally appropriate design standards to minimize stormwater runoff. New or expanded parking areas for oceanside locations are identified in ORV Use Areas Table.
	A	**B**	**C**	**D**	**E**	**F**
Non-ORV Parking Area Characteristics	None	None	Establish standards/amenities for non-ORV parking areas. Could include: * Each site would have a boardwalk or other appropriate pedestrian route for crossing the dune. * Parking areas with 50? 100? (to be have determined) or more parking spaces would waste receptacles and toilet facilities.	* Each site would have a boardwalk or other appropriate pedestrian route for crossing the dune.	* Each site would have a boardwalk or other appropriate pedestrian route for crossing the dune. * Parking areas with 50? 100? (to be have determined) or more parking spaces would waste receptacles and toilet facilities.	* Each site would have a boardwalk or other appropriate pedestrian route for crossing the dune. * Parking areas with 25 (to be determined) or more parking spaces would waste receptacles and toilet facilities.

SUBCOMMITTEE DOCUMENT

	A	B	C	D	E	F
Alternative	Alternative transportation is not provided	Same as alternative A.	Refer to Use Areas Table	Refer to Use Areas Table	Refer to Use Areas Table	Refer to Use Areas Table
Transportation	at the Seashore.					
	A	**B**	**C**	**D**	**E**	**F**
Restroom Facilities	Existing porta-potties located throughout	Same as alternative A.	To be determined	To be determined	To be determined	At all locations with 25 or more spaces
	the seashore.					
	A	**B**	**C**	**D**	**E**	**F**
	Per 36 CFR 2.15: The following are prohibited:		Same as alternative A, except that pets,	Same as alternative A, except pets	Same as alternative A, except pets	Pets are to be regulated by 36 CFR 2.13
	Possessing a pet in an area closed to the	Same as alternative A.	even if on a leash, are prohibited in	prohibited in Resource Areas year-round.	prohibited in Resource Areas	
	possessionof pets by the superintendent.		Resource Areas from		March 15 – August 31.	
Pets	Failing to crate, cage, restrain on a leash		March 15 – October 15.			
	which shall not exceed six feet in length, or					
	otherwise physically confine a pet at all times.					
	Pets are prohibited in all resource closures.					
	Pets are prohibited, even if on a leash, from					
	the landward side of the posts delineating the					
	ORV corridor at the spits (Bodie, Hatteras,					
	Ocracoke) and Cape Point.					
	A	**B**	**C**	**D**	**E**	**F**
	Permitted per 36 CFR 2.13. Prohibited		Beach fires prohibited 12:00 AM – 6:00 AM			Beach fires are allowed per 36 CFR 2.13 and
Beach Fires	12:00 midnight to 6:00 AM per	Same as alternative A.	year-round. Permit required for any beach	Same as alternative C.	Same as alternative C.	prohibitted 12:00 midnight to 6:00am.
	Superintendent's Compendium Section 2.13.		fire to ensure user is informed of basic			No fires are are allowed within 100 meters of a
			safety and resource protection measures,			known turle nest.
			including no fires within a 100 meters of a			
			known turtle nest.			
	A	**B**	**C**	**D**	**E**	**F**
	Camping*, as defined in 36 CFR § 1.4, is	Camping, as defined in 36 CFR § 1.4, is	Camping, as defined in 36 CFR § 1.4, is			
	prohibited on seashore beaches per	prohibited on seashore beaches per	prohibited on seashore beaches per	Same as alternative C.	Same as alternative C	To be determined by committee.
Nighttime Beach Use	Superintendent's Compendium § 2.10(a).	Superintendent's Compendium § 2.10(a).	Superintendent's Compendium § 2.10(a).			
	ORVs allowed on beach overnight only if	See allowable hours of ORV operations	See allowable hours of ORV operations			
	someone associated with the vehicle is actively	for this alternative.	for this alternative.			
	fishing.					
			Unattended beach equipment (i.e., chairs,			
	ORVs allowed on all areas of the seashore		canopies, volleyball nets, water sports .			
	24 hours a day, year round.		gear, etc) is prohibited on the Seashore at			
			night.Turtle patrol and law enforcement will			
	**Camping means the erecting of a tent or shelter*		tag equipment found at night.			
	of natural or synthetic material, preparing a		Owners have 24 hrs to remove equipment			
	sleeping bag or other bedding material for use,		before it will be removed by NPS staff.			
	parking of a motor vehicle, motor home or trailer,					
	or mooring of a vessel for the apparent purpose					
	of overnight occupancy. (36 CFR § 1.4)					

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SUBCOMMITTEE DOCUMENT

	A	B	C	D	E	F
	Launch sites, as designated under 36 CFR	Same as alternative A.	Same as alternative A.	Same as alternative A.	Same as alternative A.	Launch sites, as designated under 36 CFR
Boat Access	§ 3.8(a)(2), are identified in the					§ 3.8(a)(2), are identified in the
	Superintendent's Compendium.					Superintendent's Compendium.
	Launching or recovery of vessels is prohibited					Launching or recovery of vessels is prohibited
	within resources closures.					within resources closures.
	A	**B**	**C**	**D**	**E**	**F**
	Authorized by permit to enter all ORV and	Same as alternative A, plus are subject to	Same as alternative A, plus may be			Same as alternative A, plus may be
Commercial Fishing	pedestrian areas that are not closed for	night driving restriction in consent decree.	authorized by special use permit to access	Same as alternative C.	Same as alternative C.	authorized by special use permit to access
Vehicles	resources protection. Treated as non-		non-ORV areas and night driving restricted			non-ORV areas and night driving restricted
	essential vehicles and may not enter		areas if there is no resource conflict.			areas if there is no resource conflict.
	resource closures.		To be determined.			To be determined.
	A	**B**	**C**	**D**	**E**	**F**
			To be determined. Need to develop “LE1”	To be determined. Need to develop “LE1”	To be determined. Need to develop “LE1”	
Law Enforcement (LE)			and “LE2” enforcement measures and	enforcement measures and staffing levels	and “LE2” enforcement measures and	To be determined by NPS
			staffing levels to complement the SM1	to complement the SM1	staffing levels to complement the SM1	
			and SM2 Resources Protection Measures	Resources Protection Measures	and SM2 Resources Protection Measures	
			(i.e., an SM1 site needs LE1 enforcement		(i.e., an SM1 site needs LE1 enforcement	
			coverage;and SM2 site needs LE2)		coverage; and SM2 site needs LE2)	
	A	**B**	**C**	**D**	**E**	**F**
Staffing			To be determined	To be determined	To be determined	To be determined by NPS
(including RM, sign crew,						
LE, Maintenance, and others?)						
	A	**B**	**C**	**D**	**E**	**F**
Materials			To be determined	To be determined	To be determined	To be determined by NPS
	A	**B**	**C**	**D**	**E**	**F**
Advisory Committee						An advisory committee shall be established to review
						the ORV Management plan annually or more often if
						requesed by the superintendent. The committee shall
						consist of a reasonable cross sectional representation
						of the visitors to Cape Hatteras National Seashore
						Recreational Area.

SUBCOMMITTEE DOCUMENT

DRAFT

NEGOTIATED RULEMAKING COMMITTEE
KEY ISSUES AND OPTIONS IDENTIFIED FOR ROUTES AND AREAS BY JOINT SUBCOMMITTEES
(February 2, 2009)

NOTES

- This document is intended to be used as a checklist to capture the primary issues that must be addressed to reach consensus and as a summary explanation of the differences shown on the routes and areas maps displayed and distributed at the February 3, 2009 Reg Neg Committee meeting. It should be read while referring to those maps.
- Column headings reflect issue areas not interest groups.
- Bullet points range from general topics requiring further discussion to specific options.
- *ASSUMPTION:* natural resource buffers and turtle management actions may apply to all areas.

OVERARCHING ISSUES

(Issues affecting resolution of other issues or applicable to multiple areas along the seashore)

- In pedestrian-only areas with resource issues, the kinds of recreation allowed or prohibited in non-breeding season. This raises questions about where activities such as horseback riding, dog walking, kite boarding, etc. can take place. This could lead to different categories of pedestrian areas, depending on the type and level of activities.
- Size of buffers for pass thru corridors at Bodie Island Spit, Cape Point, and South Point (Ocracoke)
- Village closures: dates, boundaries, and criteria for reopening.
- The meaning of "purple" on the maps?
- The significance and hierarchy of scientific studies relating to natural resources.

BODIE ISLAND (Ramp 1 to Bodie Island Spit)

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Oregon Inlet Campground Oceanside		• Seasonal closure in front of campground	

This document was prepared by the facilitators for discussion purposes based on discussions during the joint natural resources/routes and areas subcommittee meeting held on January 21-22, 2009. It does not represent Committee member agreement.

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OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Ramp 4	• Interdunal Road to Bait Pond (wetlands, feasibility issues)		
Ramp 4 to Spit	• Starting point from All Year Access (green) to Conditional Seasonal (purple)		• Pass thru corridor o width (50, 33, 10 m) o length (.4 or .5 mile) • Appropriate buffers during breeding season (SM2 or pass thru) • Vegetation management

HATTERAS ISLAND NORTH (Salvo line south to Buxton)

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Salvo Line to 2 miles south	• Open to ORVs	• Pedestrian only area (to extend village pedestrian area, close to parking)	
Ramp 27 to Ramp 30	• ½ open to ORV either side of a new ramp 28.5, subject to resource closures (fishing tournaments Fall & Spring)	• ORV corridor (low pedestrian value)	• All (27 to 30) closed year-round for natural resources (AMOY & non-breeding habitat)
Avon Line to 2 miles north	• Open to ORVs	• Pedestrian only area	
Ramp 38 to Buxton Line	• ORV to new Ramp 39; 39 to Buxton Pedestrian only	• 1 mile pedestrian only mile N and S of new 39	

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OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Salvo Line to Cape Point point			• 20% of non-village beaches closed for non-breeding foraging/resting (July to May)

CAPE POINT (Buxton Line to 45)

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Lighthouse Beach to Ramp 43	• ORV from Ramp 43 north some distance (spillover area during closure and fishing tournaments fall & spring)	• Pedestrian from Buxton line all the way to 43	
Ramp 44 to Cape Point point		• Equestrian use access	• Wilson Plovers • Corridor width – 50-100m in breeding season
Cape Point point to Ramp 45	• Length of Cape Point "west side" oceanside ORV corridor along high tide line (e.g. kiteboarding/fishing)	• Pedestrian access below high tide line during breeding season	

SOUTH BEACH (Ramp 45 to Frisco Village Line)

SUBCOMMITTEE DOCUMENT

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OCEANSIDE LOCATION	ORV	PEDESTRIAN & OTHER	NATURAL RESOURCE
Ramp 45 to Ramp 49		• Equestrian use access, including current special use permittee	• ORV closure via interdunal road or 50 m buffer from high tide line for non-breeding habitat o Length (0 to 2 miles) o Location (45 to .5 miles east of 49) o Kinds of activities allowed o Linkage to opening and closing of breeding and non-breeding closures o Impact on commercial fishing
New Ramp 49 to Frisco Village Line	• Open to ORVs - possibly close ORV areas in front of campground when campground is open provided access on either side is available	• Pedestrian area only by moving 49 to east end of campgrounds and make new 49 to Frisco Pedestrian only	
Interdunal Road	• Location and ramps?	•	

HATTERAS SPIT (55 to Hatteras Spit)

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OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Ramp 55 to Hatteras Spit	• Fishing tournaments fall & spring		• Non-breeding closure options: o Pole Road .6 miles to Bone Road closed o Pole Road east 1.2 miles, 50 m f/high tide line closure o Ramp 55 to Pole Road closed o Kinds of activities allowed

NORTH OCRACOKE (59 to Point)

Option #1 (depends on length of pedestrian only area, see Ocracoke Variation maps):

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
Pilings north to and around Point		• Oceanside, narrow pedestrian corridor along high tide mark part way around	• Full closure to year-round habitat protection
Oceanside from old pilings to Ramp 59	• Open to ORV	• Year-round pedestrian closure to Ramp 59	

OCRACOKE (Ramp 59 to Ramp 72)

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES

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Ramp 59 to Ramp 72	• Balancing ORV, pedestrian, and breeding and non-breeding habitat		
Campground Beach (around Ramp 68)	• Self-contained area on beach when Campground closed		

SOUTH POINT OCRACOKE (Ramp 72 to Point)

OCEANSIDE LOCATION	ORV	PEDESTRIAN/OTHER	NATURAL RESOURCES
72 to Point		• Special use permit for equestrian activity	
0.5 miles south of Ramp 72 to 0.8 miles further southwest			• Pass thru corridor length (.8 or longer) • Corridor width (10 m or wider) in breeding & non-breeding season. • Kinds of activities allowed in non-breeding season? • Appropriate buffers (SM2 or pass thru) for pass thru corridor during breeding season • Vegetation management
1 mile or so past Ramp 72	• Soundside access in non-breeding season		

This document was prepared by the facilitators for discussion purposes based on discussions during the joint natural resources/routes and areas subcommittee meeting held on January 21-22, 2009. It does not represent Committee member agreement.

National Park Service

Groundrules for the Public

at CAHA Negotiated Rulemaking Meetings

To ensure a productive meeting and enable the RegNeg Committee to do its work, we request that the public follow these groundrules. There are three public comment periods set aside on the agenda. Please focus your comments on the topics listed on the agenda.

- ✓ Please hold your comments for the public comment periods
- ✓ Be creative and propose solutions
- ✓ Express your own views
- ✓ Encourage civility and respect for all
  - ◆ Focus on the problem, not the people
  - ◆ Disagree, without being disagreeable
  - ◆ Refrain from personal attacks
  - ◆ Refrain from expressing approval or disapproval of other comments

Written comment for the Committee may be sent to: Designated Federal Official, 1401 National Park Drive, Manteo, NC 27954; or CAHA_Superintendent@nps.gov

0076455

February 3, 2009
To: Mr. Mike Murray, DFO
CHNSRA REG-.NEG. Committee
From: Don E. Morris
511 Broad Creek Loop Rd
Newport NC 28570 PH: 252-622-4407

I rise today to question the validity of the SELC assertions that the Piping Plover is endangered or threatened and deserve extraordinary protection. If the proposed extreme protection regulations utilized in the 2008 nesting season are imposed on a permanent basis they will deprive Americans of their right to use ORV's for recreation on the CHNSRA.

I have been a mobile surf fisherman since 1959 and have driven beaches from Nova Scotia to South Carolina in quest of a #50 Lb. Striped Bass. Maybe I will get lucky by attending this hearing.

In my 50 years of surf fishing I have witnessed the Piping Plover nesting and hatching little ones within 10 ft. of vehicle tracks and successfully raising their young. Just this last summer as we have done for several years, members of my fishing club, RIMS (Rhode Island Mobile Sportfisherman), in co-operation with USFWS worked to baby sit several hatches of Piping Plovers to their fledging. All the while RIMS members were still accessing favorite fishing spots. We have been co-operating with the USFWS in this endeavor for several years and have a good rapport with them. Attached are a few pictures I took this last summer during the nesting season. All of the nests shown were within 20 feet of the traveled sand trail. One of the nests shown was washed away because it was too close to the tide line. There were at least eight new chicks that successfully fledged this summer in the short 11/2 mile of beach where I travel to fish every morning during the summer season.

As the fall fishing season began in mid-October I witnessed flocks of 40-50 birds every morning for 10 days resting on the beach. I assume these Plovers are from the Cape Cod area where there have also been large hatches for several years. I feel they are on their way to southern wintering grounds.

I believe the decreasing number of nesting sites of the Piping Plover in CHNSRA are caused by the phenomenon of global warming which is shifting nesting areas further north every year. There are probably several Piping Plovers wintering over in the CHNSRA. These birds are adults and need no protection as the adult Piping Plover is a very plucky bird who will survive with vehicles driving on the beach front.

The biggest danger to the Piping Plover is the ever increasing development of large summer homes and condominiums where nesting areas used to be. Development is a bigger cause of the loss of habitat than a fisherman who uses the beach for a few hours and then leaves. The beaches belong to all the people and not just a privileged few. The Piping plover will always survive fishermen using the beach but they cannot survive a permanent 3 story structure or a row of condominiums where they used to nest.

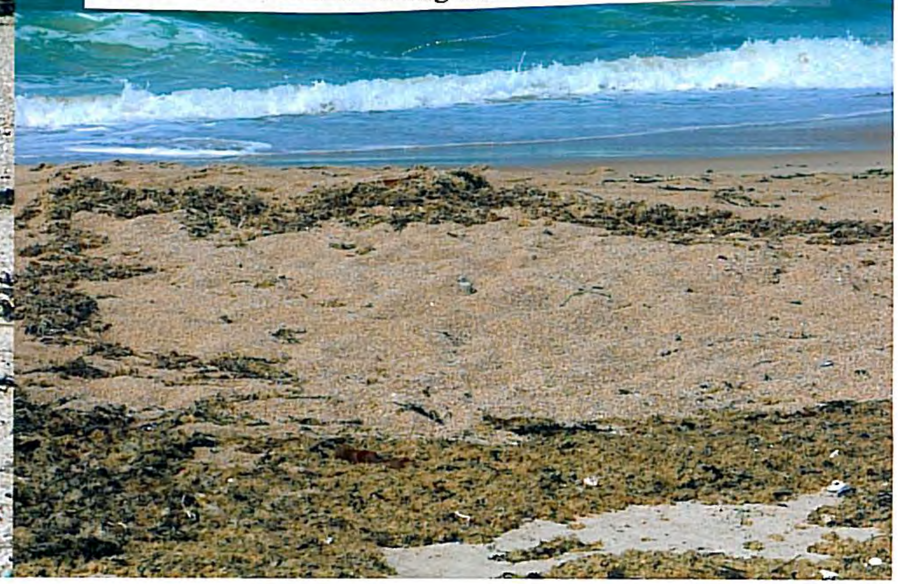
CHNSRA belongs to all of the people of the US and should be available for their enjoyment. The Park service is the steward of that precious resource. To this end the Park Service should institute a permitting process that includes user fees, required education of permitees, inspections to assure properly equipped vehicles, and sensible rules to protect wildlife. Responsible fishing organizations and their members have always worked with the Park Service to protect the wildlife resources of CHNSRA. With sensible rules this mutual co-operation between The Park Service, fishing organizations, USF@W, Birders, and the general public will assure continued use for our grandchildren and the Piping Plover too.

Don E. Morris

Don E. Morris

This nest survived washover. 2 chicks hatched and fledged

This nest close to tide line. It washed away on storm tide
Mother moved to new nesting site



Chick under mother. Note post delineating sand trail
At top of photo

Nest 6 feet from sand trail. Note yellow rope barrier
4 eggs hatched and chicks fledged

0076456

Date: 2/3/09
To: Cape Hatteras National Seashore Regulatory Negotiation Committee
From: H. Wayne Clark
Edwards of Ocracoke
Rooms and Cottages

Ideas/Thoughts on the ORV Issue

General

Good afternoon. My name is Wayne Clark. My family consisting of my son, his wife, my wife and me operate a Family Owned Motel and Cottage Operation on Ocracoke Island; Edwards of Ocracoke. We have eleven motel units, and in addition ten cottages and apartments. Our "reason to be" is to provide comfortable, affordable lodging in the historic village that adjoins the park. We have owned the business since 1996. The Motel was the first motel on the Island having been constructed by Stanley Wahab in the late thirties. Our goal is to offer very functional facilities with an "Old Ocracoke" theme. We have no grandiose ideas. We just want to make a living in an environment and surroundings that we love and enjoy living in. The Park is very much a part of our everyday life and livelihood...

Economic Impact

Surf Fishing has historically been a tremendous draw for Ocracoke Island. Access to both inlets (Hatteras and Ocracoke) is important to these Fisherman both during day light and night hours. The Shoulder Seasons (spring and fall) provide for excellent fishing and extend our tourist season significantly. These type Park Visitors are very instrumental as to the ability of the local economy to sustain itself.

The economy of Ocracoke Village is significantly dependant upon the continuing, historical use attraction of the Park. Surf Fishing and the use of ORVs is an important draw for many Visitors. Without primary consideration for the historical use of the beach relative to surf fishing and ORV use, the livelihoods of the entire Village is at risk. Noting that the local economy has been allowed to grow and become increasingly dependant on Tourism by way of ORV Access and convenient beach access for Surf Fisherman, it is very concerning that significant changes of use are being considered; especially given that little off setting or mitigating plans are being considered.

The local citizens, businesses and Park Visitors did not contribute to the current regulatory problem. The Ocracoke Citizens have based there livelihood on the only economic engine available (Tourism). To change regulations as to park use that could have a negative impact on the local economy is both reckless and irresponsible unless done with the utmost consideration for "historical uses" and the use of "mitigation" as an offset.

If regulations need to be changed relative to environmental/endangered species concerns; be it birds, turtles or whatever; changes only need to be considered after making allowances for the historical use of the Park. Significant changes that reduce the historical use particularly in reference to ORVs and Surf Fisherman should be limited to what are "proven needs" by sound facts and not based on speculation. A Community and Way of Life are at risk through "no fault of their own".

It is my view that there could very well be "legal issues" relative to implementing regulations that have a negative impact on Local Businesses, Property Values and Citizens of Ocracoke Island. I have heard of "historical precedents" whereby citizens and/or businesses must be compensated for loss of economic value when restrictions are placed on public use areas that have a "direct, negative, economic impact". Without some type of mitigation or offset as to "use", it is my view that this type remuneration needs to be explored be it a suit involving the Park Service or the Organizations that are favoring more restrictions.

It is recognized that certain areas of the Island are more environmentally sensitive than others (North and South Points). These areas need "special review" but any "use limitations" (changes) should only be considered after giving much thought to the historical use and providing mitigation relative to the potential impact on the local economy.

I ask this question to those of you on the Negotiating and Rule Making Committee and NPS who advocate major changes that could directly cause harm to the local economy by imposing restrictions on ORV use and Surf Fishing access; "how would you feel if the means of livelihood for you, your family and community were being threatened? Most all our citizens are very concerned, some to the point of outright hysteria. In my view you should be as understanding and concerned for mankind (our citizens) as you are for the environment and wild life. I am sure you would expect that of us if the "shoe were on the other foot"!

Possible Means of Mitigation

I do have the following thoughts should it becomes necessary to significantly change the historical use of the Ocean Front relative to ORV use and the availability of "prime surf fishing areas".

With the advent of a new Federal Effort to booster the economy by way of spending funds on Road Projects and related, it makes sense to consider "opening up" the sound side of the Park to ORV use. This could be done by putting in place a Sound Side ORV Trail (running parallel to the sound) complete with beach access and parking areas. The Sound Side Trail could be geared towards recreational use (Wade Fishing, Birding, Swimming, Kite Boarding and Beach Combing). With publicity to make the public aware of this new, sound side recreational opportunity; perhaps it would offset some of the potential economic negatives that could come from additional restrictions as to historical use on the ocean front?

Perhaps with a Sound Side ORV Trail the NPS would be opening up sound side access to areas that are less environmentally sensitive than some on the ocean side. This would assist in compensating for the Public's loss of use relative to environmentally sensitive areas on the ocean front. There appears to be a real need for a Sound Side Beach similar to the Ocean Side Beach Walk Over Access near Ocracoke Village. This would offer an alternative for Park Visitors when the weather conditions on the Ocean Beach are less than optimal.

Currently many stretches of ocean side beach are not open in "peak periods" (summer). Perhaps the NPS can actually open more ocean side beaches in the summer to compensate for areas that must be closed relative to being environmentally sensitive? There definitely needs to be more access areas for Surf Fishing if the ocean side is going to be more restricted.

Funding for the Capital Projects (Sound Side ORV Trail, Parking and Beach Access) could come from the Federal Plan for stimulating the economy. Funding to police the additional use of the Park could come from "new user fees". Environmental Groups and Organizations that are advocating closure as to "historical use" should also assist in funding.

I implore those on the Committee that feel additional restrictions of use need to be put in place to at a minimal provide some means to mitigate the "real potential" of economic loss to the Island Citizens and Businesses This can best be accomplished by way of additional access in less environmentally sensitive areas.

Thank you for your time and effort!

H. Wayne Clark
Edwards of Ocracoke
Rooms and Cottages
Ocracoke Island

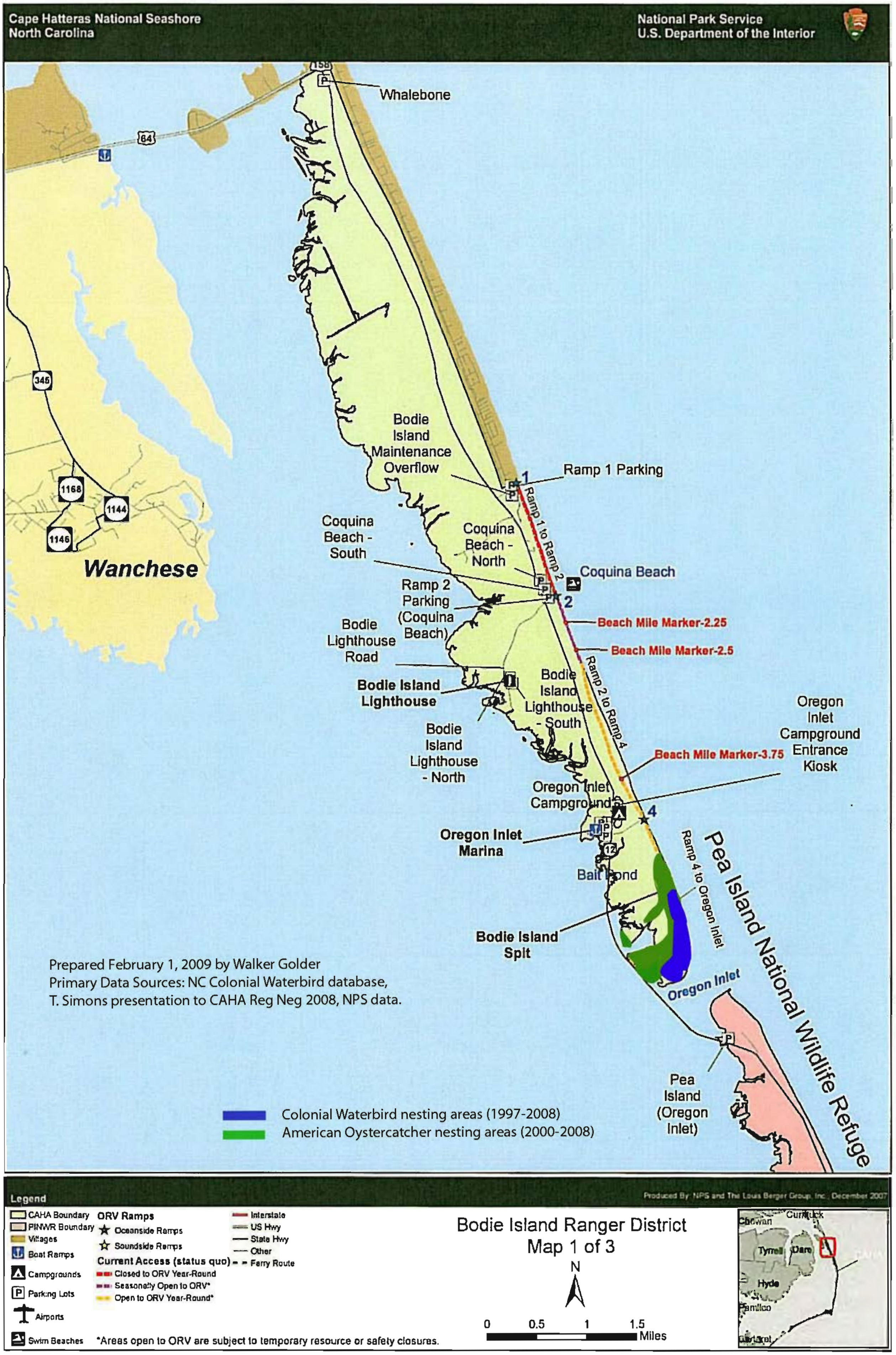
NEGOTIATED RULEMAKING COMMITTEE

CAHA NON-BREEDING SHORE BIRD AREAS AND COLONIAL WATERBIRD AND AMERICAN OYSTER CATCHER NESTING AREAS

The following maps were prepared on February 1, 2009 by Walker Golder, National Audubon Society, North Carolina State Office.

The maps were prepared using data from the following sources:
NC Colonial Waterbird database
International Shorebird database
Atlantic Coast REKN survey
International PIPL survey data
CBC Database
T. Simons presentation to CAHA Reg Neg 2008
M. Erwin presentation to CAHA Reg Neg 2008
A. Hecht presentation to CAHA Reg Neg 2008
NPS waterbird data
NPS Shorebird data
Dinsmore et al 1998
Cohen et al 2008
Callazo et al 1995
Barbee 1994
Erwin 2005
Cohen 2005
Meyers 2005
Harrington 2008
Parnell et al. 1993
Parnell and Shields 1990

0076461



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Whalebone
Bodie Island Maintenance Overflow
Ramp 1 Parking
Coquina Beach - South
Coquina Beach - North
Ramp 1 to Ramp 2
Coquina Beach
Wanchese
Ramp 2 Parking (Coquina Beach)
Beach Mile Marker-2.25
Beach Mile Marker-2.5
Bodie Lighthouse Road
Bodie Island Lighthouse
Bodie Island Lighthouse - South
Ramp 2 to Ramp 4
Oregon Inlet Campground Entrance Kiosk
Bodie Island Lighthouse - North
Beach Mile Marker-3.75
Oregon Inlet Campground
Oregon Inlet Marina
Ramp 4 to Oregon Inlet
Pea Island National Wildlife Refuge
Bait Pond
Bodie Island Spit
Oregon Inlet
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Pea Island (Oregon Inlet)
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
Produced By: NPS and The Louis Berger Group, Inc., December 2007
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Bodie Island Ranger District
Map 1 of 3
N
0 0.5 1 1.5 Miles

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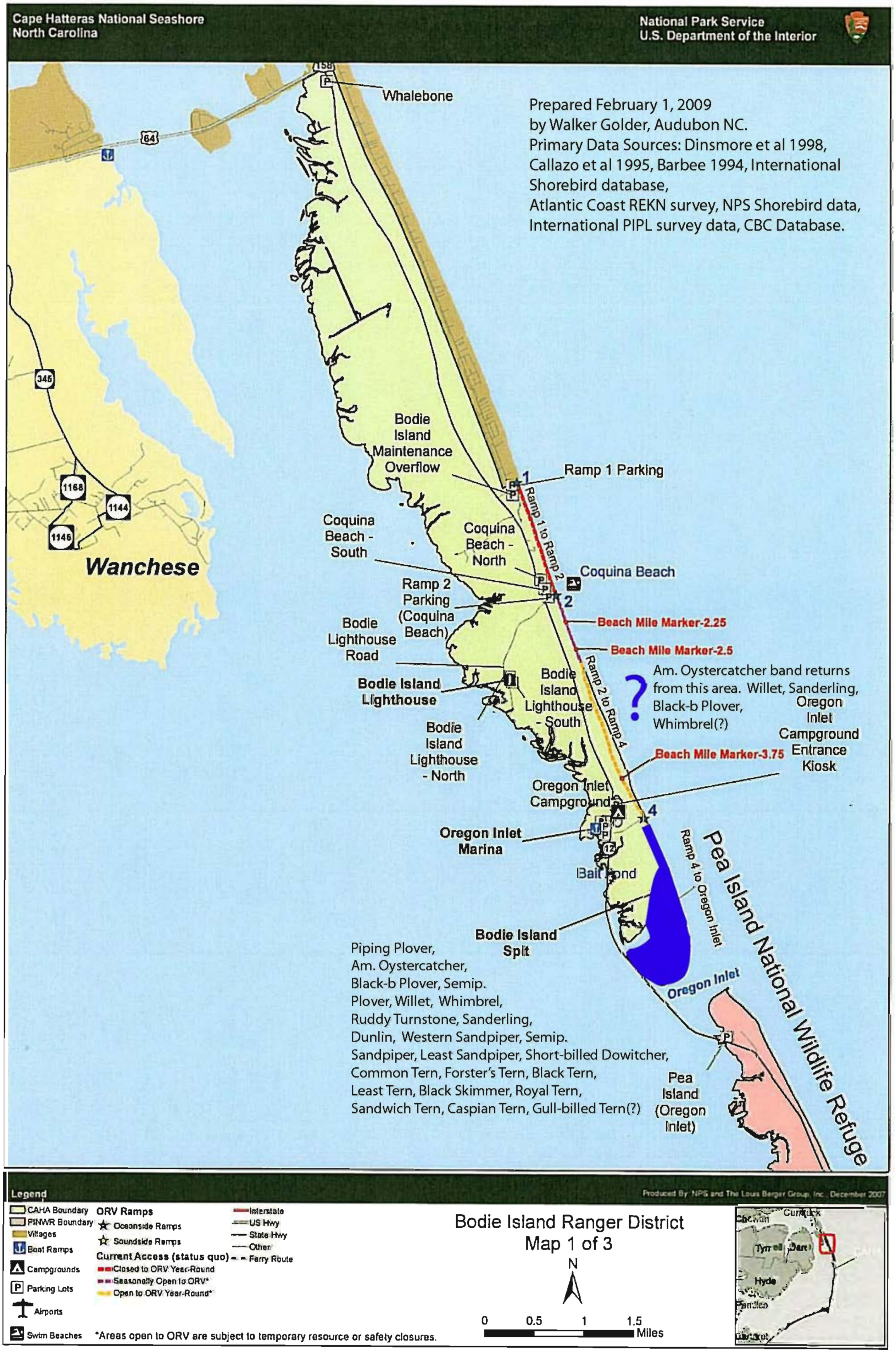

Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998,
Callazo et al 1995, Barbee 1994, International
Shorebird database,
Atlantic Coast REKN survey, NPS Shorebird data,
International PIPL survey data, CBC Database.
Whalebone
158
64
345
1168
1144
1146
Wanchese
Bodie Island Maintenance Overflow
Ramp 1 Parking
Ramp 1 to Ramp 2
Coquina Beach - South
Coquina Beach - North
Coquina Beach
Ramp 2 Parking (Coquina Beach)
Beach Mile Marker-2.25
Beach Mile Marker-2.5
Bodie Lighthouse Road
Bodie Island Lighthouse
Bodie Island Lighthouse - South
Ramp 2 to Ramp 4
Am. Oystercatcher band returns from this area. Willet, Sanderling, Black-b Plover, Whimbrel(?)
?
Oregon Inlet Campground Entrance Kiosk
Bodie Island Lighthouse - North
Beach Mile Marker-3.75
Oregon Inlet Campground
Oregon Inlet Marina
12
Bait Pond
Ramp 4 to Oregon Inlet
Pea Island National Wildlife Refuge
Bodie Island Spit
Piping Plover,
Am. Oystercatcher,
Black-b Plover, Semip.
Plover, Willet, Whimbrel,
Ruddy Turnstone, Sanderling,
Dunlin, Western Sandpiper, Semip.
Sandpiper, Least Sandpiper, Short-billed Dowitcher,
Common Tern, Forster's Tern, Black Tern,
Least Tern, Black Skimmer, Royal Tern,
Sandwich Tern, Caspian Tern, Gull-billed Tern(?)
Oregon Inlet
Pea Island (Oregon Inlet)
Legend
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
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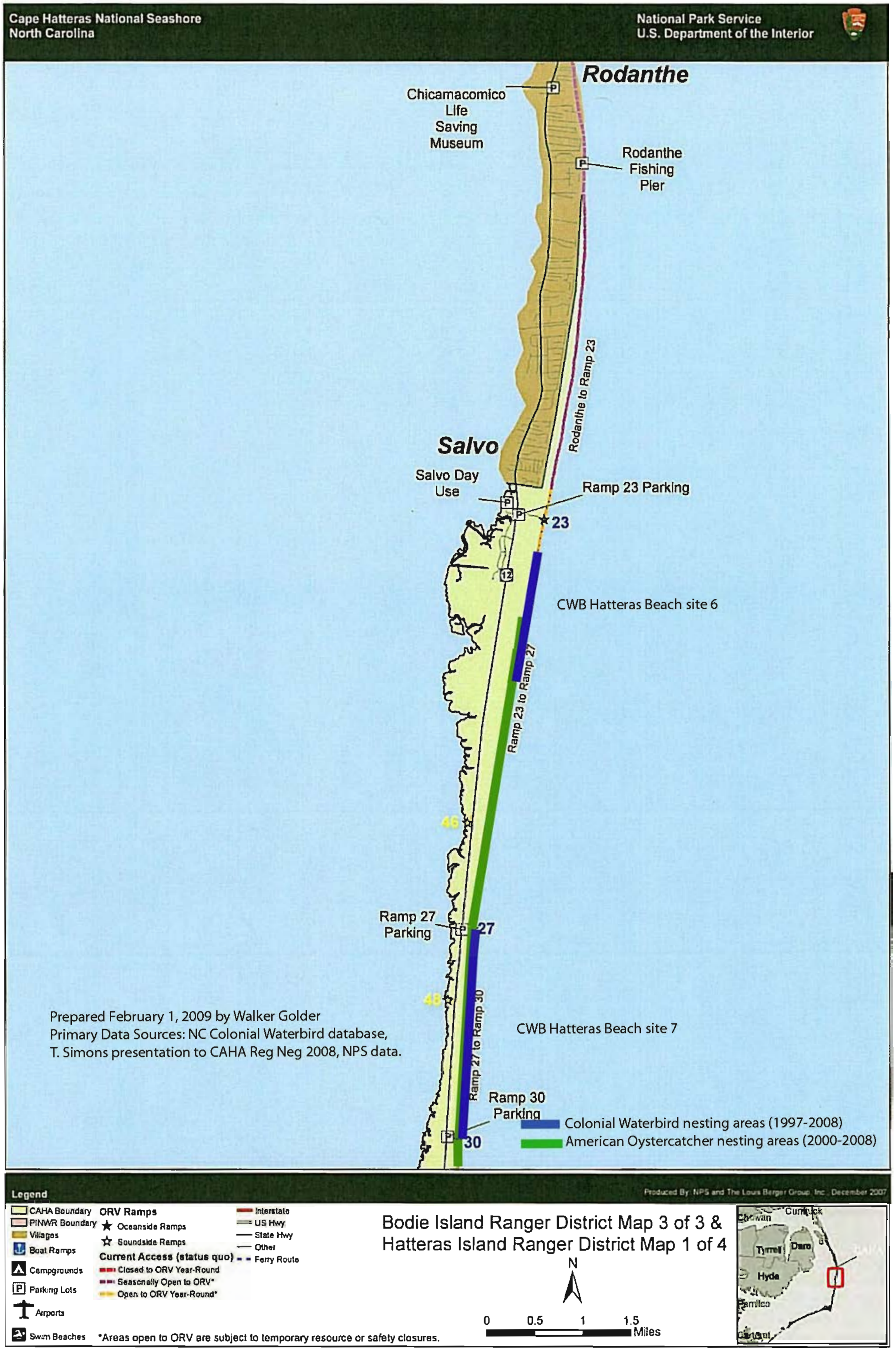
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Produced By: NPS and The Louis Berger Group, Inc., December 2007
Bodie Island Ranger District
Map 1 of 3
N
0 0.5 1 1.5 Miles
Currituck
Tyrrell
Dare
Hyde



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Rodanthe
Chicamacomico Life Saving Museum
Rodanthe Fishing Pier
Rodanthe to Ramp 23
Salvo
Salvo Day Use
Ramp 23 Parking
23
12
CWB Hatteras Beach site 6
Ramp 23 to Ramp 27
Ramp 27 Parking
27
Ramp 27 to Ramp 30
CWB Hatteras Beach site 7
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database, T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Ramp 30 Parking
30
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Bodie Island Ranger District Map 3 of 3 &
Hatteras Island Ranger District Map 1 of 4
N
0 0.5 1 1.5 Miles
Produced By: NPS and The Louis Berger Group, Inc., December 2007
Currituck
Dare
Tyrrell
Hyde

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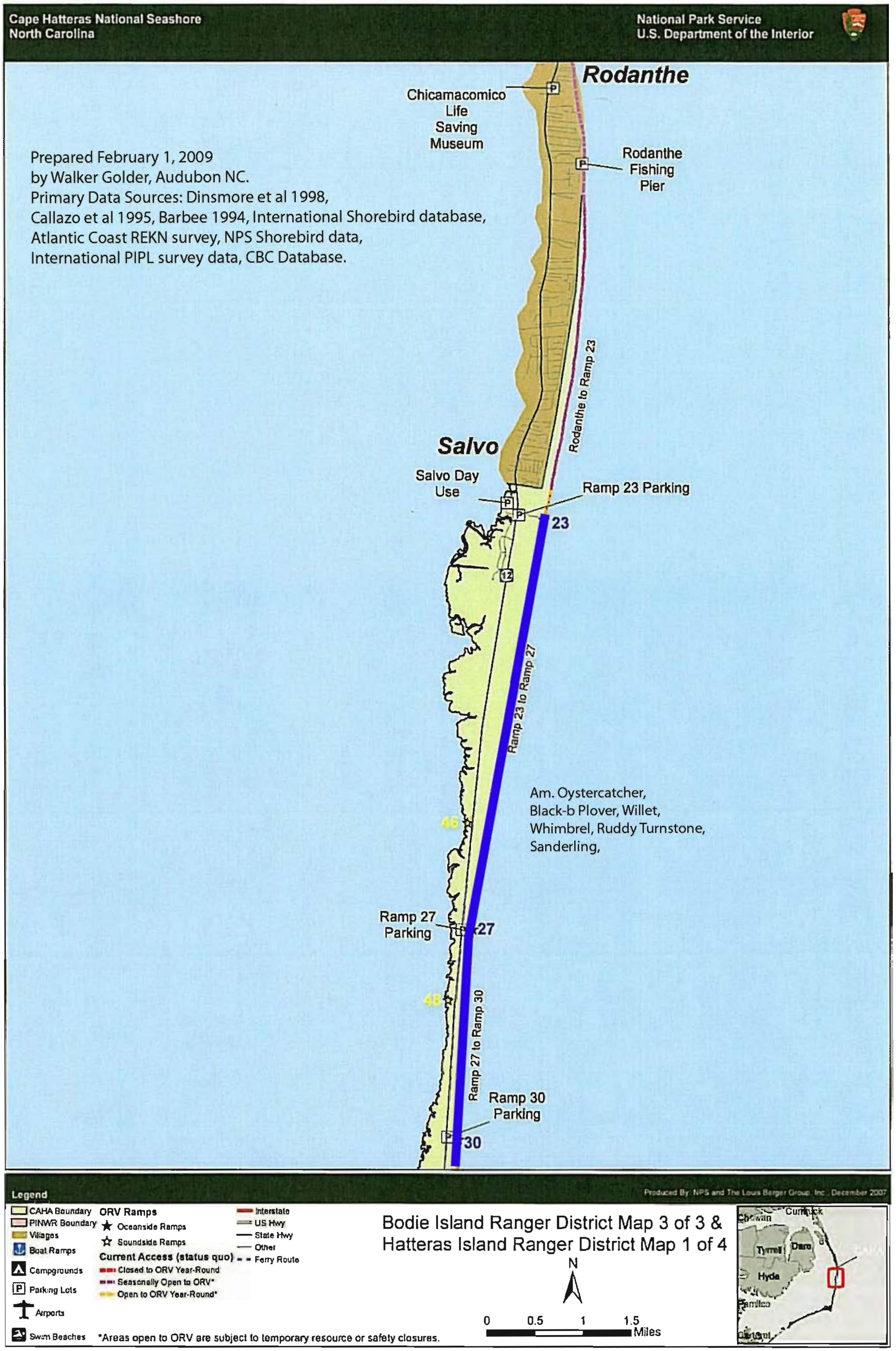
Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Rodanthe
Chicamacomico Life Saving Museum
Rodanthe Fishing Pier
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998,
Callazo et al 1995, Barbee 1994, International Shorebird database,
Atlantic Coast REKN survey, NPS Shorebird data,
International PIPL survey data, CBC Database.
Rodanthe to Ramp 23
Salvo
Salvo Day Use
Ramp 23 Parking
23
12
Ramp 23 to Ramp 27
Am. Oystercatcher,
Black-b Plover, Willet,
Whimbrel, Ruddy Turnstone,
Sanderling,
46
Ramp 27 Parking
27
48
Ramp 27 to Ramp 30
Ramp 30 Parking
30
Legend
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
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Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Produced By: NPS and The Louis Berger Group, Inc., December 2007
Bodie Island Ranger District Map 3 of 3 &
Hatteras Island Ranger District Map 1 of 4
N
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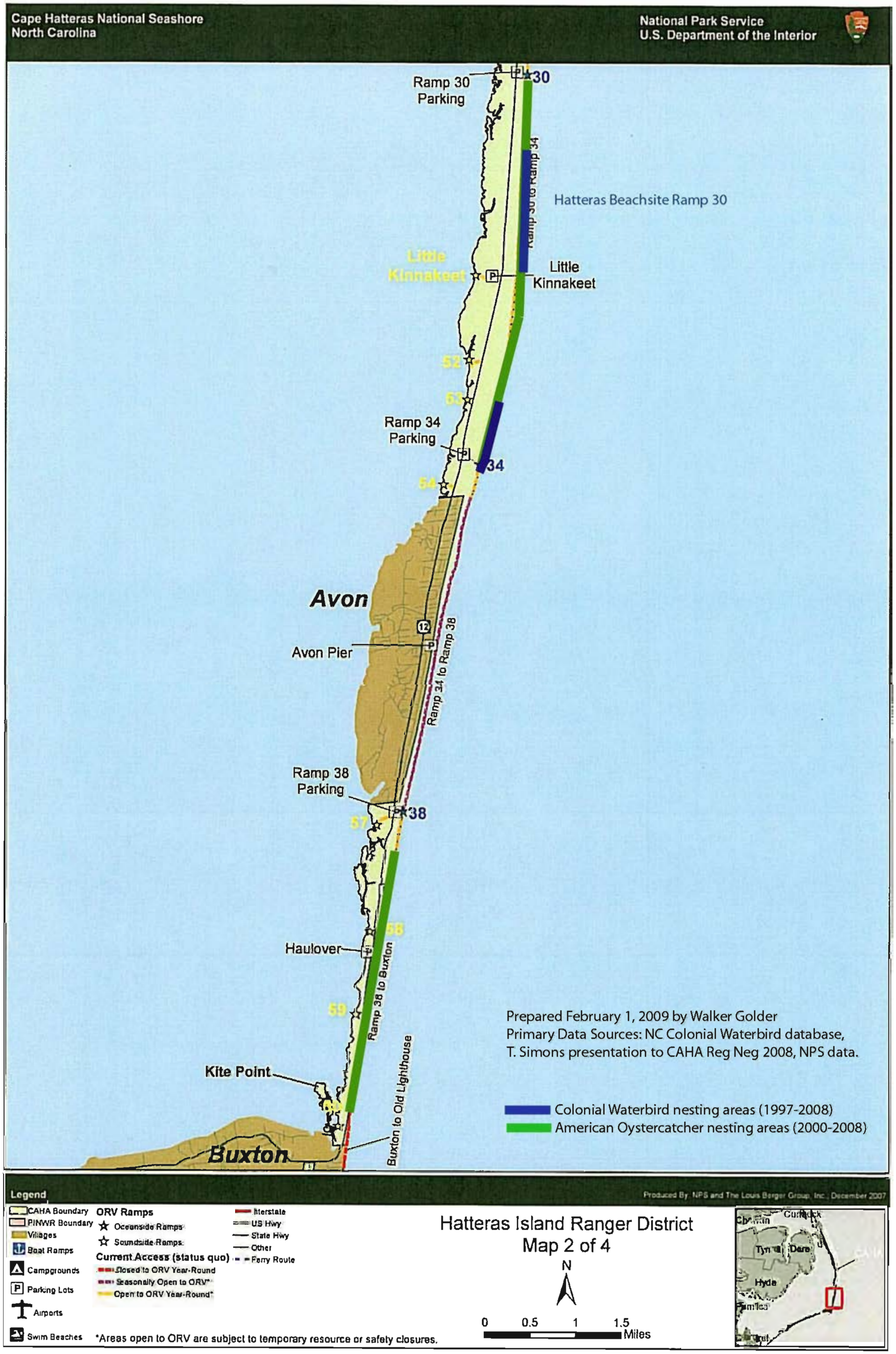
Miles
Chowan
Currituck
Tyrrell
Dare
Hyde
Pamlico

0076465



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Ramp 30
Parking
30
Hatteras Beachsite Ramp 30
Little
Kinnakeet
Little
Kinnakeet
52
53
Ramp 34
Parking
34
54
Avon
12
Avon Pier
Ramp 34 to Ramp 38
Ramp 38
Parking
38
57
58
Haulover
Ramp 38 to Buxton
59
Kite Point
Buxton to Old Lighthouse
Buxton
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
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Interstate
US Hwy
State Hwy
Other
Ferry Route
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Hatteras Island Ranger District
Map 2 of 4
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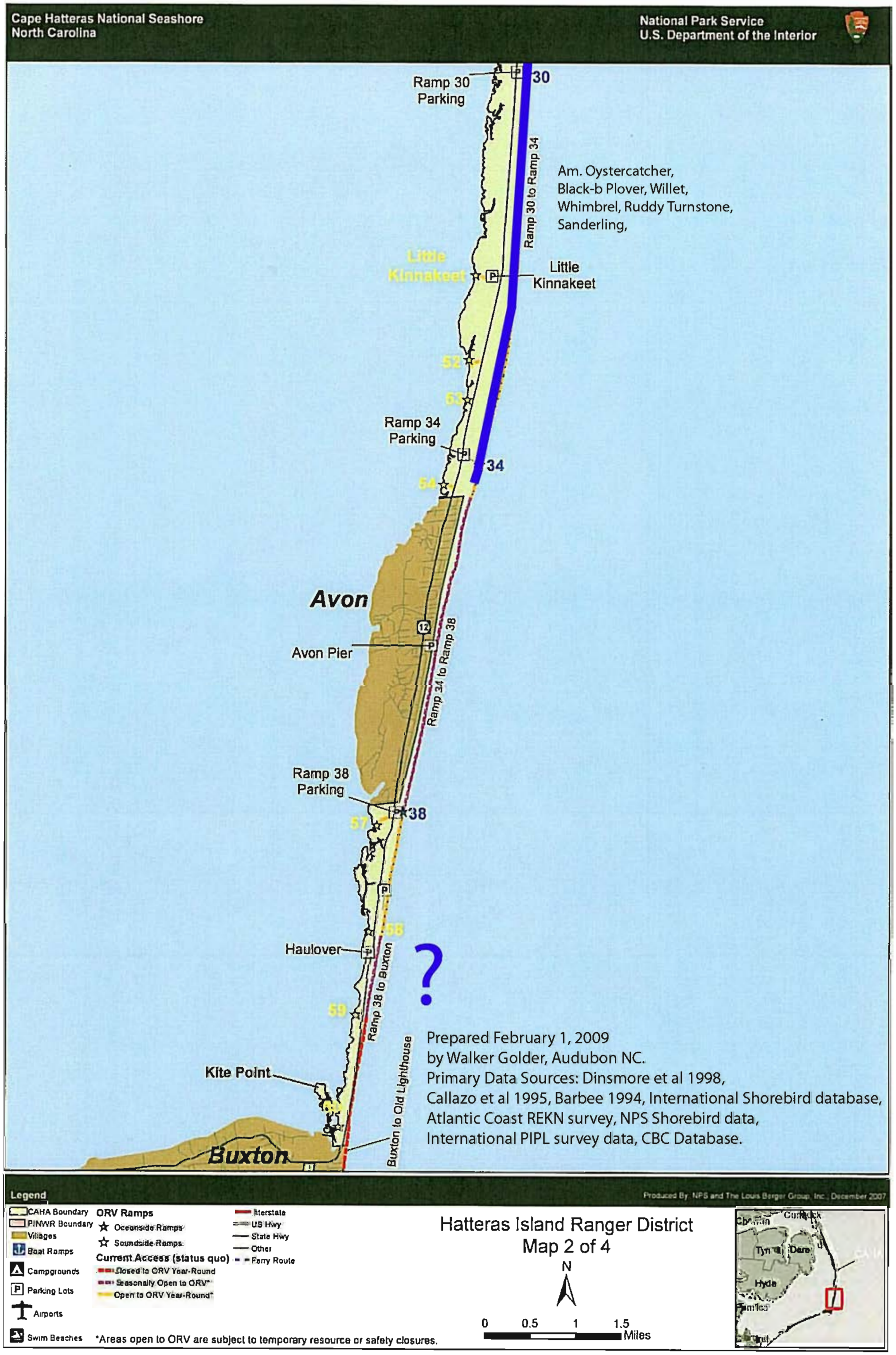
1.5
Miles
Dare
Hyde

0076466


Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Ramp 30 Parking
30
Ramp 30 to Ramp 34
Am. Oystercatcher,
Black-b Plover, Willet,
Whimbrel, Ruddy Turnstone,
Sanderling,
Little Kinnakeet
Little Kinnakeet
52
53
Ramp 34 Parking
34
54
Avon
12
Avon Pier
Ramp 34 to Ramp 38
Ramp 38 Parking
38
57
58
Haulover
?
Ramp 38 to Buxton
59
Kite Point
Buxton to Old Lighthouse
Buxton
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998,
Callazo et al 1995, Barbee 1994, International Shorebird database,
Atlantic Coast REKN survey, NPS Shorebird data,
International PIPL survey data, CBC Database.
Legend
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CAHA Boundary
PINWR Boundary
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Other
Ferry Route
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Hatteras Island Ranger District
Map 2 of 4
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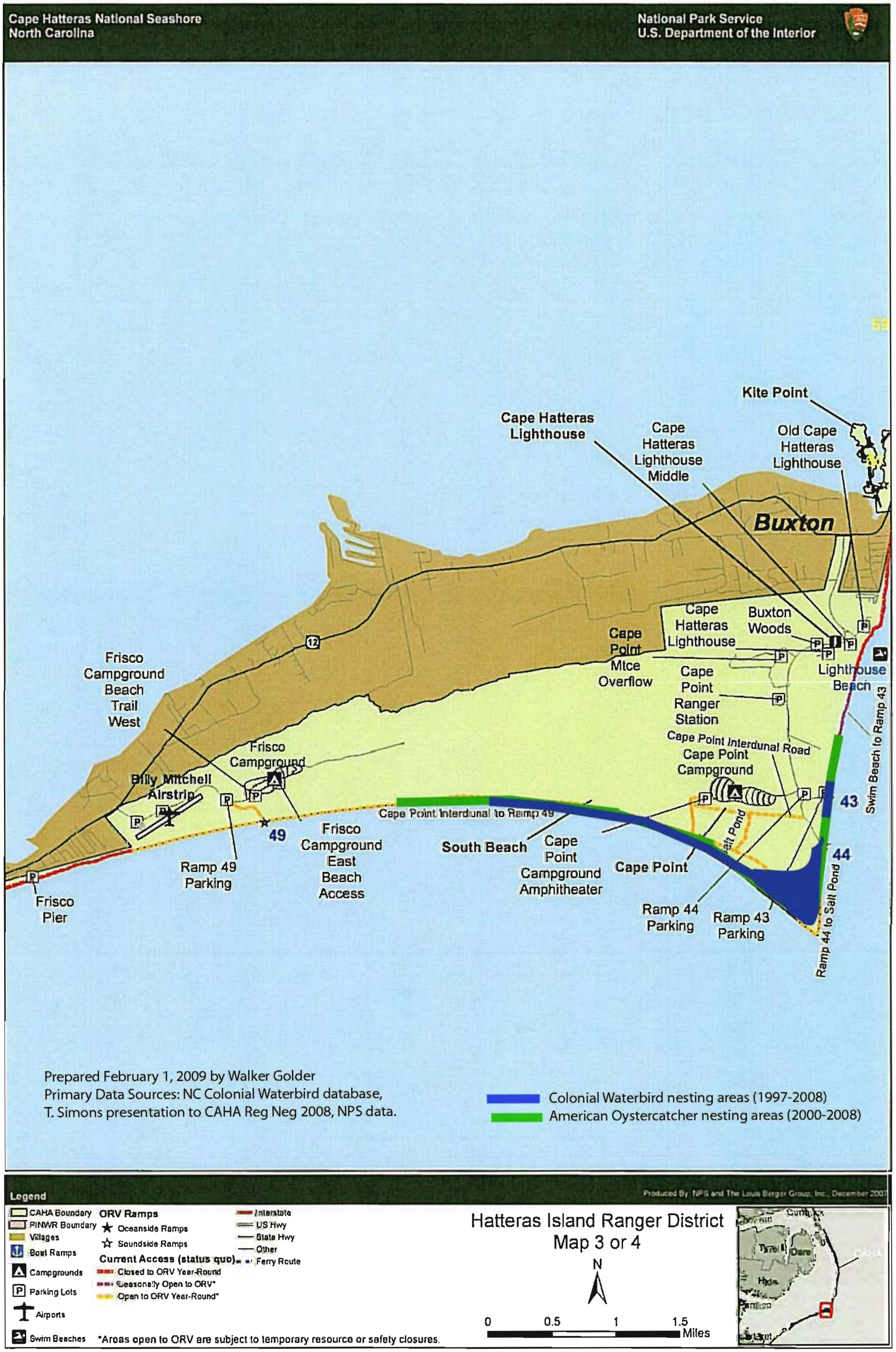
1.5
Miles
Currituck
Dare
Hyde

0076467


Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Kite Point
Cape Hatteras Lighthouse
Cape Hatteras Lighthouse Middle
Old Cape Hatteras Lighthouse
Buxton
Buxton Woods
Cape Hatteras Lighthouse
Cape Point Mtce Overflow
Cape Point Ranger Station
Lighthouse Beach
Swim Beach to Ramp 43
Cape Point Interdunal Road
Cape Point Campground
43
44
Salt Pond
Ramp 44 to Salt Pond
Cape Point
Ramp 44 Parking
Ramp 43 Parking
Cape Point Campground Amphitheater
South Beach
Cape Point Interdunal to Ramp 49
Frisco Campground East Beach Access
Frisco Campground
49
Ramp 49 Parking
Billy Mitchell Airstrip
Frisco Campground Beach Trail West
Frisco Pier
12
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
Produced By: NPS and The Louis Berger Group, Inc., December 2007
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PINWR Boundary
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Parking Lots
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Swim Beaches
ORV Ramps
Oceanside Ramps
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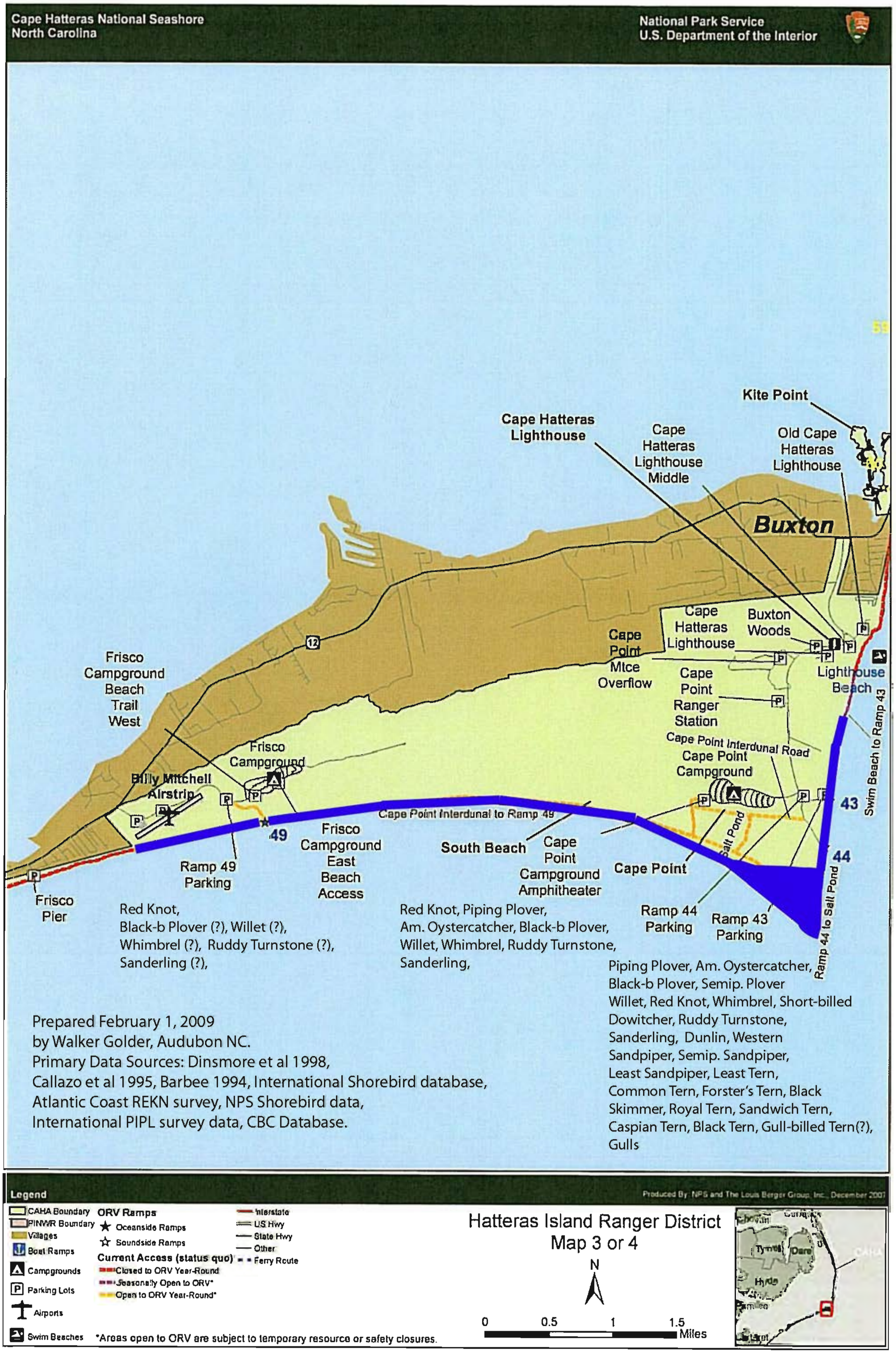
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Hatteras Island Ranger District
Map 3 or 4
N
0
0.5
1
1.5
Miles
Dare
Hyde

0076468



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Kite Point
Cape Hatteras Lighthouse
Cape Hatteras Lighthouse Middle
Old Cape Hatteras Lighthouse
Buxton
Buxton Woods
Cape Hatteras Lighthouse
Cape Point Mtce Overflow
Cape Point Ranger Station
Lighthouse Beach
Swim Beach to Ramp 43
Cape Point Interdunal Road
Cape Point Campground
Frisco Campground Beach Trail West
Frisco Campground
Billy Mitchell Airstrip
12
Cape Point Interdunal to Ramp 49
49
43
44
Salt Pond
Ramp 44 to Salt Pond
Frisco Pier
Ramp 49 Parking
Frisco Campground East Beach Access
South Beach
Cape Point Campground Amphitheater
Cape Point
Ramp 44 Parking
Ramp 43 Parking
Red Knot,
Black-b Plover (?), Willet (?),
Whimbrel (?), Ruddy Turnstone (?),
Sanderling (?),
Red Knot, Piping Plover,
Am. Oystercatcher, Black-b Plover,
Willet, Whimbrel, Ruddy Turnstone,
Sanderling,
Piping Plover, Am. Oystercatcher,
Black-b Plover, Semip. Plover
Willet, Red Knot, Whimbrel, Short-billed
Dowitcher, Ruddy Turnstone,
Sanderling, Dunlin, Western
Sandpiper, Semip. Sandpiper,
Least Sandpiper, Least Tern,
Common Tern, Forster's Tern, Black
Skimmer, Royal Tern, Sandwich Tern,
Caspian Tern, Black Tern, Gull-billed Tern(?),
Gulls
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998,
Callazo et al 1995, Barbee 1994, International Shorebird database,
Atlantic Coast REKN survey, NPS Shorebird data,
International PIPL survey data, CBC Database.
Legend
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CAHA Boundary
PINWR Boundary
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Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Hatteras Island Ranger District
Map 3 of 4
N
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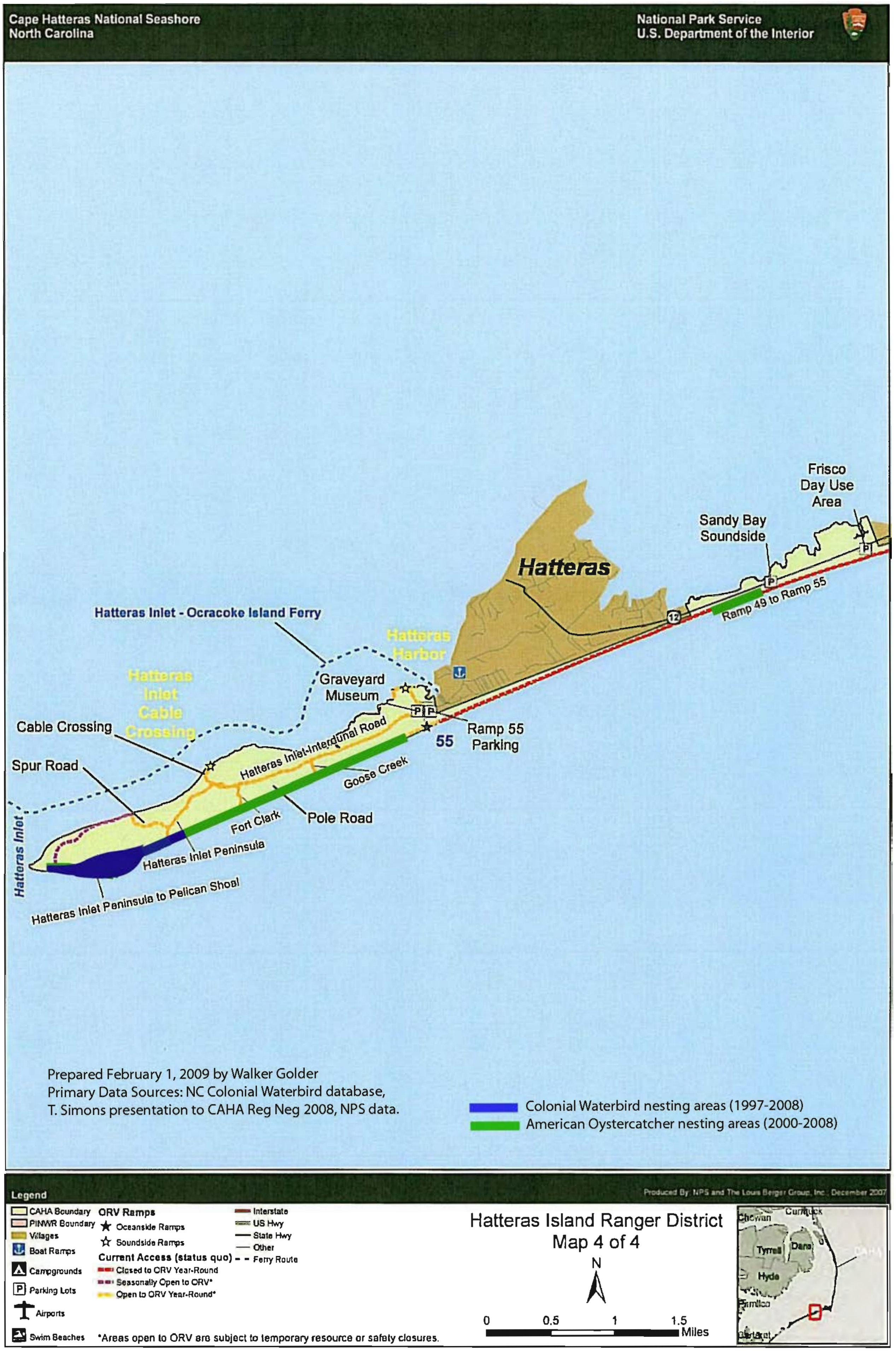
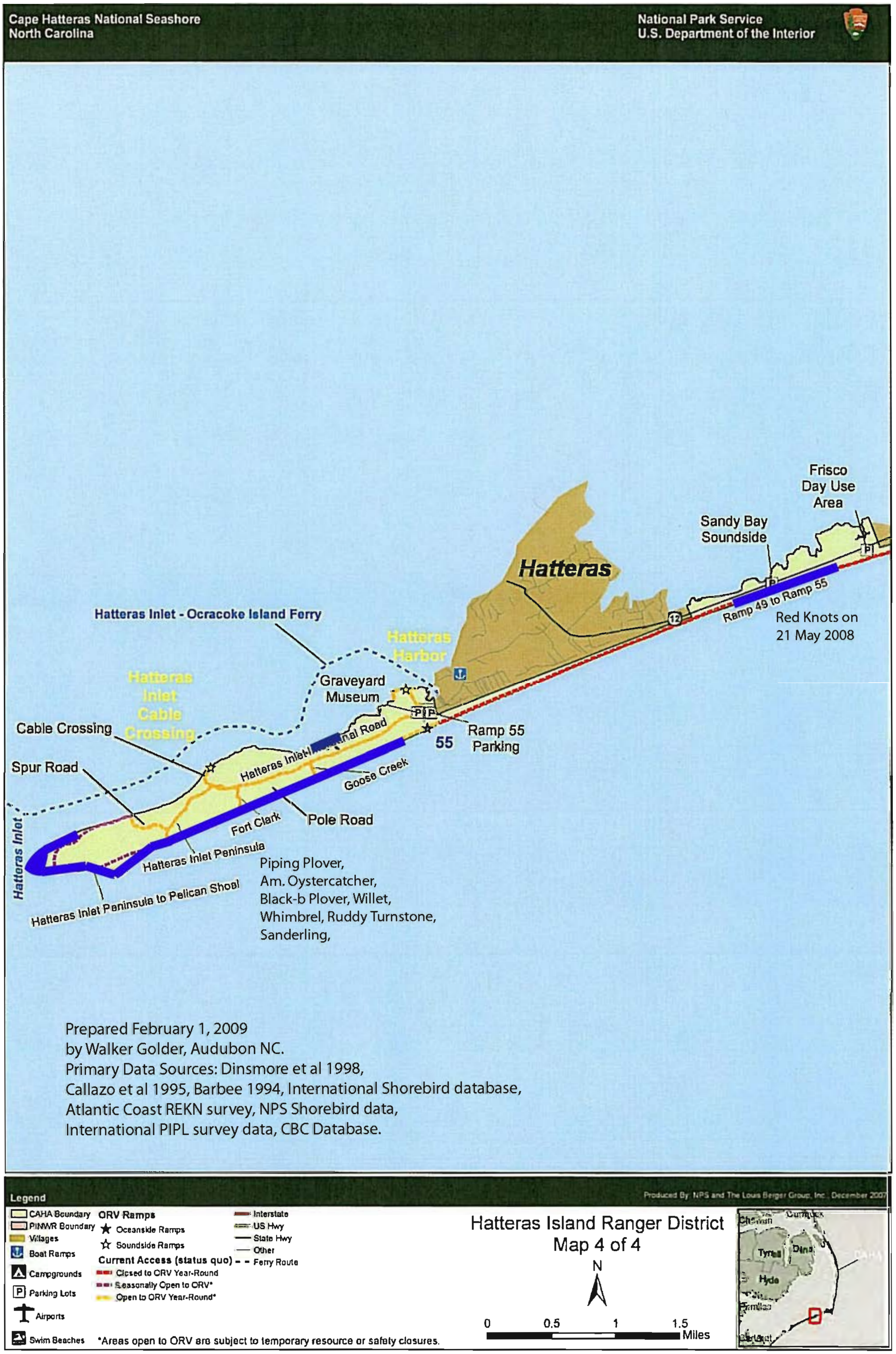
1.5
Miles
Tyrrell
Dare
Hyde

0076469

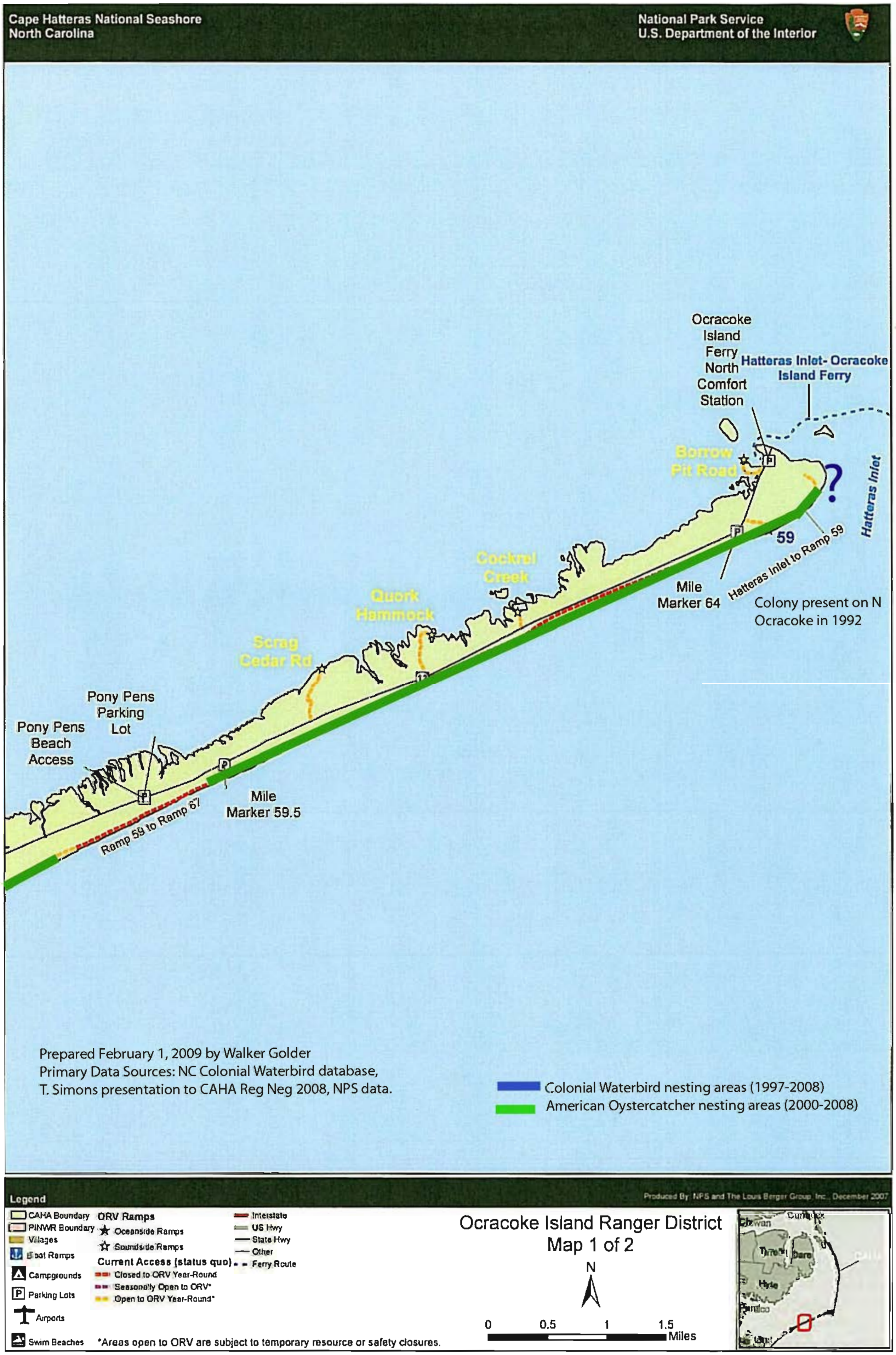

Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Frisco
Day Use
Area
Sandy Bay
Soundside
Hatteras
Ramp 49 to Ramp 55
Hatteras Inlet - Ocracoke Island Ferry
Hatteras
Harbor
Hatteras
Inlet
Cable
Crossing
Graveyard
Museum
Cable Crossing
Ramp 55
Parking
55
Spur Road
Hatteras Inlet-Interdunal Road
Goose Creek
Pole Road
Fort Clark
Hatteras Inlet
Hatteras Inlet Peninsula
Hatteras Inlet Peninsula to Pelican Shoal
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
Produced By: NPS and The Louis Berger Group, Inc., December 2007
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Hatteras Island Ranger District
Map 4 of 4
N
0
0.5
1
1.5
Miles
Tyrrell
Dare
Hyde

0076470

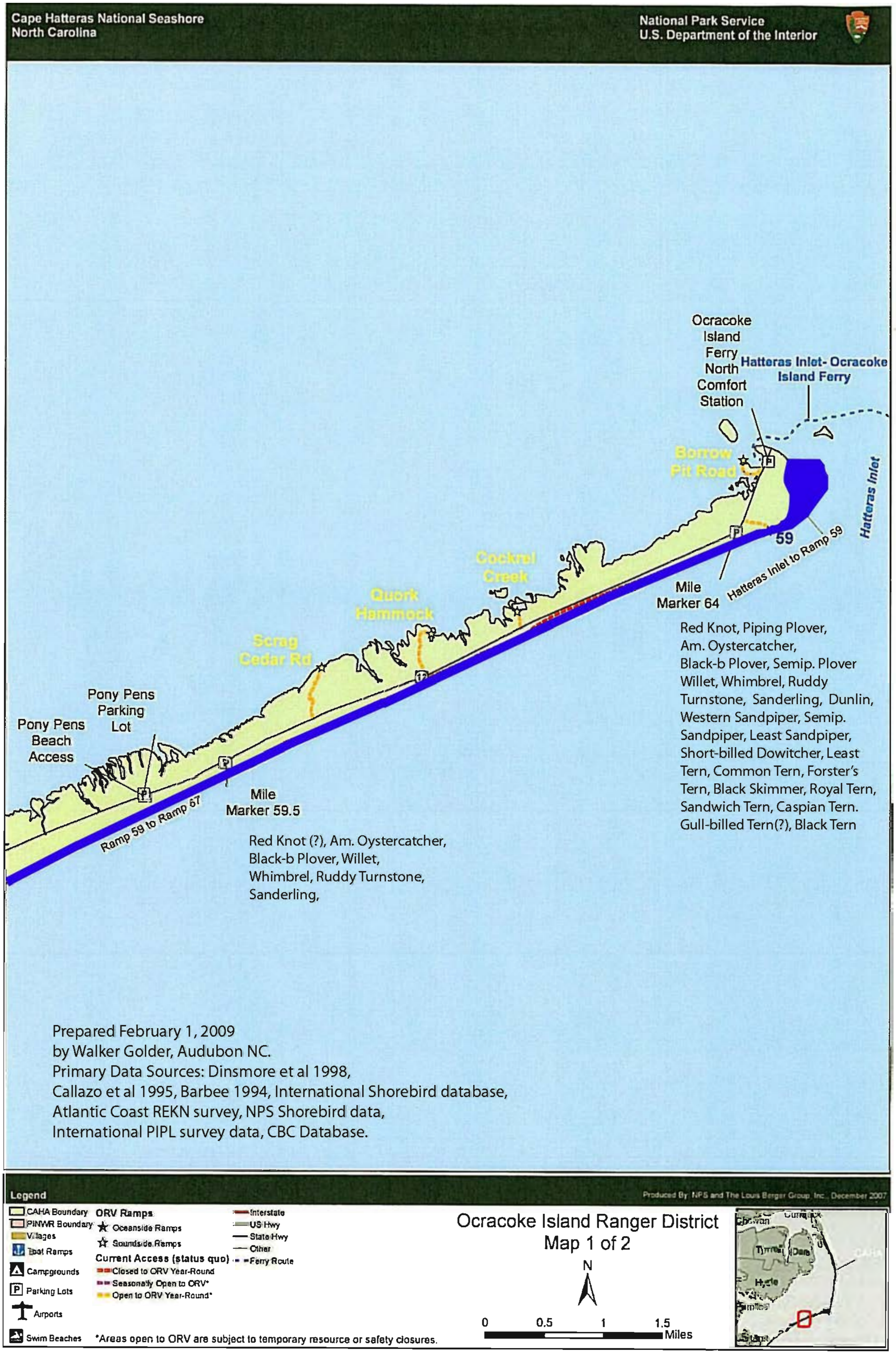


Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Frisco
Day Use
Area
Sandy Bay
Soundside
Hatteras
Ramp 49 to Ramp 55
Red Knots on
21 May 2008
Hatteras Inlet - Ocracoke Island Ferry
Hatteras
Harbor
Hatteras
Inlet
Cable
Crossing
Graveyard
Museum
Cable Crossing
Ramp 55
Parking
55
Spur Road
Hatteras Inlet
Goose Creek
Pole Road
Fort Clark
Hatteras Inlet Peninsula
Hatteras Inlet Peninsula to Pelican Shoal
Piping Plover,
Am. Oystercatcher,
Black-b Plover, Willet,
Whimbrel, Ruddy Turnstone,
Sanderling,
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998,
Callazo et al 1995, Barbee 1994, International Shorebird database,
Atlantic Coast REKN survey, NPS Shorebird data,
International PIPL survey data, CBC Database.
Legend
Produced By: NPS and The Louis Berger Group, Inc., December 2007
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Hatteras Island Ranger District
Map 4 of 4
N
0
0.5
1
1.5
Miles
Tyrell
Hyde

0076471

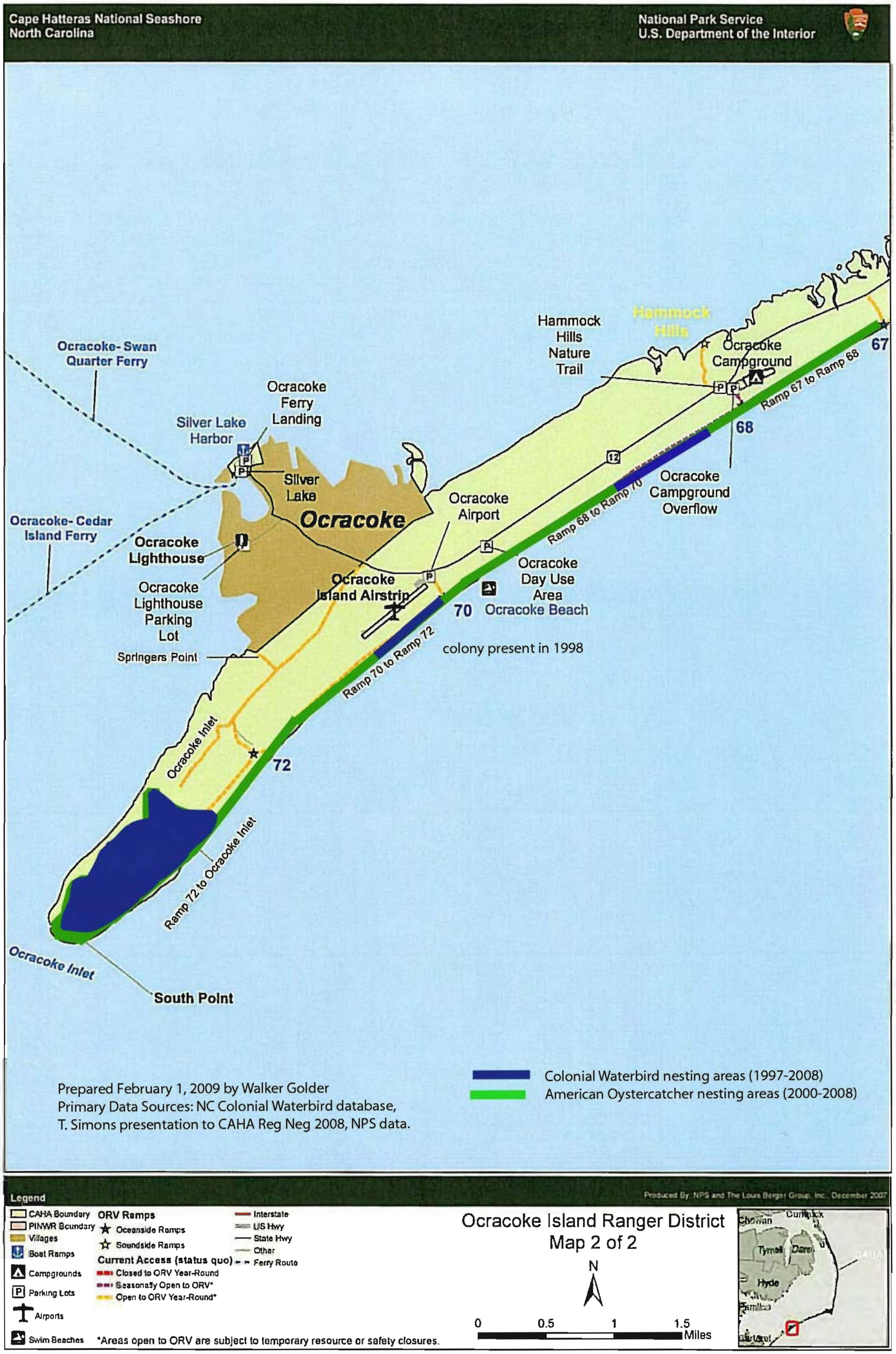

Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Ocracoke Island Ferry North Comfort Station
Hatteras Inlet- Ocracoke Island Ferry
Hatteras Inlet
Borrow Pit Road
?
59
Hatteras Inlet to Ramp 59
Mile Marker 64
Colony present on N Ocracoke in 1992
Cockrel Creek
Quork Hammock
Scrag Cedar Rd
Pony Pens Parking Lot
Pony Pens Beach Access
Mile Marker 59.5
Ramp 59 to Ramp 67
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Produced By: NPS and The Louis Berger Group, Inc., December 2007
Ocracoke Island Ranger District
Map 1 of 2
N
0
0.5
1
1.5
Miles
Hyde

0076472



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Ocracoke Island Ferry North Comfort Station
Hatteras Inlet- Ocracoke Island Ferry
Hatteras Inlet
Borrow Pit Road
59
Hatteras Inlet to Ramp 59
Mile Marker 64
Cockrel Creek
Quork Hammock
Scrag Cedar Rd
Pony Pens Parking Lot
Pony Pens Beach Access
Mile Marker 59.5
Ramp 59 to Ramp 67
Red Knot, Piping Plover, Am. Oystercatcher, Black-b Plover, Semip. Plover Willet, Whimbrel, Ruddy Turnstone, Sanderling, Dunlin, Western Sandpiper, Semip. Sandpiper, Least Sandpiper, Short-billed Dowitcher, Least Tern, Common Tern, Forster's Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern. Gull-billed Tern(?), Black Tern
Red Knot (?), Am. Oystercatcher, Black-b Plover, Willet, Whimbrel, Ruddy Turnstone, Sanderling,
Prepared February 1, 2009
by Walker Golder, Audubon NC.
Primary Data Sources: Dinsmore et al 1998, Callazo et al 1995, Barbee 1994, International Shorebird database, Atlantic Coast REKN survey, NPS Shorebird data, International PIPL survey data, CBC Database.
Legend
Produced By: NPS and The Louis Berger Group, Inc., December 2007
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
Parking Lots
Airports
Swim Beaches
ORV Ramps
Oceanside Ramps
Soundside Ramps
Current Access (status quo)
Closed to ORV Year-Round
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Ocracoke Island Ranger District
Map 1 of 2
N
0
0.5
1
1.5
Miles

0076473



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Ocracoke-Swan Quarter Ferry
Ocracoke-Cedar Island Ferry
Silver Lake Harbor
Ocracoke Ferry Landing
Silver Lake
Ocracoke
Ocracoke Lighthouse
Ocracoke Lighthouse Parking Lot
Springers Point
Ocracoke Island Airstrip
Ocracoke Airport
Hammock Hills Nature Trail
Hammock Hills
Ocracoke Campground
Ocracoke Campground Overflow
Ocracoke Day Use Area
Ocracoke Beach
colony present in 1998
Ramp 67 to Ramp 68
Ramp 68 to Ramp 70
Ramp 70 to Ramp 72
Ramp 72 to Ocracoke Inlet
Ocracoke Inlet
67
68
70
72
12
South Point
Prepared February 1, 2009 by Walker Golder
Primary Data Sources: NC Colonial Waterbird database,
T. Simons presentation to CAHA Reg Neg 2008, NPS data.
Colonial Waterbird nesting areas (1997-2008)
American Oystercatcher nesting areas (2000-2008)
Legend
CAHA Boundary
PINWR Boundary
Villages
Boat Ramps
Campgrounds
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ORV Ramps
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Soundside Ramps
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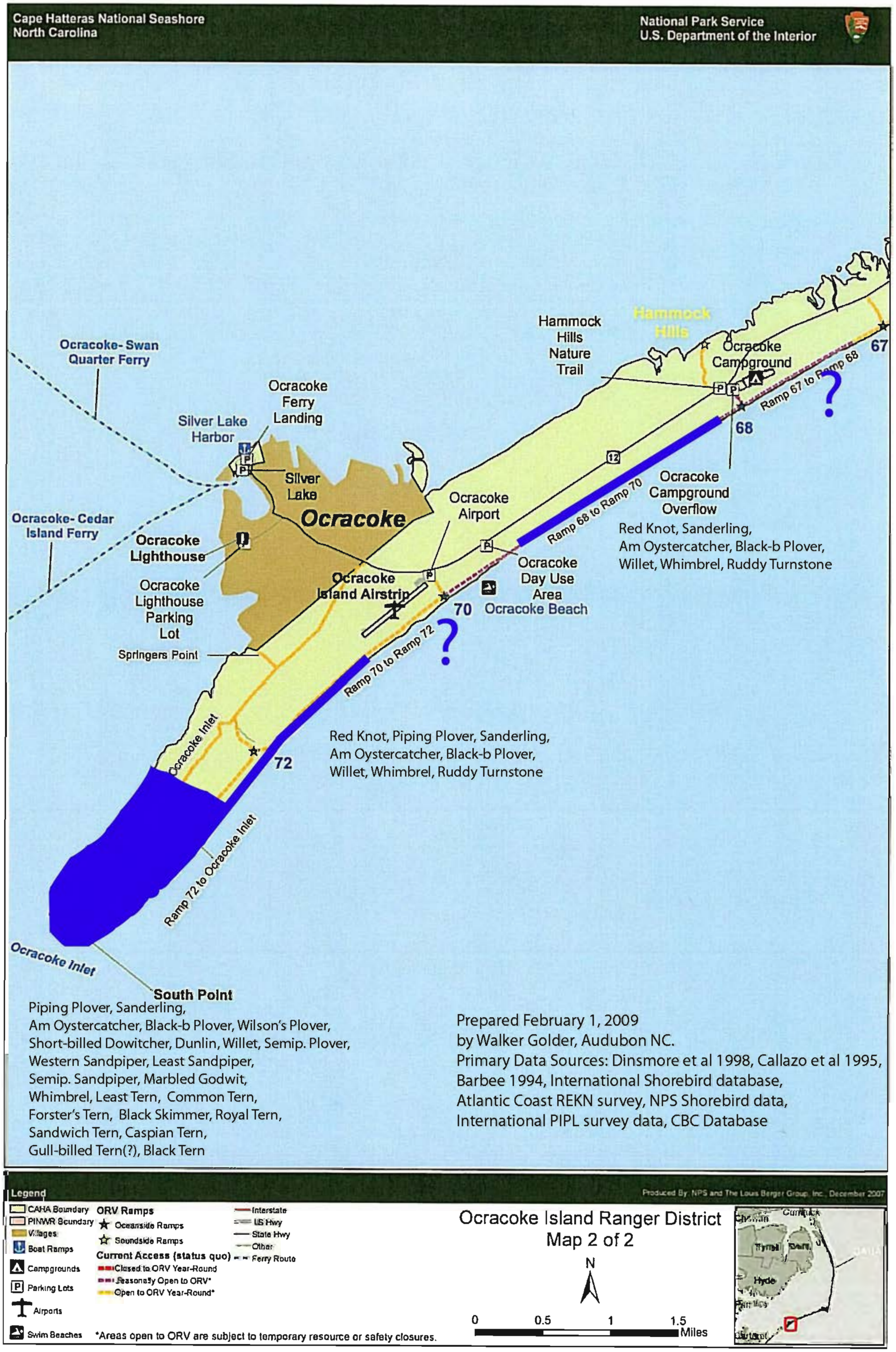
Seasonally Open to ORV*
Open to ORV Year-Round*
Interstate
US Hwy
State Hwy
Other
Ferry Route
*Areas open to ORV are subject to temporary resource or safety closures.
Produced By: NPS and The Louis Berger Group, Inc., December 2007
Ocracoke Island Ranger District
Map 2 of 2
N
0
0.5
1
1.5
Miles
Currituck
Chowan
Tyrrell
Dare
Hyde

0076474



Cape Hatteras National Seashore
North Carolina
National Park Service
U.S. Department of the Interior
Hammock Hills
Hammock Hills Nature Trail
Ocracoke Campground
67
Ramp 67 to Ramp 68
?
68
Ocracoke-Swan Quarter Ferry
Ocracoke Ferry Landing
Silver Lake Harbor
Silver Lake
Ocracoke
Ocracoke Airport
12
Ramp 68 to Ramp 70
Ocracoke Campground Overflow
Red Knot, Sanderling,
Am Oystercatcher, Black-b Plover,
Willet, Whimbrel, Ruddy Turnstone
Ocracoke-Cedar Island Ferry
Ocracoke Lighthouse
Ocracoke Lighthouse Parking Lot
Ocracoke Island Airstrip
Ocracoke Day Use Area
70
Ocracoke Beach
?
Springers Point
Ramp 70 to Ramp 72
Ocracoke Inlet
Red Knot, Piping Plover, Sanderling,
Am Oystercatcher, Black-b Plover,
Willet, Whimbrel, Ruddy Turnstone
72
Ramp 72 to Ocracoke Inlet
Ocracoke Inlet
South Point
Piping Plover, Sanderling,
Am Oystercatcher, Black-b Plover, Wilson's Plover,
Short-billed Dowitcher, Dunlin, Willet, Semip. Plover,
Western Sandpiper, Least Sandpiper,
Semip. Sandpiper, Marbled Godwit,
Whimbrel, Least Tern, Common Tern,
Forster's Tern, Black Skimmer, Royal Tern,
Sandwich Tern, Caspian Tern,
Gull-billed Tern(?), Black Tern
Prepared February 1, 2009
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Ocracoke Island Ranger District
Map 2 of 2
N
0
0.5
1
1.5
Miles
Hyde

EFFECTS OF HUMAN DISTURBANCE ON SHOREBIRD POPULATIONS OF HATTERAS, OCRACOKE, AND NORTH CORE BANKS ISLANDS, NORTH CAROLINA

Eric A. Barbee

A Thesis Submitted to the University of North Carolina at Wilmington in Partial Fulfillment of the Requirements for the Degree of Master of Science

Department of Biological Sciences

University of North Carolina at Wilmington

1994

Approved by

Advisory Committee

Chair

Accepted by

Dean, Graduate School

This thesis has been prepared in a style and format

consistent with the journal

Journal of Field Ornithology

TABLE OF CONTENTS

ABSTRACT

Impacts of human use of barrier island beaches on shorebirds along North Carolina's Outer Banks were determined during a 16-month period (April 1992 - July 1993) by observing shorebird numbers and behavior relative to human activities in six pairs of beach plots. Within each pair, one plot was open to human use and the other was closed to all human traffic. Human beach use peaked in the fall, coinciding with shorebird migration and highest shorebird numbers. Human disturbance levels decreased from time of high tide to low tide. More shorebirds were observed within plots closed to humans than in open areas. Shorebirds were also more abundant during intermediate and low-tide phases than high tide. Shorebirds spent more time foraging during periods of low and intermediate tide than at high tide. Although time spent foraging did not differ significantly between open and closed plots, high levels of human activity may have reduced shorebirds' feeding efficiency by disrupting flocking behavior along the intertidal beach. More time was spent resting on upper beach areas during high tide than during other tide phases. Resting time was reduced by nearly 50 percent in areas open to human activity. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for of shorebirds.

ACKNOWLEDGMENTS

First and foremost I wish to thank Dr. James F. Parnell for the chance to participate in this project and for giving me two of the best years of my life. His guidance and support as chairman of my graduate committee helped immensely in getting me through the program. Thanks to Dr. Lawrence Cahoon and Dr. Paul Hosier for their interest as committee members and editors on this project. I appreciate Dr. Martin Posey's patience in the face of incessant statistical questioning. Sincere thanks to Dr. Jefferey Walters, the Department of Zoology of North Carolina State University, the Department of Biological Sciences at the University of North Carolina at Wilmington, and the National Park Service for technical and financial support. Special appreciation is given to the rangers at Cape Hatteras National Seashore for making my field work both possible and enjoyable. I am especially grateful to Suzanne Wrenn for field assistance. Without her this project could not have been completed.

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INTRODUCTION

Little detailed information is available concerning effects of human use of oceanfront beach on shorebirds. Studies in the northeastern United States observed human disturbance and its effects on shorebird behavior (Burger 1981, 1986). This study was conducted in an effort to determine the impact of human recreational use of barrier-island beaches on shorebirds along North Carolina's Outer Banks. The barrier beaches of the Outer Banks face mostly east to southeast with sandy, gentle slopes. They usually experience moderate wave action in spring and summer with heavy wave action in fall and winter that can move large quantities of sand, drastically altering beach faces. The Outer Banks are not as heavily developed as many Atlantic coast beaches, providing substantial feeding and roosting habitat for large numbers of migratory shorebirds each year (Fussel and Lyons 1990). With human access to these islands greatly increased in recent years through bridge construction and ferry service, recreational use of these beaches has steadily increased (Parnell et al. 1992). Helmers (1992) found human disturbance energetically expensive to colonially nesting waterbirds as they increased attempts to avoid beachcombers, off-road vehicles (ORV's), and pets. Reduced fertility and fecundity, severe changes in social and individual behavior, increased mortality, population declines, and range reductions of colonially nesting waterbirds have been related to human disturbance along North Carolina's Outer Banks (Buckley and Buckley 1976). Because shorebirds are more susceptible to human disturbance than many other coastal birds such as gulls, terns, and waterfowl (Burger 1981), there is increasing concern about shorebirds throughout their ranges.

METHODS

Impacts of human activities on shorebird numbers and behavior were measured by comparing shorebird use of paired beach plots. Six paired plots were established: four on Hatteras Island, two on Ocracoke Island, and one on North Core Banks (Fig. 1). Within each pair, 1 plot was closed to all human activities (pedestrians, vehicles, fishing, swimming, etc.) and one plot was left open to human activity. All pairs of plots, except Cape Point (open) and North Core Banks (closed), were adjacent to each other and each measured approximately 0.5 km from end to end. Each included the beach area from dune to ocean edge. I was unable to place the plots randomly because of legal and political constraints within the national seashore. The National Park Service (NPS) designated certain segments of beach that were already closed to vehicular traffic as available for our study. These areas were subsequently closed to all pedestrian traffic as well and were posted with closure signs from the dune line to the high tide line. One site, at Hatteras Inlet (Fig. 1), did not have a previous closure. Here a closure was posted from the high-tide line to a point 70 m above the high-tide line. Pedestrian and vehicular access was permitted around this plot between the closure and the dune line. There was

Figure 1. Study sites along North Carolina's Outer Banks. Each site consisted of two paired beach plots, one open to human use and one closed to all human activities. The open plot at Cape Point was paired with the closed plot at North Core Banks.

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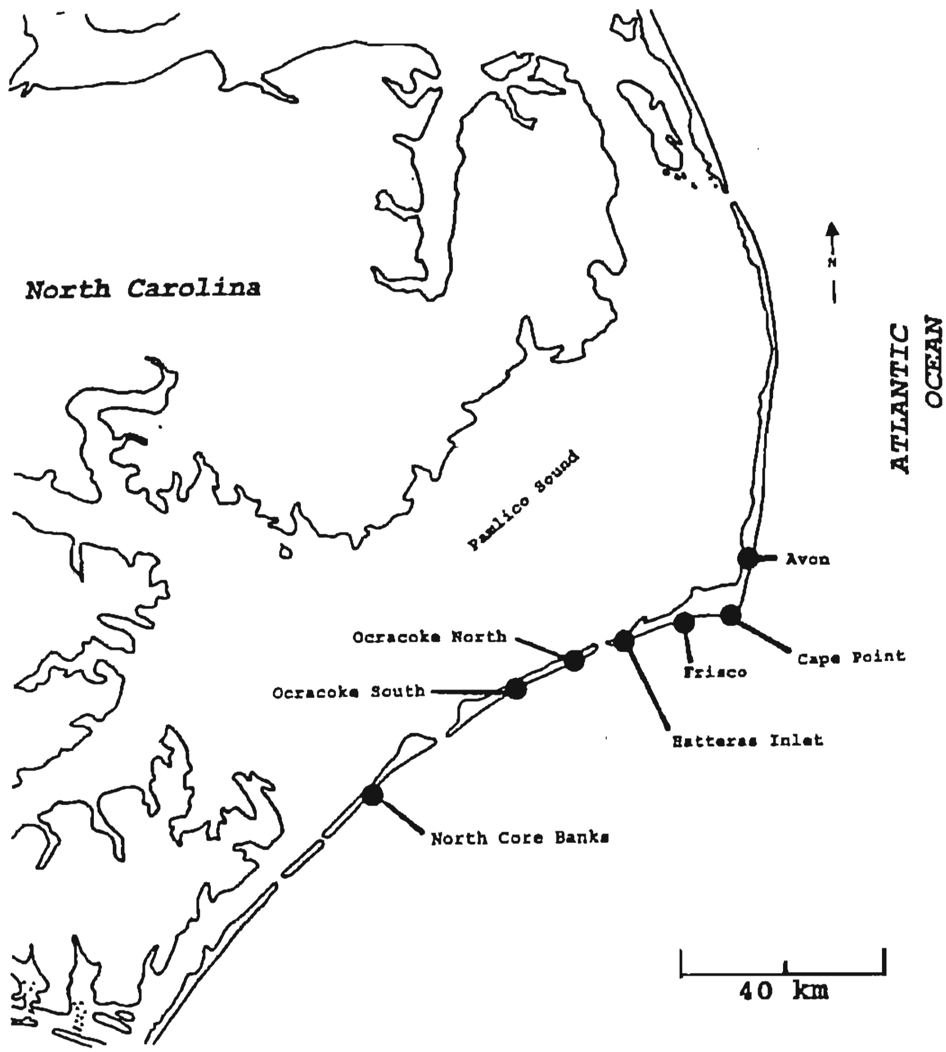


Figure 1. Study sites along North Carolina's Outer Banks. Each site consisted of two paired beach plots, one open to human use and one closed to all human activities. The open plot at Cape Point was paired with the closed plot at North Core Banks.

no prior knowledge or consideration of bird use or disturbance levels among the available sites so I think that site placement was random in relation to those factors. The limits of our site selection and dynamic nature of the barrier beach environment did not allow for physically identical plots.

Three different types of data were collected during each sampling period: 1) Species composition and abundances were gathered through census scans in which all species of birds in the plot were identified and counted. 2) Behavior was determined by focal scans during which a single bird was observed and all behavior changes recorded for 5 minutes or until the bird left the plot. Target species for focal scans were Sanderling (Calidris alba), Black-bellied Plover (Pluvialis squatarola), Whimbrel (Numenius americanus), and Red Knot (Calidris canutas). 3) Disturbances were measured by scans during which all disturbance events, human or otherwise, within the plot were recorded along with species responses. Disturbances were classified as stationary vehicles, moving vehicles, stationary humans, moving humans, and other which included disturbance events such as aircraft, boats, swimmers, surfers, and pets.

Each pair of plots was sampled three times each month; once at high tide, once at low tide, and once during an intermediate tide phase. The order of sampling between open and closed plots was determined randomly prior to the sampling period. Samples were begun 1 hour before the appropriate tide phase and concluded one hour following the same tide phase. Although many species forage at night, most shorebird species in the northern hemisphere forage during the day (Puttick 1984). My sampling was limited to tide phases occurring during daylight hours.

Census scans were conducted twice during each sampling period, once at the beginning of the hour and once at the end of the hour. After each census scan, a disturbance scan was conducted followed immediately by a focal scan. Focal scans and disturbance scans were alternated for approximately 50 minutes with a different bird observed during each focal scan. If there were not enough birds present for all 8 scans, some individuals were observed more than once. After a maximum of 8 focal and disturbance scans, the final census scan was conducted and sampling was shifted to the next plot.

Sampling was conducted from April 1992 through July 1993. During that period, 600 census scans, 2600 disturbance scans, and 2600 focal scans were conducted. Data were not collected from October 1992 - December 1992 due to the low numbers of shorebirds in the area during those months.

We expected that disturbance levels in the closed plots would be lower than in the open plots. In response to different disturbance levels, we anticipated that bird numbers, time spent foraging, and time spent resting would be different between open and closed plots. Three-way ANOVA's were used to test for significance of seasonal effects on average per scan values for census data, disturbance values, time spent resting, and time spent foraging. To nullify seasonal effects, which masked other significant trends, deviations from monthly averages were used in subsequent three-way ANOVA's testing for treatment, site, and tide effects. Student-Newman-Keuls tests were used to determine when differences between treatments, seasons, tide phases, and sites were significant.

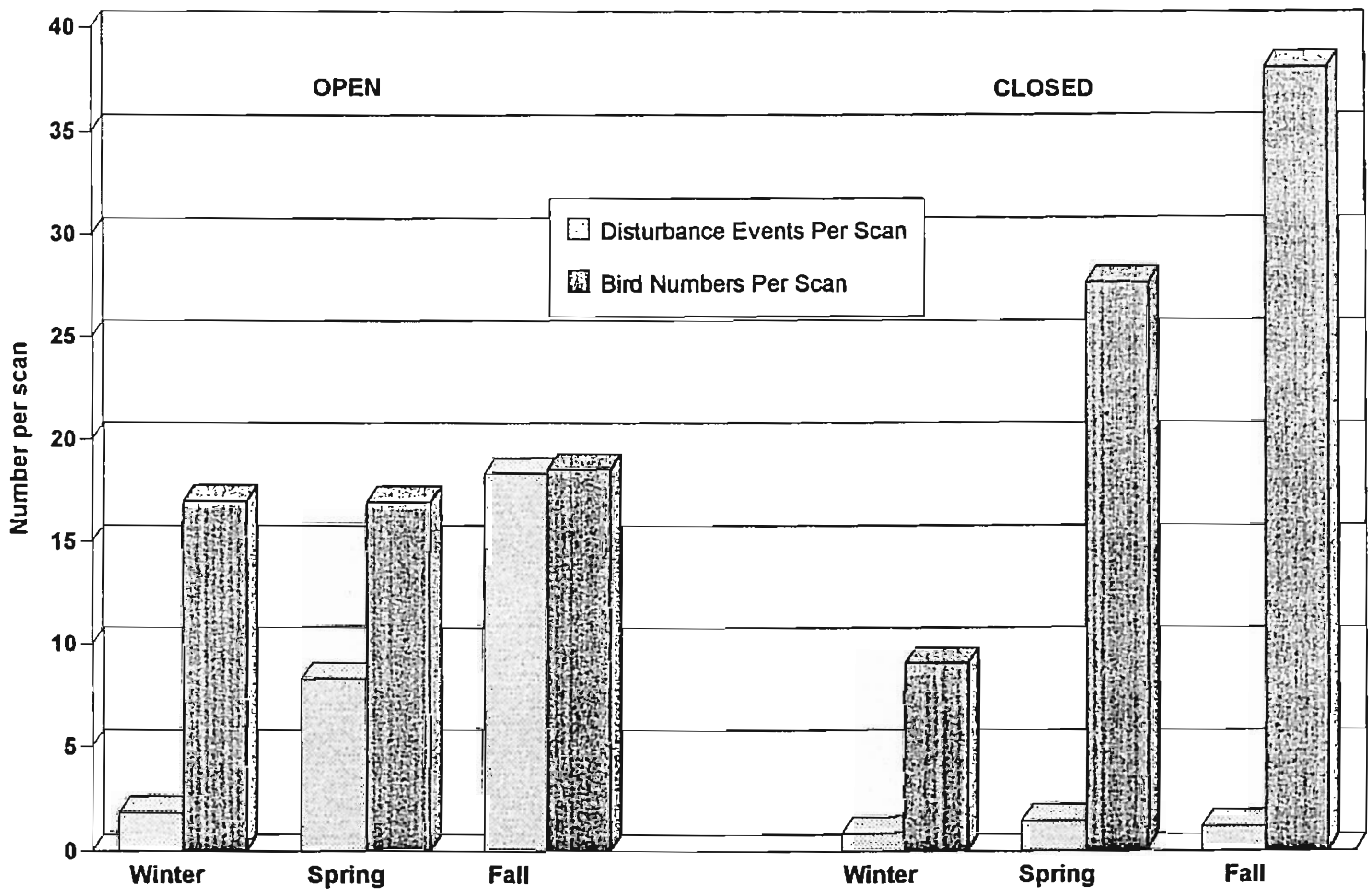
RESULTS

Disturbance levels in open plots varied by season ($F = 8.92$, $P < 0.002$, $df = 2$) with nearly 10 times more disturbance events in fall than in spring and winter (Fig. 2). Disturbance levels in closed plots were much lower and showed little seasonal variation (Fig. 2). A significant interaction occurred between treatment and season ($F = 8.01$, $P < 0.003$, $df = 2$). Although bird numbers were higher in fall than winter and spring ($F = 3.90$, $P < 0.04$, $df = 2$), the time shorebirds devoted to feeding ($F = 0.55$, $P < 0.58$, $df = 2$) and resting ($F = 2.58$, $P < 0.10$, $df = 2$) did not change with respect to season (Fig. 4).

Disturbance was consistently higher in open plots than in those closed to human activity ($F = 327.77$, $P = 0.0001$, $df = 1$) (Figs. 2 and 3). There were also variations in disturbance levels between sites ($F = 27.69$, $P < 0.0001$, $df = 5$). Disturbance events increased in number from low to high tide but those differences were not statistically significant (Fig. 3).

Shorebird numbers were always significantly higher in closed plots than in open plots ($F = 5.81$, $P < 0.03$, $df = 1$). The number of shorebirds per scan ranged between 15 and 20 in open plots (Fig. 2). Bird numbers were higher in the closed plots, with fall numbers of 35 to 40

Figure 2. Average disturbance events per scan and average bird numbers per scan during winter, spring, and fall.


OPEN
CLOSED
Disturbance Events Per Scan
Bird Numbers Per Scan
Number per scan
0
5
10
15
20
25
30
35
40
Winter
Spring
Fall
Winter
Spring
Fall

0076492

Figure 3. Average disturbance events per scan and average bird numbers per scan at high, intermediate, and low tides.

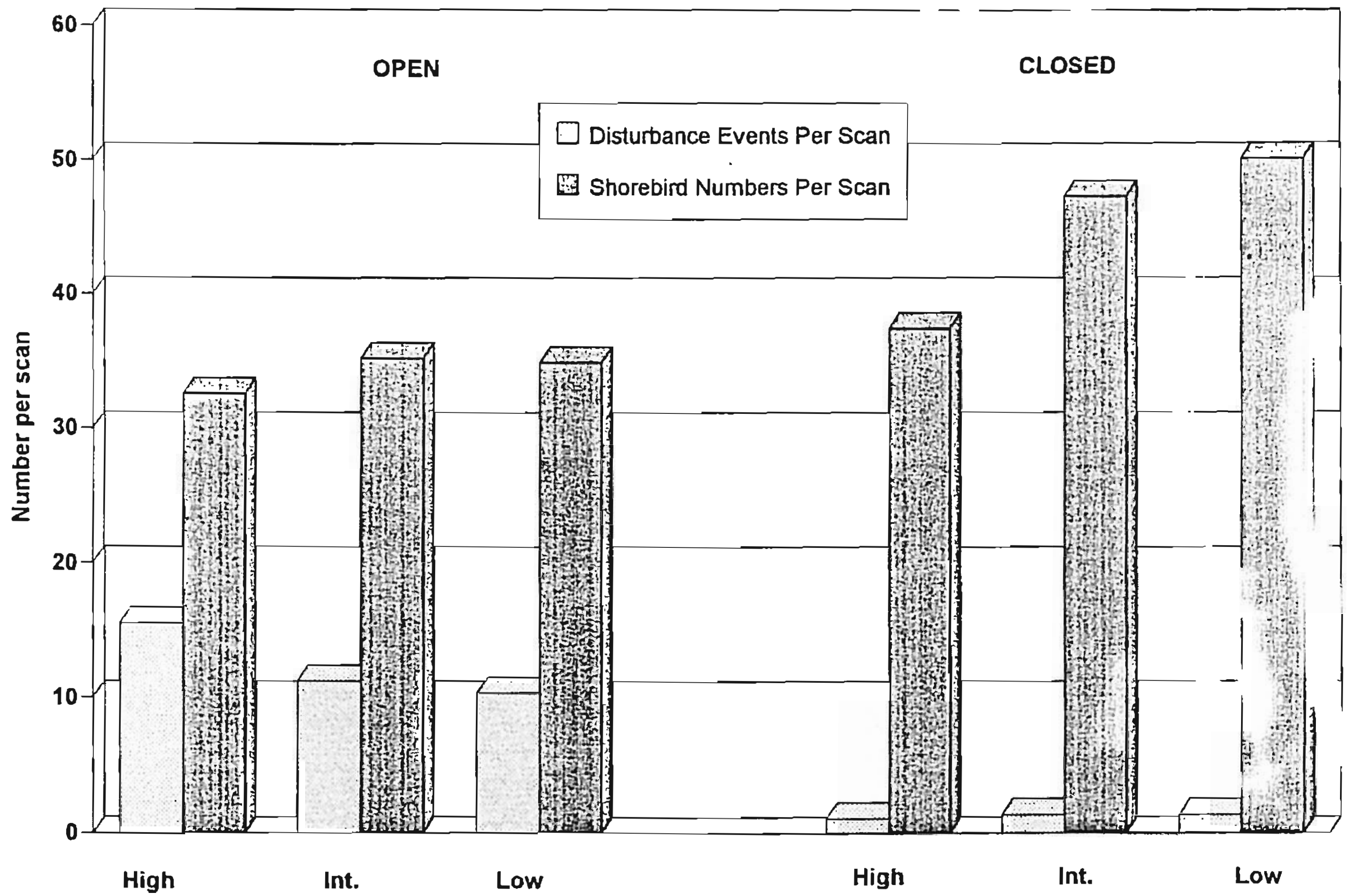
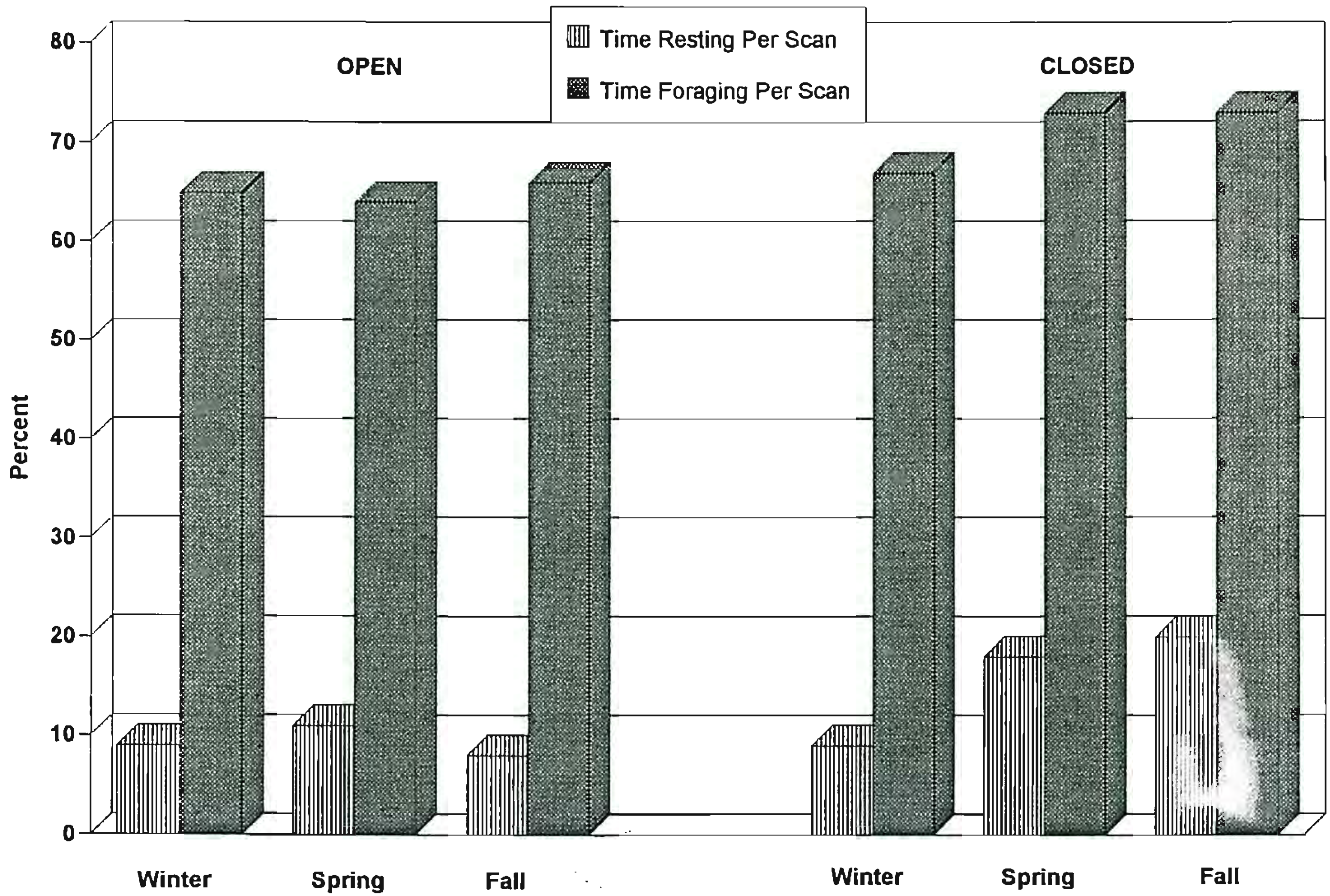

60
50
40
30
20
10
0
Number per scan
OPEN
CLOSED
Disturbance Events Per Scan
Shorebird Numbers Per Scan
High
Int.
Low
High
Int.
Low

Figure 4. Average time spent resting and average time spent foraging per scan during winter, spring, and fall.

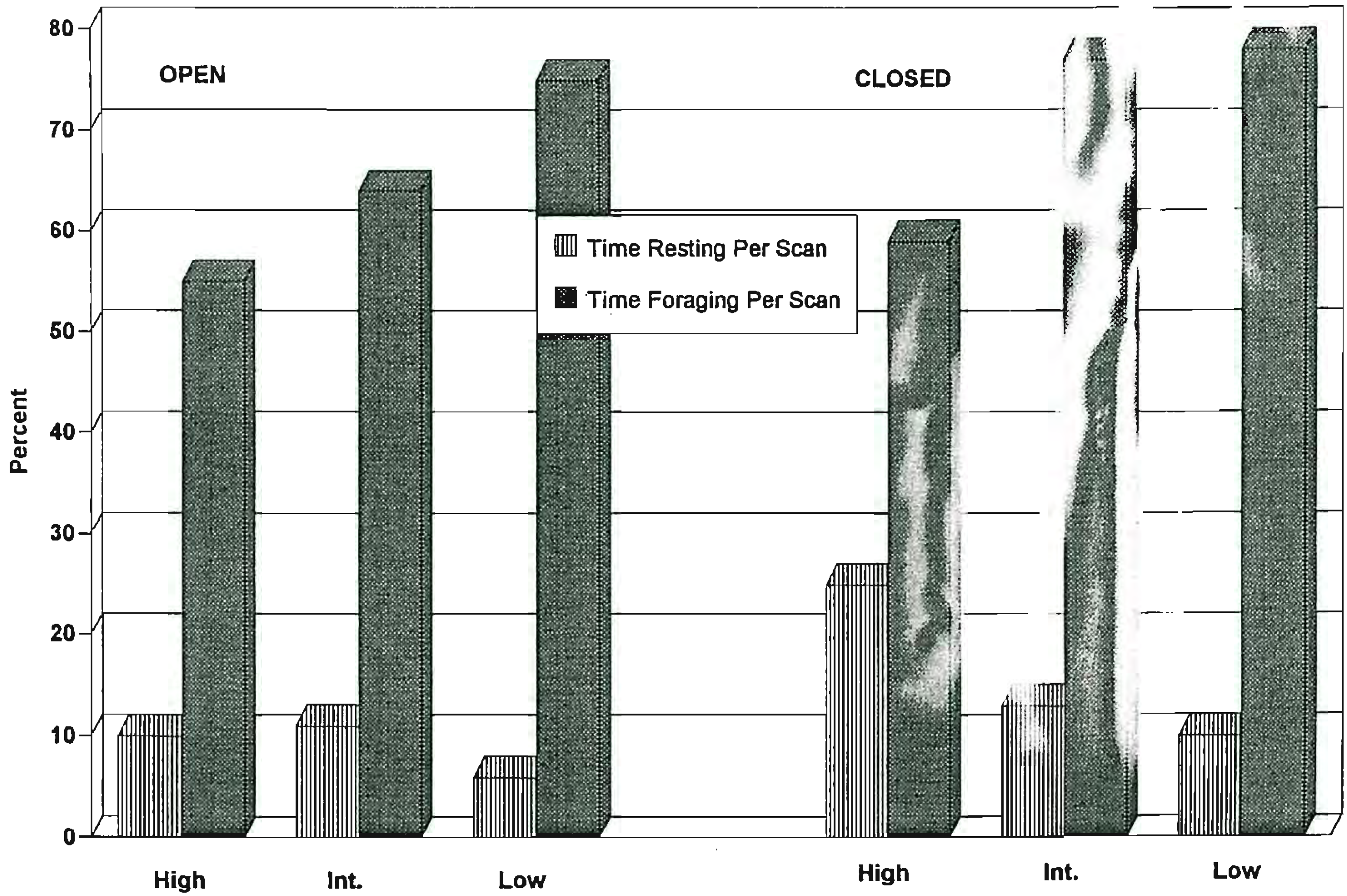

Time Resting Per Scan
Time Foraging Per Scan
OPEN
CLOSED
Percent
80
70
60
50
40
30
20
10
0
Winter
Spring
Fall
Winter
Spring
Fall

shorebirds per scan. These were nearly 4 times larger than winter values (Fig. 2). Differences in the number of individuals seen per scan also varied among sites ($F = 9.26$, $P < 0.0001$, $df = 5$). Tide effects were not significant although more birds were usually present at low tide than at high or intermediate stages (Fig. 3).

Shorebird foraging times were not significantly different ($F = 2.06$, $P = 0.1663$, $df = 1$) between open plots and plots closed to people, nor were they significantly different with regard to season (Fig 4). Time spent foraging did, however, vary significantly ($F = 13.24$, $P < 0.0002$, $df = 2$) with tide cycle (Fig. 5). Shorebirds spent more time feeding during intermediate and low tides than at high tide. There were no significant differences in foraging times among sites.

Shorebirds spent nearly twice as much time resting in closed plots than in open plots ($F = 13.42$, $P < 0.002$, $df = 1$) (Figs. 4 and 5), and significantly more time was spent resting ($F = 7.66$, $P < 0.003$, $df = 2$) at high tide than during intermediate or low tides. Resting times were similar among all sites ($F = 1.52$, $P < 0.22$, $df = 5$).

Figure 5. Average time spent resting and average time spent foraging per scan at high, intrmediate, and low tides.



Percent
80
70
60
50
40
30
20
10
0
OPEN
CLOSED
Time Resting Per Scan
Time Foraging Per Scan
High
Int.
Low
High
Int.
Low

DISCUSSION

Closing the beach to human traffic significantly reduced disturbance levels. Even at sites with the most human activity, disturbance levels in the closed plots were always much lower than in the adjacent open plots. Closed plot disturbance values averaged less than 2 events per scan for all sites, and these often represented the research assistants who needed to sit in the center of the plots in order to conduct scans. There was a significant 10:1 difference in average disturbance events per scan between open and closed plots.

Disturbance levels in open plots increased during spring and peaked in fall with disturbance levels nearly 10 times higher than winter values. Fall data were collected in July, August, and September to coincide with fall shorebird migration (Fussel and Lyons 1990) and to allow for equal sample sizes among seasons. Our findings agreed with Burger (1986) who found disturbance levels in Jamaica Bay, New York, to peak between May and August. During these peak disturbance times along the Outer Banks, it was not unusual to record up to 400 individual sources of human disturbance, including vehicles, pedestrians, fishermen, swimmers, and dogs, during a single disturbance scan in an open plot. The most disturbed plots were at Frisco and Cape Point, which were grouped together by SNK testing as having significantly higher disturbance levels than all other sites. These beaches were adjacent to campgrounds and had several nearby off-road vehicle (ORV) ramps. They were constantly used by tourists and residents because of their accessibility and proximity to the towns of Buxton and Frisco. The Avon site had the least disturbance. The nearest ORV ramp was about 2 km north of the site and there was limited pedestrian access. These differences in disturbance levels likely accounted for higher bird numbers seen at the Avon site. In Raritan Bay and Delaware Bay in the northeastern United States, Burger (1986) saw fewer birds on beaches with high levels of disturbance than on beaches with low disturbance, indicating that high disturbance levels reduced shorebirds' use of beach habitat. During winter, when disturbance levels in open plots were about the same as in closed plots, more shorebirds were observed in open areas (Fig. 2). They may have been exploiting foraging and roosting habitats that were unavailable to them during spring and fall when human activity kept them out of those areas.

Most species of shorebirds seen along the Cape Hatteras National Seashore are using those beaches as stopovers between breeding and wintering grounds. My data reflected this with higher numbers of shorebirds observed during spring and fall migrations than in winter (Fig. 2).

Shorebird numbers increased significantly during spring migration and peaked in the fall with as many as 526 shorebirds per census scan in the 0.5-km-closed study plots. Higher numbers of shorebirds were observed during fall migration than during spring. This may have been due to some species' use of different migration routes for spring and fall. Shorebirds also tend to migrate slower during fall and may have spent more time in the study area than during spring migration. Overall, average bird numbers were significantly higher in the closed plots than in the disturbed plots agreeing with Burger (1986); however, sites at Hatteras Inlet and Ocracoke North did not conform to that pattern (Table 1). Although recorded disturbance levels for the Hatteras Inlet site were low in comparison to other sites (Table 1), there were regular trespasses into this closed plot. Tire tracks through the plot and broken sign posts were observed at almost every sampling period. Beach visitors were seemingly less likely to drive or walk through closed plots when researchers were present. There were also notable differences in the physical characteristics of the beach itself. A steep scarp was formed in the closed plot at Hatteras Inlet during a winter storm. This steep beach gradient reduced the amount of usable beach for shorebirds providing little intertidal beach for foraging. The amount of foraging area is related to the number of shorebirds one

Table 1. Disturbance events , shorebird numbers, time spent foraging, and time spent resting for open and closed plots at all sites. (Numbers are averages per scan.)

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Avon	High	2.58	0.92	16.33	50.34	69.33	58.00	11.11	31.11
	Int	3.86	1.07	34.06	67.89	61.22	81.89	6.11	13.33
	Low	3.33	1.94	23.44	67.22	72.67	70.78	5.22	19.44
Cape Point and North Core Banks	High	17.17	0.78	7.56	15.25	50.67	76.17	5.11	26.20
	Int	15.86	0.98	6.00	17.38	43.89	92.00	22.44	7.60
	Low	11.79	1.09	9.28	20.88	72.22	79.67	6.78	9.60
Frisco	High	16.17	0.97	7.50	12.78	51.44	57.11	0.22	21.44
	Int	16.89	1.10	20.83	20.79	57.33	78.33	7.56	13.22
	Low	20.54	1.10	28.91	56.28	72.67	82.00	4.56	11.67
Hatteras Inlet	High	6.31	1.15	4.22	2.44	38.00	35.67	15.11	13.44
	Int	5.70	0.92	21.89	13.91	68.78	65.11	12.56	3.78
	Low	6.49	1.60	9.22	9.67	76.44	69.78	18.89	8.44

Table 1. Continued

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Ocracoke	High	5.15	1.31	34.72	8.44	63.89	52.89	7.33	21.56
North	Int	5.52	1.65	10.39	9.28	79.11	86.89	12.22	17.56
	Low	3.25	1.19	12.50	9.39	86.78	80.22	10.22	6.89
Ocracoke	High	9.43	0.98	19.33	24.50	70.56	64.44	7.56	30.22
South	Int	13.00	1.06	19.72	32.22	77.67	68.78	11.22	15.78
	Low	10.35	1.06	19.56	18.78	77.89	84.11	77.89	7.56

can expect to see in any given area (Recher 1966, Burger 1977, Puttick 1984). The upper beach area, usually used for roosting, was bordered on 3 sides by open beach with fairly heavy vehicle traffic. The open plot at Hatteras Inlet had a broad gentle slope with more intertidal foraging area and more uninterrupted roosting space. These physical conditions were likely responsible for higher shorebird numbers in the open plot than in the closed plot at the Hatteras Inlet site.

The Ocracoke North site had a wide beach in the open and closed plots and both experienced relatively little disturbance. An area between the open and closed plots had been previously closed to vehicles but not to pedestrians. Large numbers of shorebirds were regularly observed feeding and roosting in the area between the 2 plots. The birds may have utilized that section of beach prior to our study due to its lower disturbance level. A general trend was seen for birds to forage northward toward the open plot then fly back south into the closed area to forage the same section of beach repeatedly. This may have been the result of higher prey densities in that area or could have been to avoid human activities in the open plot.

Analyses of variance showed no significant differences in bird numbers or disturbance levels among tide phases. There was however, a pattern of increasing numbers of birds present from high tide to low tide as seen in other studies (Burger et al. 1977, Meyers 1984, Puttick 1984, Helmers 1992) and decreasing average disturbance levels from high to low tide (Fig. 3). The increase in bird numbers may be attributed to lower disturbance levels (Burger 1986) or to increased feeding opportunity the birds encountered at low tide (Recher 1966, Burger et al. 1977, Meyers 1984, Puttick 1984, Maron and Meyers 1985, Swennen et al. 1989, Helmers 1992) or most likely a combination of the two.

Feeding time did not vary significantly between closed plots and open plots. In open plots, however, feeding areas in the intertidal zone were often divided into small, irregularly spaced sections between groups of humans. This division of the foraging habitat did not allow shorebirds to congregate into large feeding flocks as they normally would, likely resulting in reduced feeding efficiency. In closed plots, we observed that birds were spending up to 70 percent of their time feeding in both large multispecies and single species flocks along the intertidal zone. Advantages of foraging in flocks may include enhanced feeding efficiency and increased safety from predators. In mixed species flocks, individuals may be able to expand their foraging niches and exploit the time and energy of other birds with minimal competition for food items (Recher 1966, Meyers 1984, Barnhard and Thompson 1985).

Most of the species we observed concentrated feeding efforts in the wet sand at the water's edge. Unfortunately, in open plots, this zone of intertidal beach was also heavily used by vehicle and pedestrian traffic. When interrupted by human activities, flocks would often take wing and move to a new location. When disturbed several times in succession, shorebirds were likely to abandon an area completely, as was also found by Burger (1986). It is possible that shorebirds left areas of high prey concentrations to forage less profitable habitat in an effort to avoid human disturbances. Even if shorebirds remained in areas of human activity, foraging behavior may have been adversely affected. Burger (1991) found that human disturbance negatively affected foraging activities of the Piping Plover (Charadrius melodius) resulting in a decrease in foraging time and an increase in time devoted to alertness. She suggests that this loss of foraging time caused a decrease in Piping Plover fitness.

Tides influence shorebird feeding habits directly through effects on the amount of time and space available for foraging (Burger 1977, Puttick 1984). Shorebirds along the Outer Banks spent nearly 80 percent of their time during low tide foraging (Fig. 5). That was an increase of 20 to 30 percent when compared to high tide. SNK grouping showed that foraging times during low and intermediate tide phases were significantly higher than foraging times during high tide. Shorebirds were taking advantage of increased foraging habitat resulting from lower water levels. In the northeastern United States, prey items found lower on the beach were found to be more abundant, larger, and may have provided more energy per item than at other tide phases (Puttick 1984). Since prey items exposed at lower tide levels were only available for a short time, shorebirds rarely ceased feeding during low tide phases and were less likely to fly away from disturbance. When disturbed, they usually ran a short distance but were quick to resume foraging with little time spent in alert postures. When foraging under time-stressed conditions, shorebirds tend to maximize foraging time by decreasing search time and handling time per prey item, which increases the overall intake of food (Swennen et al 1989).

Large, multispecies flocks of shorebirds used upper beach areas in undisturbed plots primarily for roosting. Those areas provided broad, flat beaches with little vegetation. Presumably the birds preferred those areas due to the reduced likelihood of predators approaching roosting flocks unobserved (Helmers 1992). In open plots, resting flocks were nonexistent or were split into smaller groups that were more susceptible to disturbance than larger flocks as was also seen by Burger (1986) along beaches of the northeastern United States. Smaller flocks were constantly running and flying to avoid humans and vehicles. With reduced resting times in disturbed plots and no changes noted in foraging times, shorebirds were expending more energy in disturbed areas to avoid pedestrians and vehicles on the beach at the expense of resting time.

Shorebirds had more resting time during high tide than at intermediate or low tide (Fig. 5). With their foraging habitat reduced by incoming tides, feeding efficiency was reduced (Helmers 1992). I observed that almost 60 percent of the shorebirds' time was still devoted to foraging, but it was done in small increments with frequent rest breaks. Often birds would stop foraging and walk to the upper beach, joining roosting flocks for several minutes before resuming foraging. It was probably more profitable for the birds to rest and wait for a falling tide that would expose more abundant prey (Helmers 1992).

Overall, I saw that the main impacts of human beach use on shorebirds in the Cape Hatteras National Seashore were displacement of shorebirds from beach habitat and interference with normal resting and foraging behaviors. The highest impacts seemed to occur during the spring and fall seasons when human beach traffic was at its peak. These times coincided with the spring and fall migrations when shorebird numbers were also highest.

Different human activities had different effects on shorebirds' behavior. Faster, erratic events such as running pets and children, seemed to upset birds more than slower, regular events such as people walking, or slow moving vehicles. This was very similar to Burger's (1986) findings in New York. Along North Carolina's Outer Banks, shorebirds seemingly ignored stationary humans and stationary vehicles on the beach, often foraging within a few feet of sunbathers and parked vehicles. Beach closures reduced impacts of human activities by allowing shorebirds to forage and roost in undisturbed habitats.

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BIOGRAPHICAL SKETCH

Eric A. Barbee was born in Charlotte, North Carolina, on 2 April 1969. Shortly thereafter, he decided he wanted to be a marine biologist. In 1987, he graduated from East Mecklenburg High School in Charlotte North Carolina. He received a Bachelor of Science in Marine Biology from the University of North Carolina at Wilmington in 1991. In 1992, he returned to UNCW for graduate school. While studying shorebird populations, he discovered his interest in wetland ecosystems. He received a Master of Science Degree in Biology in December 1994. He plans to remain in the southeastern U.S. to pursue his interests in ecosystem management.

1995

FACTORS AFFECTING REPRODUCTION AND MIGRATION OF WATERBIRDS ON THE NORTH CAROLINA BARRIER ISLANDS

Final Report

to the

National Park Service

Cape Hatteras and Cape Lookout Seashores

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PROJECT SUMMARY

This project was designed to study three aspects of the ecology of aquatic birds in the Outer Banks of North Carolina, namely, (1) to assess the seasonal abundance and distribution of aquatic birds, and for selected shorebird species, assess the relative importance of outer beach habitats on the Outer Banks; (2) study the effects of human disturbance on aquatic species using the outer beach habitats; and (3), study the breeding biology of Piping Plover (Charadrius melodus) and factors affecting their reproductive success. Over 110,000 individuals of 21 species of shorebirds were found during the study, the most abundant being Sanderling, Red Knot, and Willet. Shorebirds were most abundant in May and August and the greatest numbers occurred on North Beach. The annual and seasonal abundances of eight species of shorebirds were examined in detail. For four species (Piping Plover, Whimbrel, Red Knot, and Sanderling), the Outer Banks appear to be an important staging area for the Atlantic Coast populations. Portsmouth Flats and the Core Sound side of North Core Banks were censuses as well. A total of 27 species of shorebirds, 5 species of gulls, and 9 species of terns were detected on censuses. Shorebirds were most numerous on the flats from November to May. Several shorebird species found on the flats in moderate to large numbers (i.e. Greater Yellowlegs, Marbled Godwit, Semipalmated Sandpiper, Western Sandpiper, Dunlin, Short-billed Dowitcher) were scarce on the beaches, probably because these species preferred tidal flats over sandy beaches. Gulls were most numerous on the flats from July to November, though numbers were low compared to beach counts. Laughing Gulls were the most numerous

species, with good numbers of Herring Gulls as well. Gull diversity was similar to that of outer beaches, except that Bonaparte's Gulls did not occur on the flats. Terns were most numerous on the flats from May to October. Most were Forster's and Least terns and Black Skimmers. As with the gulls, they were probably using the flats as a roosting place. On the Core Sound side of North Core, High Hills, Mile 9 and Old Drum Inlet were censused. High Hills was the location where the highest numbers of any aquatic group was recorded. Shorebirds were most abundant during spring. Gulls did not exhibit strong seasonal patterns, with counts ranging from 50 to 100 individuals. Counts were, by and large, evenly distributed among the three count locations. Terns, in contrast, exhibited strong seasonal trends. Highest counts were recorded in spring and fall. Herons also exhibited a strong seasonal patterns of high counts during spring and fall. Additional species observed in the Flats or Core Sound-North Core were the Brown Pelican, Double-crested Cormorant, White Ibis, Canada Goose, American Black Duck, and Clapper Rail.

Another aspect of the study dealing with shorebirds was an effort to quantify the population dynamics and turnover rates of migrant Sanderlings. This species is one of the most abundant in the Outer Banks but is one exhibiting population declines throughout eastern North America. This information allow us to learn more about the role of the Outer Banks as migratory stopover and where does it fit relative to other stopover sites along the eastern seashore. A total of 964 Sanderlings was individually marked in 1993 to estimate residence probabilities and population size using the Jolly-Seber model. Birds remained on the Outer Banks, on average, about two weeks in spring and for nearly four weeks in fall. Sanderlings of two body mass classes had different residence probabilities in fall, but not in spring. The Sanderling population using the Outer Banks was estimated at 35-40,000 birds, with the majority present during fall. According to the Western Hemisphere Shorebird Reserve Network, the Outer Banks are a site of regional importance. A comparison of population estimates generated from the mark-resight study with those from beach censuses revealed that the mark-resight estimates were consistently higher. Beach counts of Sanderlings, when multiplied by a factor of 1.235, provided reasonable estimates of the number present based on the results of this study. The Outer Banks appear to be an important staging area for Sanderlings. It ranked as the site with the highest peak count during fall migration when compared to seven other sites along the Atlantic Coast. Delaware Bay in New Jersey is the only site to record higher peak counts than those on the Outer Banks. The demographic implications of these results are clear. The Outer Banks of North Carolina provide a critical link in the migratory path of several shorebird species. Significant portions of the Atlantic Coast populations of some species may depend on the Outer Banks to complete their annual migrations. This detailed study of Sanderlings hints at the implications of habitat loss or alteration on the Outer Banks. If such losses were to occur, a significant portion of the Atlantic Flyway population of sanderlings would be negatively impacted, perhaps exacerbating population declines. Other shorebird species could be similarly affected. Given the regional significance of this area, further protection for shorebirds under the guidelines of the Western Hemisphere Shorebird Reserve Network is necessary.

Impacts of human use of barrier island beaches on shorebirds along North Carolina's Outer Banks were determined during a 16-month period (April 1992 - July 1993) by observing shorebird numbers and behavior relative to human activities in six pairs of beach plots. Within each pair, one plot was open to human use and the other was closed to all human traffic. Human beach use peaked in the fall, coinciding with shorebird migration and highest shorebird numbers. Human disturbance levels decreased from time of high tide to low tide. More shorebirds were observed within plots closed to humans than in open areas. Shorebirds were also more abundant during intermediate and low-tide phases than high tide. Shorebirds spent more time foraging during periods of low and intermediate tide than at high tide. Although time spent foraging did not differ significantly between open and closed plots, high levels of human activity may have reduced shorebirds' feeding efficiency by disrupting flocking behavior along the intertidal beach. More time was spent resting on upper beach areas during high tide than during other tide phases. Resting time was reduced by nearly 50 percent in areas open to human activity. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for of shorebirds. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for shorebirds.

Colonial waterbirds are doing well at both Cape Hatteras and Cape Lookout. Both parks provide nesting habitat for significant regional populations of nesting colonial waterbirds. Reproductive success appears to be good, and the management strategy of posting colony sites and providing patrol of these sites appears to be effective. Protection of nesting sites has allowed beach nesters to be successful most years in spite of heavy use of beaches by people. This strategy is now being copied by the State of North Carolina at Ft. Fisher and is allowing nesting to be successful there as well. Primary threats to beach nesting within the national seashores appear to be overwash and vegetative encroachment. Predation, especially by mammals such as feral cats (*Felis domesticus*) and raccoons (*Procyon lotor*) may also be important occasionally. Overwash may destroy colonies when it occurs during the nesting season, but will likely be beneficial in the long run, as it helps to maintain the open sandy beach that is used by nesting terns and skimmers. Encroachment of beach nesting sights by plants is a normal part of the succession of overwash communities. Growth is slowed by frequent overwash and now by the action of ORVs. When colony sites are posted throughout the year, vegetation may grow rapidly and the period of use by nesting terns and skimmers will be shortened. Under natural conditions the birds would be expected to move to new bare areas elsewhere up or down the beach or to offshore dredged-material islands. This is much more difficult now that much beachfront is developed and dredging practices no longer result in the regular deposition of new surfaces on islands along dredging channels.

To assure that important sites where nesting birds are successful and where management is possible, we recommend that ORV traffic be allowed in such key colony sites as Cape Point, Hatteras Inlet, Power Squadron Spit, and the west end of Shackleford Island during the fall and winter to assist in maintaining the bare or nearly bare upper beach habitat necessary for nesting terns and skimmers. Terns and skimmers that nest on bare or nearly bare sites need the most assistance. Laughing Gulls, nesting in dense *Spartina patens* meadows on islands along the sound are in habitat that is abundant and that will persist for relatively long periods. These are also areas little used by people and so human disturbance is less frequent. We do recommend that such sites be posted and visited occasionally by park personnel. Herons and egrets usually nest in dense thickets along the back side of the barrier island or on old offshore islands where thickets have developed. There appears to be sufficient habitat, and such sites may be utilized for many years by nesting birds. Human disturbance is most unlikely as such places are decidedly inhospitable. Such sites should, however, be posted. The exception to the natural safety of such sites is when a site is a potential target for development as is the case for the colony near Ocracoke Village.

Because of its threatened status on the East Coast, the piping plover and its breeding success was of special interest to our study of shorebirds in CAHA and CALO. CAHA and CALO certainly represent the principal breeding sites for piping plovers in North Carolina, where productivity historically has been low. Being at a lower latitude and along the edge of the species' breeding range, habitat and conditions for piping plovers breeding in North Carolina are different than those experienced by birds in northern regions, where most previous piping plover research has been conducted. These previous studies have determined major factors that affect reproductive success in northern regions such as human disturbance, habitat loss and predation. A major goal of our study was to determine how these and other possible factors may be influencing production by piping plovers on North Carolina seashores.

We surveyed breeding population size from 1992-1994. The number of breeding pairs increased slightly at CALO and remained steady at CAHA. Reproductive success for the two seashores was quite low and was lower than the average for Atlantic coast plovers. We monitored a total of 196 piping plover nests on CAHA and CALO from 1992-1994. Of these nests, 132 (67%) did not hatch, 47 (24%) produced fledglings, and 17 (9%) hatched but fledged no chicks. Of all hatched nests, 73% fledged at least one chick. These general statistics illustrate that on CAHA and CALO, piping plover reproductive success is most strongly affected by factors reducing hatching success.

A major factor affecting hatching success was predation. Over the three years of our study, predation accounted for 34% of nest losses on CAHA and CALO. We employed predator exclosures experimentally on CALO during the 1993 and 1994 breeding seasons, and on CAHA during the 1994 breeding season. Of 46 exclosed nests, 25 (54%) hatched, and of 76 control nests, 14 (18%) hatched, which was a significant difference ($X^2 = 18.88$, $p<.0001$, df=1). Depending on prevailing weather pattern during the breeding season, flooding was an additional factor affecting hatching success, especially on CALO. In 1994, 37% of the nests found in both parks were lost due to flooding. Flooding of piping plover nesting areas is particular to North Carolina (storms of this nature are much less common in more northern areas [George Lemon, NWS; pers. com.]), and may help explain why piping plover productivity is usually low.

Observations of breeding pairs were conducted to better understand the factors of human disturbance, temperature, foraging habitat use and predation in terms of their possible effect on productivity. We also investigated the nature of interactions between adults and chicks during brood rearing in detail, in order to better understand the determinants of successful reproduction. Through our observations of incubating adults and adults tending chicks, we found that piping plovers are only rarely disturbed by encounters with vehicles, planes or humans on foot. More consequential disturbances were caused by interactions with natural predators and competitors. Due to the nature of the piping plover habitat in these two parks (containing interior washover areas which are preferred by piping plovers for nesting and foraging), interaction between humans and piping plovers is slight. At this present level of park use, park closures would likely have minimal effect on piping plover reproductive success.

Over our three year study, piping plovers in North Carolina exhibited an interesting demographic pattern: reproductive success was very low while the population numbers increased slightly. To understand this pattern, basic information on population dynamics must be ascertained. We discuss the possibilities and information needed to know how the population of piping plovers is regulated in North Carolina. Determining how the population is regulated, including and understanding of differences in biology related to an extreme southern and peripheral location, is the key to devising appropriate management.

Our brief study of piping plover breeding biology has revealed that factors affecting reproductive success in North Carolina are different than those in northern regions. Being along the edge of the piping plover's breeding range and at a lower latitude, the environment at North Carolina seashores is likely to have different conditions for survival and reproduction. Storms in the early part of the breeding season cause breeding losses and delays, and high temperatures, especially late in the breeding season, impose heat stress that may indirectly cause chick mortality. For these reasons, productivity goals set in the recovery plan (1.5 fledged chicks/pair/year), established from studies of more northern populations, are probably unrealistic for North Carolina. Still, productivity can be improved over current levels, especially through use of predator exclosures. The little information that exists suggests that more realistic productivity levels may be sufficient to increase the population.

We make the following recommendations to help enhance the populations of CAHA and CALOI: (1) Continue to use predator exclosures on all piping plover nests. (2) Monitor exclosures to record any instances of predation or accumulation of sand over the nest. If raccoons learn to dig under the fencing, the fencing should be buried deeper (eight inches instead of four). If raccoons climb the fencing, the netting should be attached more securely to the fencing (as was done in 1995 on CALO). Exclosures should be monitored at least every other day according to USFWS guidelines. If sand builds up over the nest due to the exclosure (as happened at mile 3 on CALO), the exclosure should be removed. (3) If "smart" predators (raccoons, crows, gulls) continue to cue to exclosures and consume eggs/chicks or cause nest abandonment, predator removal should be conducted where feasible. (4) Monitor mink predation on Ocracoke. Predator removal may have to be initiated to prevent the spread of the mink population. (5) Continue vegetation removal at Cape Point along the south shore of the brackish pond. To delay the regrowth of vegetation in these treated areas, it may be beneficial to use raking machinery after disking to prevent vegetative growth from cuttings. Growth of vegetation in other piping plover foraging and nesting areas of CAHA should be monitored; additional areas may need to be maintained. Preservation of interior wet and mud flats on CAHA is critical; otherwise piping plovers may only find suitable foraging habitat along the ocean intertidal zone where human disturbance is a problem. (6) At present, beach closures are unnecessary and are not likely to favorably impact breeding piping plovers on the islands. (7) Piping plover population numbers and reproductive success must be consistently monitored so that reliable population trends can be tracked as a means to determine how the NC population is maintained.

General Introduction

and

Project Objectives

The North Carolina estuaries and barrier islands extend for 500 km north (Virginia) to south (South Carolina) (Parnell and Soots 1979). The Cape Hatteras (CAHA) and Cape Lookout (CALO) National Seashores are located along the barrier islands and encompass 161 km of the islands system. These islands provide habitat for nesting, migratory and wintering waterbirds. Available information suggested that at least 20,000 shorebirds used the barrier islands as stopover areas during fall and spring each year (Senner and Howe 1984). The Outer Banks is used as wintering habitat by about 47 shorebird, seabird and wading bird species (Root 1975). Of these species, the Piping Plover (Charadrius melodus) is federally and State listed, and Sanderlings (Calidris alba), Short-billed Dowitchers (Limnodromus griseus) and Whimbrels (Numenius paeopus) have undergone significant population declines (Howe et al. 1989). The barrier islands also serve as nesting grounds for shorebirds, wading and sea birds (Coutu et al. 1990, Parnell and Soots 1979, Parnell and Shields 1990). Parnell and Shields (1990) identified 125 nesting sites for 25 species of colonial waterbirds in coastal North Carolina. Of these, 16 were located within the two National Seashores Parks (CAHA & CALO). Species nesting in the Seashores included various herons, Least Terns (Sterna albifrons), Common Terns (Sterna hirundo), Gull-billed Terns (Gelochelidon nilotica) and Black Skimmers (Rynchops nigra). Unfortunately, complementary information on migratory and wintering shorebirds for the National Seashores is not available or is fragmentary at best. Descriptive information on shorebird migrations is available for Cape Hatteras (Buckley and Buckley 1973, Boone 1988), but estimates on numbers using the National Seashores is not, especially for Cape Lookout.

Colonial nesting as well as migratory and wintering waterbirds are particularly vulnerable to habitat alterations and degradation, and human disturbance (Myers 1983, Senner and Howe 1984, Myers et al. 1987, Parnell and Shields 1990, Pfister et al. in press). Parnell and Shields (1990) documented the use of a wide array of habitats by nesting waterbirds in the barrier islands and underscored the need for habitat management and protection. Parnell et al. (1989) noted that significant habitat changes occurred in the Cape Hatteras National Seashore during the past 25 years. In particular, the abundance of grassland and sparsely vegetated upper beach has decreased, and large sections of high beach have become vegetated. Some of these changes occurred on sites that at one time had significant numbers of ground-nesting terns and shorebirds. Migratory shorebirds concentrate and depend on stopover areas to complete their annual migratory cycle. Demographic parameters such as overwintering survival rates and subsequent reproductive output can be significantly affected by the quality of these areas and their continued availability (Myers et al. 1985). These habitats are equally important to wintering waterbirds, particularly those undergoing population declines (Howe et al. 1989). Information on abundance and distribution, and nesting locations of waterbirds throughout the year is necessary to design appropriate management strategies ensure the availability of suitable habitat for this avian assemblage.

The response of waterbirds to human disturbance is complex: responses are species-specific and often seasonally dependent. Human activities may affect a species either directly by disturbing individual birds repeatedly while feeding or nesting (Pomerantz et al. 1988, Erwin 1989, Belanger and Bedard 1989 & 1990, Parnell and Shields 1990); or it may affect a species indirectly by altering the structure of its habitat (Buckley and Buckley 1973, Parnell et al. 1989), introducing new predators or competitors to the system (Kress 1983, McKitrick 1975), altering the abundance of important food sources, or contaminating critical feeding areas (Ohlendorf et al. 1979).

Human activity on Atlantic coast beaches has apparently contributed to declines of species, such as the piping plover, that use these areas for nesting (Parnell and Soots 1979, Erwin 1979, Flemming et al. 1988). This species nests and winters at Cape Hatteras and Cape Lookout National Seashores in areas that experience moderate to high levels of human disturbance (Gifford 1974 & 1977; Golder 1985 & 1986; Nicholls and Baldassare 1990a & 1990b, Coutu et al. 1990). Beaches in several areas (e.g., Parker Island NWR and Monomy NWR, Mass) have been closed during the summer months to try to remove this source of disturbance to enhance the reproductive performance of the threatened piping plover (Christopher Marsh, Coastal Carolina College, S.C., personal communication). Feral cat populations are often associated with areas of increased human activity, and therefore, in addition to restricting public access, predator exclusions have been employed to protect nests (Rimmer and Deblinger 1990).

Human activity also can disturb birds during the non-breeding seasons and may reduce their ability to obtain sufficient caloric intake, which in turn, may reduce their survivorship or reproductive output. Although most research has focused on waterfowl concentrations (Bélanger and Bédard 1990, Derksen et al. 1990), a few recent studies indicate that non-breeding shorebirds also can be adversely affected by high levels of human disturbance (Howe 1989, Pfister et al. in press). At present, species specific responses to human disturbance and the levels of human disturbance that cause significant reductions in feeding time of shorebirds are poorly understood.

The extensive and aesthetic barrier islands, of which the National Seashores are part, attract millions of tourists every year. This creates a potential conflict in some areas between human recreational use and avian species sensitive to anthropogenic activities, and the need to provide essential habitat to meet life history requirements of resident and migratory waterbirds. Thus, to manage the North Carolina National

Seashores properly, information must be available on the extent and nature of use of available habitats by resident, migratory and wintering waterbirds, on how these bird populations and human recreational use interact, and on how adverse anthropogenic impacts on bird populations can be minimized. To address these needs a 3 year project was implemented to develop baseline data to promote the conservation of essential habitat and populations of listed waterbirds and the community as a whole, while still providing the public recreational access to the two National Seashores.

Specifically, we report on the abundance, distribution and species composition of aquatic birds along the entire beach front habitats of the two Seashore Parks. Emphasis was placed on understanding the population dynamics of migrant Sanderlings and regional importance of the Seashores to this species because it represented one of the most abundant migrant species on the Seashores and because the eastern population of this species had exhibited significant population declines (Howe et al. 1989). Research efforts also focused on finding and characterizing locations of breeding aquatic species (e.g., terns, gulls) throughout the Seashores. Two major components of our research efforts were to evaluate the effects of human disturbance on shorebird habitat use and distribution, and to describe and quantify the breeding biology and factors affecting the reproductive success and viability of Piping Plovers. Finally, ancillary data were collected to fill some obvious voids in our knowledge of the avifauna of the Seashores. For instance, a complementary bird checklist was prepared for Cape Lookout Seashores to match that already available for Cape Hatteras. Also, data on abundance and species composition were collected along the sound-side of Cape Lookout (e.g., Core Sound) and at Portsmouth Flats. These data were also summarized and included in this report.

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Seasonal numbers, distribution and population dynamics of shorebirds on the Outer Banks of North Carolina.

Chapters I and II

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INTRODUCTION

Recently, attention has been focused on the conservation of many migratory bird species, including shorebirds (Myers et al. 1987). However, our lack of understanding about the factors regulating shorebird populations and our inability to estimate population sizes accurately have hampered these efforts. Without such vital baseline information, effective conservation plans cannot be formulated.

Many shorebirds are long-distance migrants, making annual migrations in excess of 25,000 km (Myers et al. 1987). These species tend to concentrate at a few stopover sites on these migrations, often in large numbers (Myers 1983, Senner and Howe 1984). Many shorebirds have evolved this migration pattern to take advantage of the short-term abundance of food resources at these sites (see Myers 1983). As the food supply is depleted or reduced at more northerly sites, birds must weigh the risks of remaining at that site versus the risks of migrating south to a site with more abundant food. Food availability is thought to be the ultimate factor responsible for causing birds to migrate (Gauthreaux 1982). Many shorebirds therefore rely on a series of stopover sites between their breeding and wintering areas, without which they could not accumulate the necessary energy reserves to complete migration (Myers et al. 1987). The critical nature of these sites to many species cannot be overemphasized. The loss of even a single site could result in significant declines in those species (Myers et al. 1987). The sensitivity of shorebird populations to the continued availability of key stopover sites is illustrated by looking at p_i^N. This simple equation states that the extinction probability of a population (p_i) is a function of its size (N), assuming that individuals die independently. In shorebirds, concentrations at key areas remove that independence and lowers the effective population size towards the number of sites (Myers et al. 1987).

Little work has focused on the dynamics of stopover sites. Several studies have ascertained patterns of food availability (e.g. Myers et al. 1980), but few have documented turnover rates and length of stay (Butler et al. 1987, Dunn et al. 1988, Holmgren et al. 1993) or annual survivorship (Boyd 1962). How these components fit with or mold migration strategies of shorebirds has not been thoroughly addressed. Alerstam and Lindstrom (1990) formulated two hypotheses (time- and energy-selected) to explain migratory patterns in shorebirds. The time-selected hypothesis proports that shorebirds may try to minimize the time spent on migration by visiting only those sites with the highest energetic returns. The energy-minimization hypothesis proposes that shorebirds will try to minimize energy expenditure during migration by departing for subsequent stopover sites as soon as they have the necessary energy reserves to complete the flight. These hypotheses highlight the importance of shorebird body condition (energy reserves) and quality of stopover sites (food availability), which in turn influence site dynamics (e.g., turnover rates). Tying together information about seasonal changes in numbers, food availability, and migratory strategies is a necessary step to fully understand the role (or importance) of stopover sites to migratory shorebirds.

This study was implemented to assess the seasonal distribution and abundance of shorebirds on the Outer Banks of North Carolina, with emphasis on the population dynamics of Sanderlings. The general objective was to evaluate the Outer Banks as a migratory stopover and wintering area for shorebirds. The study focused on four specific objectives:

1) To describe the distribution and seasonal abundance of shorebirds on the Outer Banks.

2) To estimate the turnover rates of Sanderlings during spring and fall migration on the Outer Banks, and to see if these rates are affected by body condition.

3) To provide monthly estimates (± confidence intervals) of the size of the Sanderling population on the Outer Banks and compare these with population counts obtained from beach censuses.

4) To describe the distribution and movement of Sanderlings within the National Seashores.

These objectives were met during the 1992 and 1993 field seasons. Results of the study are described in the chapters that follow. Data on the seasonal numbers of shorebirds using the Outer Banks (Chapter 1) may be used to minimize human activities on areas used by large numbers of birds. Information on the site fidelity of Sanderlings (Chapter 1) hints at the dependence on Outer Banks by this species to complete their annual migratory cycle. Information about the turnover rates and population size of Sanderlings (Chapter 2) can be used to assess (evaluate) the effectiveness of shorebird censusing techniques and the relative importance of the Outer Banks when compared to other sites. As a whole, the study adds to our knowledge about the role of the Outer Banks to migrant shorebirds and will hopefully assist the National Park Service in developing plans for their conservation.

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CHAPTER 1

SEASONAL DISTRIBUTION AND NUMBERS OF SHOREBIRDS ON

As a group, shorebirds are very diverse with at least 49 species known to breed in North America (Morrison 1984). Many of these species make annual migrations in excess of 25,000 km between their Arctic breeding grounds and wintering areas in the tropics (Myers et al. 1987). Howe et al. (1989) noted that 36 of these species spend most of the year on wintering areas. Shorebirds have low reproductive potential (Winkler and Walters 1983) but high adult annual survivorship, often 75-80% or higher (Evans and Pienkowski 1984), to offset the investment in migration.

During their annual migratory cycle, many shorebirds concentrate at a few stopover sites (Myers 1983, Senner and Howe 1984, Myers et al. 1987). These sites often provide a unique combination of food resources and habitat requirements necessary to support a large number of birds (Myers 1986, Myers et al. 1987). The fact that a large proportion of a given species' population may be concentrated at one or a few sites during migration makes them particularly vulnerable to habitat loss and degradation, and thus, to population decline (see Gill and Handel 1990). Coastal areas, where the vast majority of these sites occur, are seriously threatened by habitat alteration and destruction from human development (Senner and Howe 1984, Davidson and Pienkowski 1987). Examples of important sites in North America are Delaware Bay (Clark et al. 1993), the Bay of Fundy (Hicklin 1987), the Copper River Delta of Alaska (Isleib 1979, Senner

1979), and Grays Harbor in Oregon (Senner and Howe 1989). Unfortunately, information for other potentially critical sites is lacking, mostly because resources to implement adequate survey programs have not been available.

The Outer Banks of North Carolina constitute a prime example of an area with limited information on migratory shorebirds (Buckley and Buckley 1973, Boone 1988). An estimated 20,000 shorebirds use the Outer Banks annually during migration (Senner and Howe 1984). The most abundant species include Black-bellied Plover (Pluvialis squatarola), Willet (Catoptrophorus semipalmatus), Red Knot (Calidris canutus), Sanderling (Calidris alba), Dunlin (Calidris alpina), and Short-billed Dowitcher (Limnodromus griseus). The area serves as a wintering ground for at least fifteen species of shorebirds (Root 1975). Only four species of shorebirds are known to breed on the Outer Banks [Wilson's Plover (Charadrius wilsonia), Piping Plover (Charadrius melodus), American Oystercatcher (Haematopus palliatus), Willet].

The Outer Banks attract millions of tourists every year and are subject to ever increasing development pressures. These factors may lead to conflicts between human uses and the conservation needs of resident and migratory shorebirds. To aid in the development of conservation measures for the Outer Banks, baseline data on the seasonal abundance and distribution of shorebirds using outer beach habitats were collected during 1992 and 1993. Outer beach habitat was the most abundant shorebird habitat on the Outer Banks, with relatively few birds using other habitats such as tidal flats and freshwater impoundments. Therefore, this study focused on species that were highly dependant on outer beach habitat. Information on the shorebird community as a whole, and the eight most abundant species, is presented here. Special attention was given to four species of concern (Piping Plovers, Whimbrels, Red Knots, and Sanderlings). Conservation needs of these species are heightened because of their endangered status (Piping Plover), recent population declines [Whimbrel (Numenius phaeopus) and Sanderling] (Howe et al. 1989), and their localized distribution along the Atlantic Flyway (Red Knot) (Morrison and Harrington 1992). In this study, the population size and turnover rates of Sanderlings were estimated using mark-resight techniques (Chapter 2). Using color-marked individuals, detailed information on the distribution and site fidelity of Sanderlings was gathered and is presented here. To assess the relative regional importance of the Outer Banks to the four species of special interest, peak counts from this study were compared to those obtained through the International Shorebird Survey (ISS, Manomet Observatory for Conservation Science) at seven selected sites along the Atlantic Flyway.

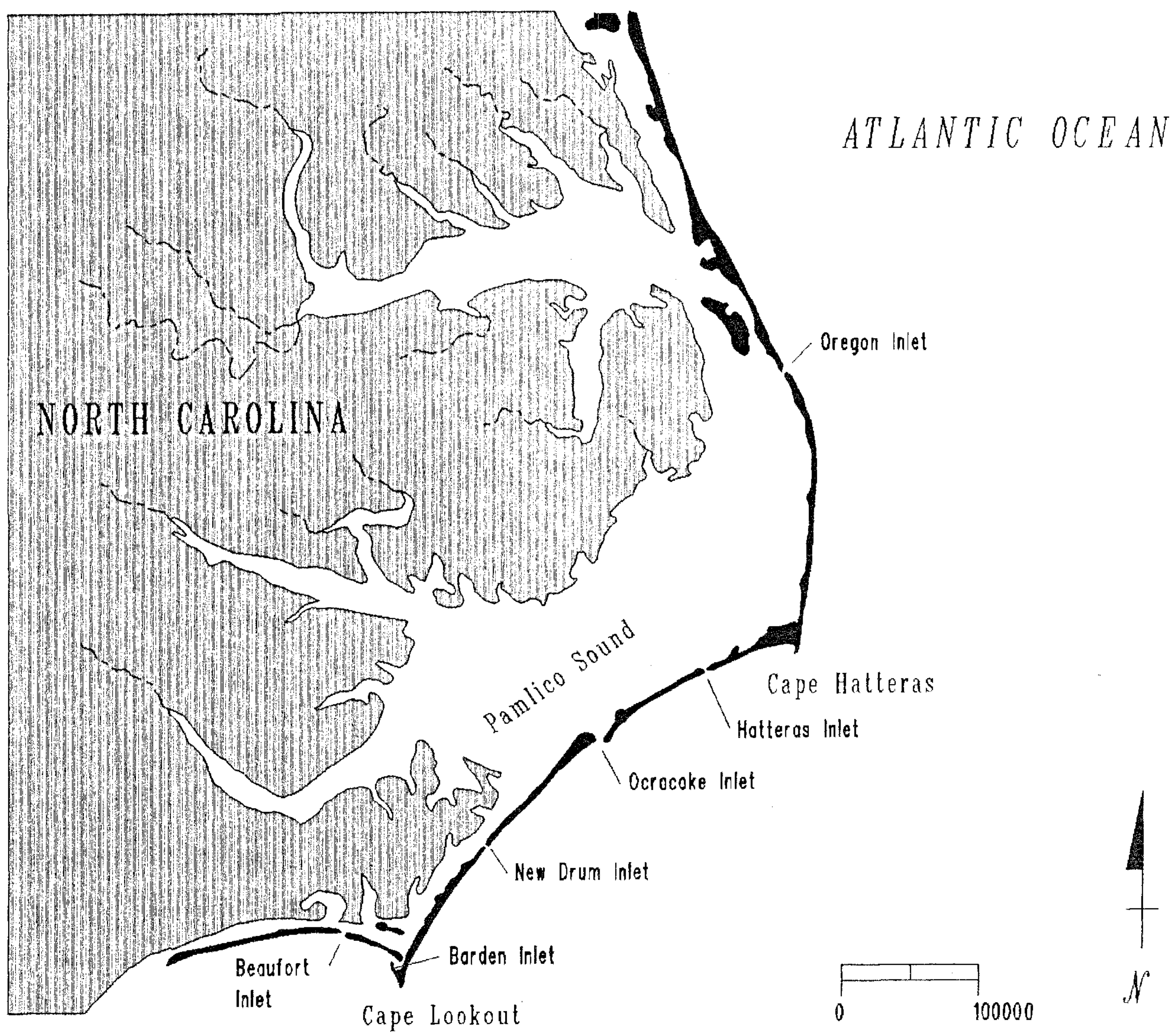
METHODS

Study Area

The Outer Banks are located along the east-central coast of North Carolina (34°34'-35°50' N lat., 75°27'-76°39' W long., Figure 1). The area consists of a series of narrow barrier islands of approximately 228 km in length, stretching from just north of Oregon Inlet in Dare County to Beaufort Inlet in Carteret County. Much of the area is included in Cape Hatteras and Cape Lookout National Seashores. Because of accessibility, this study was restricted to the northern portions of the Outer Banks north of New Drum Inlet. The topography is typical of barrier islands, with a low elevation and flat relief. Outer beach occupied by shorebirds is defined as the area from the base of the dune line to the ocean edge, including that portion of the intertidal zone exposed at low tide. Soundside tidal flats at inlets or other mudflat habitats were not surveyed since small numbers of shorebirds used those habitats. Mean tidal amplitude is approximately 1 m.

Censuses

From March 1992 to December 1993, five outer beach sites ranging from 9-34 km in length were surveyed. Bodie Island (9 km) extended from the south edge of Nags Head south to Oregon Inlet. North Beach (28 km) extended from the Rodanthe pier south to a point 1 km north of the Buxton town limit. South Beach


ATLANTIC OCEAN
NORTH CAROLINA
Oregon Inlet
Pamlico Sound
Cape Hatteras
Hatteras Inlet
Ocracoke Inlet
New Drum Inlet
Barden Inlet
Beaufort Inlet
Cape Lookout
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N

(24 km) extended from just south of the Cape Hatteras lighthouse south to Cape Hatteras point, then west to Hatteras Inlet. Ocracoke Island (28 km) included the entire island from Hatteras Inlet south to Ocracoke Inlet. North Core Banks (34 km) included the entire island from Ocracoke Inlet south to New Drum Inlet. The total amount of outer beach surveyed monthly for shorebirds was 123 km. Additionally, a stretch of Pea Island National Wildlife Refuge (19 km) extending from the Oregon Inlet jetty south to Rodanthe was censused during the fall 1993 season.

Surveys were conducted twice per month by vehicle. All surveys were begun 1.5 h before low tide, except for two counts on North Core Banks in July and August 1992 that were begun 1.5 h before high tide. Numbers of all shorebirds present on the outer beach were recorded. Flying birds were not recorded, unless they were clearly disturbed by the person(s) conducting the census. Since large shorebird concentrations (>500 birds) were rare, data here represent actual counts and not estimates.

Abundance was expressed as the mean of the two monthly censuses. This minimized variance problems associated with repeated measures within month. For a few sites, there was only one count in a given month and this was treated as the estimate for that month. Annual and seasonal numbers were obtained by summing monthly counts. Abundance data were expressed in two ways. First, annual patterns of abundance are described for each of the eight shorebird species. Second, a model was developed to test for seasonal patterns in abundance. In this model, seasons were defined as spring (April-June) and fall (July-November). These seasons span the major migration periods for the species examined. The effects of site and year on the variability of monthly counts were tested. Month, a repeated measure within season, was nested under the appropriate factor in the nested factorial ANOVA model. To reduce count variance, data were log or square root transformed. The most appropriate transformation was determined by examining plots of residuals. The relative abundance of the eight shorebird species (birds/km) was also calculated for each site.

Peak fall counts of Piping Plovers, Whimbrels, Red Knots, and Sanderlings obtained during this study were compared to similar counts obtained at seven other sites, except Delaware Bay, along the Atlantic Coast and the Gulf Coast of Florida. Counts were obtained from International Shorebird Survey (ISS) data for the fall migration period (July to November) in 1972-92. Delaware Bay was excluded because counts at this site were not represented in the ISS data set. Only marine sites surveyed over at least nine years were used for these comparisons. Censuses at ISS sites were generally conducted at 10-day intervals. Since sampling effort was variable, the peak count of each species was treated as the estimate for the site (see Colwell and Cooper 1993). Counts obtained during this study were ranked with counts for the other seven sites to assess the importance of the Outer Banks to each of these species.

Distribution and site fidelity of Sanderlings

To examine the seasonal distribution and site fidelity of Sanderlings, birds were color-marked during 1992-93. Sanderlings were caught primarily with a rocket net, though some were initially caught in mist nets. Most birds were caught at roost sites where they were herded in front of the rocket net for capture. A few were caught as they concentrated at foraging areas along the outer beach. Birds were removed from the net immediately after capture and transferred to cardboard holding boxes. All birds were fitted with an aluminum U.S. Fish and Wildlife Service leg band and a series of either four (1992) or three (1993) color bands arranged in a unique combination. The color bands were U.V. stable PVC bands (A.C. Hughes, London, England). Combinations were derived from six and ten possible colors during 1992 and 1993, respectively. Color band seams were melted together to reduce the possibility of band loss. Birds were released at the capture site within three hours of capture.

Because of seasonal changes in distribution, Sanderlings were trapped at North Core Banks in spring and at four sites on Cape Hatteras National Seashore during fall. Trapping efforts were from 28 April-27 May and 29 July-16 October in 1992 and from 22 April-23 May and 27 July-4 November in 1993.

Surveys for marked birds were done by four-wheel drive vehicle. During surveys, complete and partial color band combinations were recorded, as well as the number of unmarked birds examined for color bands. Very large (>500 birds) concentrations of Sanderlings were rare, which increased the ease of examining birds for color bands. The within-season site fidelity of Sanderlings was examined during fall 1993. During that season, birds were marked at Bodie Island, Pea Island, North Beach, and South Beach. Resighting efforts were conducted on all sites except North Core Banks. Only birds resighted at least once in each of two different capture periods were used in this analysis. A bird was site-faithful if at least two thirds of the resightings were from the banding site. The percentages of birds that were faithful to their banding site are reported by banding location.

The inter-annual site fidelity of Sanderlings was examined by looking at 1993 resightings of birds banded in 1992 at North Core Banks, Bodie Island, and North Beach. Only birds resighted after April 1, 1993 were used since most overwinter mortality should have occurred by then. Resighting probabilities were assumed to be equal between sites. Birds resighted at >1 location in 1993 were excluded from this analysis. This resulted in the loss of 117 birds, or 31% of those resighted in 1993. A chi-square test for homogeneity of resightings by location was computed for each of the three locations. Given three sites (A,B,C), the observed values for each site were calculated by determining the number of birds marked at a given site (e.g., site A) and resighted at sites A, B, and C. The same calculations were made for birds marked at sites B and C. The expected value for each test was then the sum of the marked birds seen at each site divided by the number of sites. In each case, the denominator was three, and each test had 2 degrees of freedom.

RESULTS

Shorebird Assemblage

A total of 21 species was recorded on surveys (see Appendix 1). Species richness was slightly greater in fall (n=21) than in spring (n=18). A total of 52,651 shorebirds was recorded on censuses during 1992 and an additional 58,935 shorebirds during 1993. Surveys revealed that Sanderling, Red Knot, and Willet were the most abundant shorebird species in Outer Beach habitat and accounted for 89% of the total numbers counted. Sanderlings were the most abundant species and accounted for 68% of the total.

Shorebirds were present on the Outer Banks throughout the study, though numbers peaked during May in spring and from July to September in fall. Seasonally, shorebirds were most abundant in May and August with the fewest recorded during June ($F_{12,46}$=4.93, P<0.0001) (Figure 2). Shorebird numbers varied

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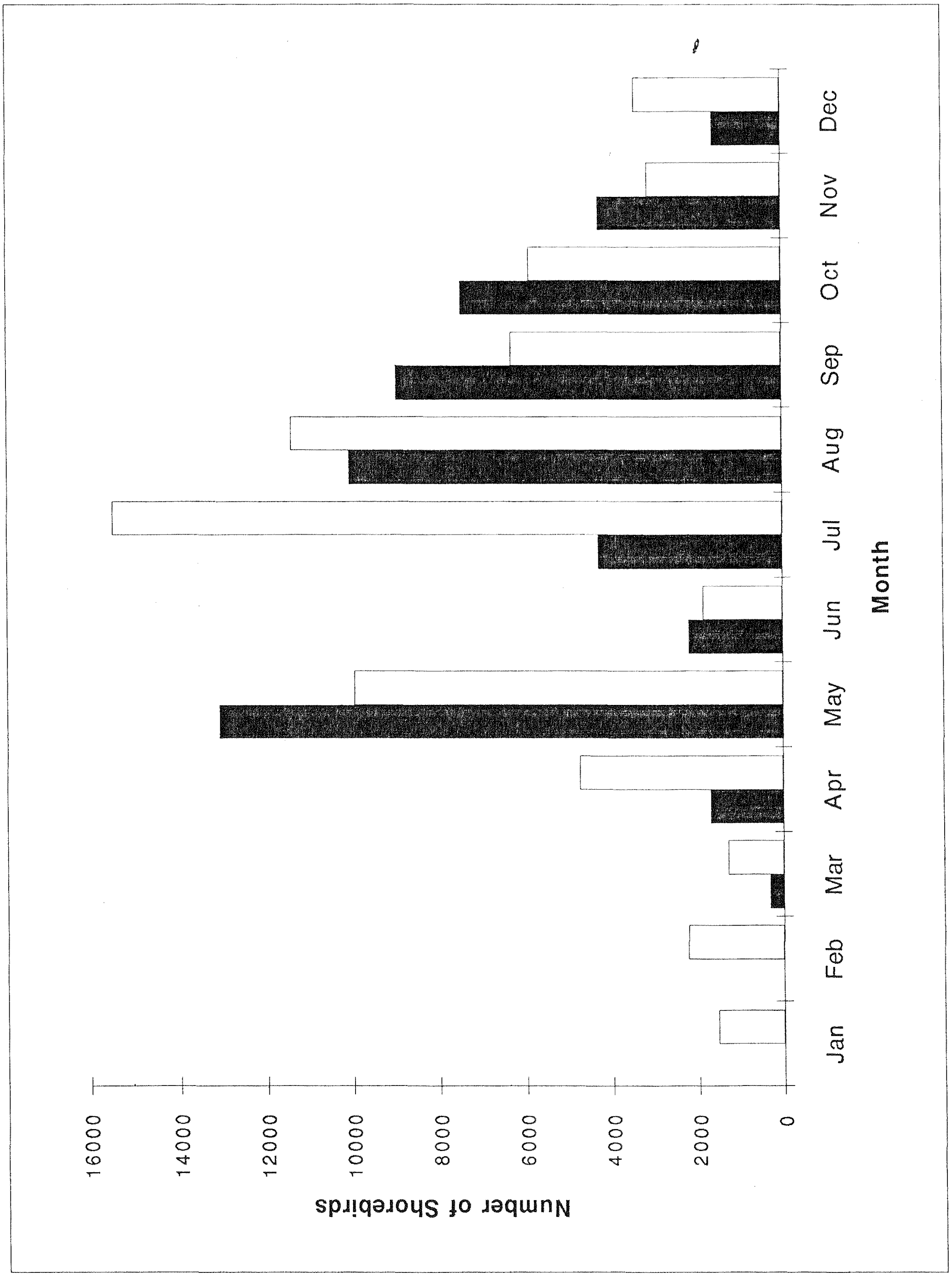

Number of Shorebirds
0
2000
4000
6000
8000
10000
12000
14000
16000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

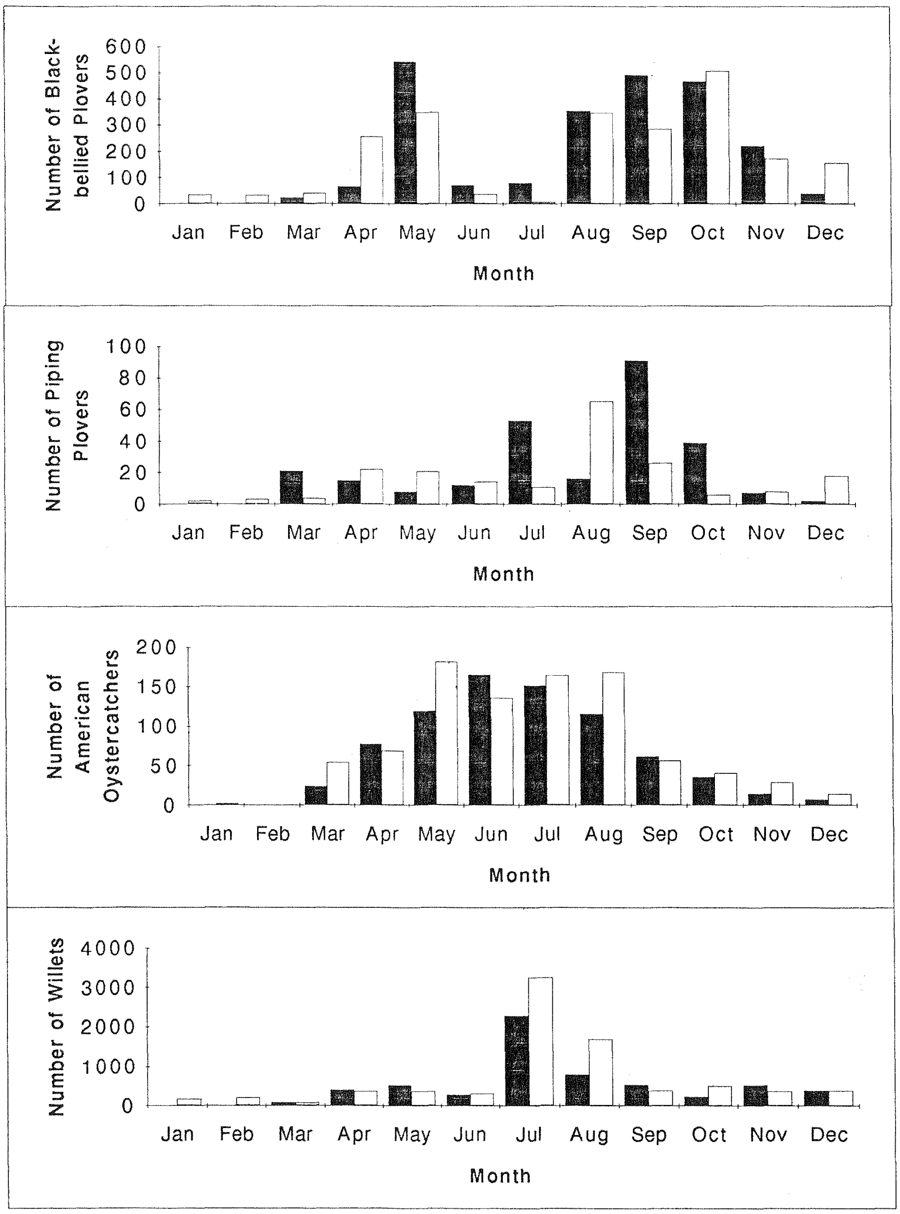
between sites and seasons ($F_{4,46}$=2.84, P=0.0348). Shorebirds were most abundant on North Beach during both years, and least abundant on South Beach during 1992 and on Bodie Island during 1993. On all sites except Ocracoke Island and North Core Banks, shorebird numbers were highest during the fall season. Relative abundance of shorebirds was slightly greater in fall (68 birds/km) than in spring (50 birds/km), with a peak at North Beach during fall (117 birds/km) (Table 1).

Species Accounts

The following accounts detail the annual and seasonal abundance of eight selected species of shorebirds. Peak numbers ar[illegible]ted for each season, and indicate the month when the mean of the 1992 and 1993 counts was greatest. Comparative information assessing the regional significance of the Outer Banks to four of these species is also presented.

Black-bellied Plover

Black-bellied Plovers were present every month of the year, though the greatest numbers were recorded in May and from August to October. The lowest numbers were recorded from January to March. Seasonally, spring migrants arrived in April, peaked in May, and were gone by early June. Fall migrants began arriving in August, peaked in October, and most departed by November ($F_{12,46}$=5.74, P<0.01) (Figure 3). Very small numbers ov[illegible]intered. Numbers did not vary by site. Black-bellied Plovers were most abundant on North Core Banks (27% of total) and North


Number of Black-bellied Plovers
600
500
400
300
200
100
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Number of Piping Plovers
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Number of American Oystercatchers
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Number of Willets
4000
3000
2000
1000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

Beach (32% of total). Numbers did not vary by season. Relative abundance was quite low at all sites, being greatest at North Beach during fall (4 birds/km) (Table 1).

Piping Plover

Piping Plovers were recorded every month of the year, with the greatest numbers recorded in July to October. Numbers from April to June were stable. Very few were recorded during January and February. Seasonally, spring migrants arrived in March with a slight peak in April. Small numbers remained to breed during the summer. Fall migrants began arriving in July, peaked in August and September, and most birds departed by November. Small numbers overwintered. There were no significant differences between months within season and year ($F_{12,46}$=1.00, P=0.47) (Figure 3). Numbers varied significantly between sites ($F_{4,46}$=3.01, P=0.03). Most (69%) Piping Plovers were on North Core Banks. Numbers did not vary between seasons. Compared to other ISS sites, the Outer Banks ranked second in regional importance to this species (Table 2). Only Monomoy National Wildlife Refuge in Massachusetts had a higher peak count than the Outer Banks. Relative abundance was very low (<1 bird/km) at all sites (Table 1).

American Oystercatcher

American Oystercatchers were recorded mostly from March to December, with almost none present in January and February. Numbers peaked from May to August. Seasonally, spring birds

Table 2. Peak numbers of four shorebird species at eight sites along the Atlantic Coast and Gulf Coast of Florida from International Shorebird Survey data and this study.

Site	Piping Plover	Whimbrel	Red Knot	Sanderling
Plymouth Beach, MA	57	19	950	2,500
Monomoy NWR, MA	100	585	3,000	5,000
Jamaica Bay NWR, NY	0	10	1,685	350
Great Egg Harbor, NJ	23	33	2,294	1,400
Chincoteague NWR, VA	50	355	2,175	11,130
Outer Banks, NC	91	453	600	11,257
Cape Romano, FL	25	7	8,115	809
Marco River, FL	24	3	1,211	457

arrived in March, with stable counts from May to August indicating breeding birds. Most birds departed in September, with a few remaining in November ($F_{12,46}$=3.36, P<0.01) (Figure 3). Numbers varied significantly by site and season ($F_{4,46}$=3.36, P=0.02). American Oystercatchers were most abundant on North Core Banks (31% of total) and South Beach (33% of total). At North Core Banks and Ocracoke Island, numbers were greatest during spring. Numbers at the other three sites were higher during fall. Relative abundance was low at all sites, being greatest at South Beach during spring (2 birds/km) (Table 1).

Willet

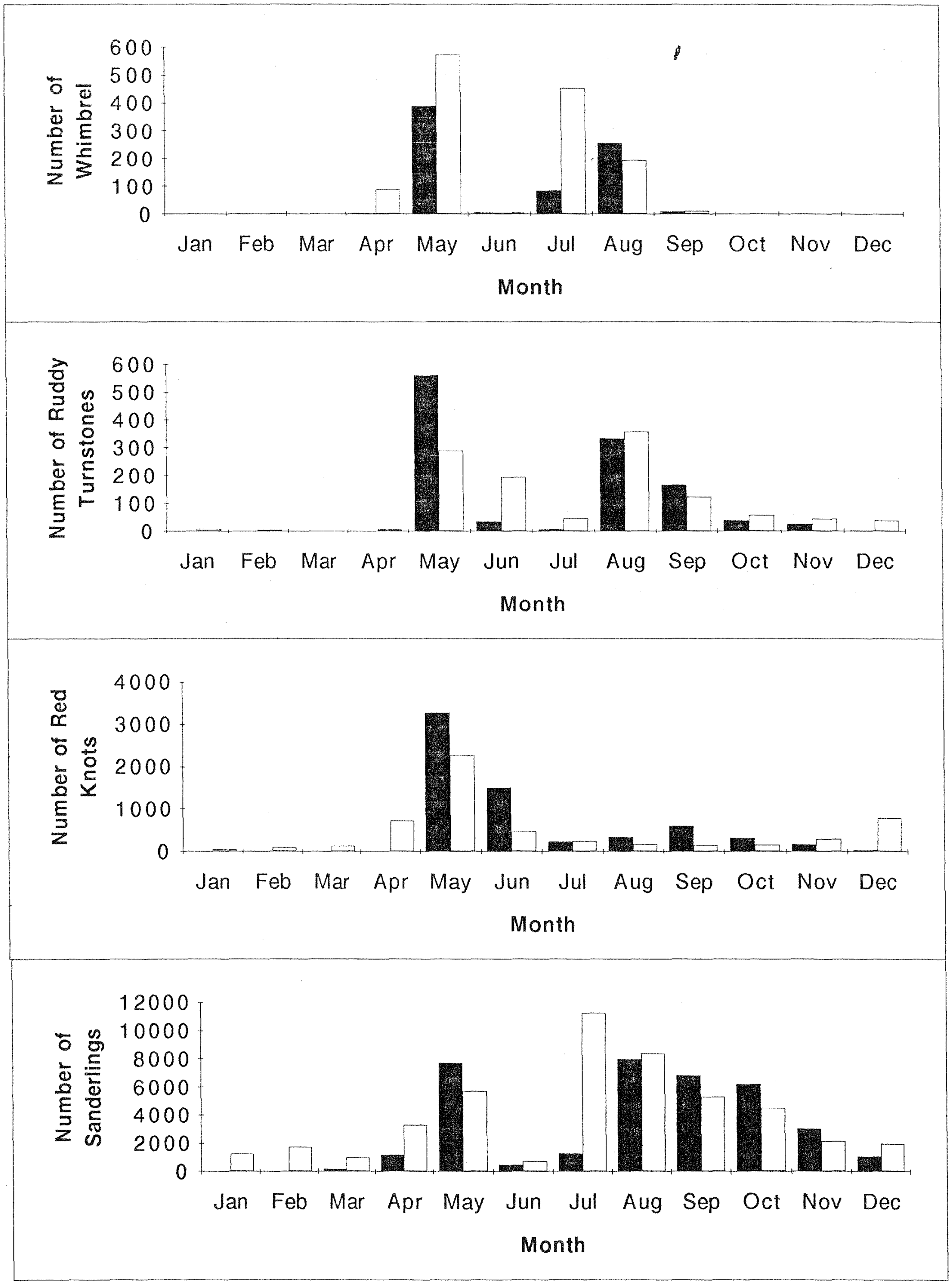
Willets were recorded every month of the year, though the greatest numbers were recorded in July and August. Otherwise, numbers were quite stable from April to December, with slightly fewer birds present from January to March. Seasonally, spring birds arrived in April, peaked in May, with some remaining into June to breed. During fall, the peak was in July, with smaller numbers remaining through November ($F_{12,46}$=7.43, P<0.01) (Figure 3). Numbers varied significantly by site and season ($F_{4,46}$=2.70, P=0.04). Willets were most abundant on North Core Banks (26% of total) and North Beach (29% of total). At all sites, numbers were higher during fall. They were three times more abundant in fall than spring at North Beach and Bodie Island. Relative abundance was much greater in fall (8 birds/km) than spring (3 birds/km) with the greatest relative abundance recorded at North Beach during fall (12 birds/km) (Table 1).

Whimbrel

Whimbrel were recorded mostly from April to September, with distinct peaks in May and in July and August. None were recorded from December to March. Seasonally, spring birds arrived in April, there was a strong peak in May, and very few remained in June. Fall migrants arrived in July, peaked in July and August, and nearly all had departed by September with a few lingering to November ($F_{12,46}$=15.63, $\underline{P}$<0.01) (Figure 4). Whimbrel were most abundant on North Beach (42% of total) and Bodie Island (24% of total). Numbers increased significantly in 1993 ($F_{1,46}$=5.50, $\underline{P}$=0.02) for all sites except North Core Banks. There was also significant variation between seasons ($F_{1,46}$=7.10, $\underline{P}$=0.01). Whimbrels were slightly more abundant in spring. Almost no Whimbrel were seen between September and March. Compared to other ISS sites, the Outer Banks ranked second in regional importance to this species (Table 2). Monomoy National Wildlife Refuge in Massachusetts was the only site to have a higher peak count for this species. Relative abundance was low at all sites except Bodie Island where the peak was recorded during fall (7 birds/km) (Table 1).

Ruddy Turnstone

Ruddy Turnstones were present every month of the year, though the majority were present from May to June and from


Number of Whimbrel
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Number of Ruddy Turnstones
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Number of Red Knots
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Number of Sanderlings
12000
10000
8000
6000
4000
2000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

August to September. Numbers were lowest from January to April. Seasonally, spring birds arrived in April, showed a strong peak in May, and most departed by June. Fall migrants arrived in July, peaked in August, and most were gone by October ($F_{12,46}$=11.49, P<0.01) (Figure 4). Ruddy Turnstones were most abundant on South Beach (33% of total) and North Beach (30% of total), though site differences were not significant. Relative abundance was low at all sites with the peak recorded at South Beach during spring (3 birds/km) (Table 1).

Red Knot

Red Knots were present every month of the year, though the greatest numbers were recorded in May and June. Numbers from July to December were fairly stable, with the lowest numbers recorded from January to March. Seasonally, spring migrants arrived in April, peaked in May, and most were gone by June. During fall, birds arrived in July, showed a small peak in September, and moderate numbers were still present in November ($F_{12,46}$=2.87, P<0.01) (Figure 4). Numbers varied significantly between sites ($F_{4,46}$=5.62, P<0.01). Most Red Knots were seen at North Core Banks (65% of total) and Ocracoke Island (28% of total). Compared to other ISS sites, the Outer Banks ranked last in regional importance to this species (Table 2). Relative abundance was much higher in spring (11 birds/km) than in fall (2 birds/km), with most birds recorded at North Core Banks (34 birds/km in spring) and Ocracoke (16 birds/km in spring) (Table 1).

Sanderling

Sanderlings were present every month of the year, though the greatest numbers were present in May and from July to October. The lowest numbers were recorded in March and June. Seasonally, spring migrants arrived in April, peaked in May, and most were gone by June. Fall migrants arrived in July, peaked in August and September, followed by a steady drop in numbers through November ($F_{12,46}$=4.19, $\underline{P}$<0.01) (Figure 4). Sanderlings were most abundant on North Beach (41% of total) and North Core Banks (20% of total), though site differences were not significant. Compared to other ISS sites, the Outer Banks ranked first in regional importance to this species (Table 2).

Sanderling relative abundance was much higher in fall (51 birds/km) than in spring (30 birds/km) (Table 1). Spring birds peaked on Bodie Island (44 birds/km) while fall birds peaked on North Beach (97 birds/km). The Outer Banks are most important to Sanderlings during fall migration, though substantial numbers use the area during spring.

Sanderlings exhibited moderate within-season site fidelity (Table 3). Most (69%) Sanderlings remained near where they were banded during the fall 1993 migration period. However, some birds (31% of total) moved, usually to an adjacent site. Movement was a short distance (<20 km) in most cases.

Table 3. Percentage of resightings of Sanderlings on the Outer Banks of North Carolina by banding location, fall 1993.

	Resighting locations						
Banding site	Bodie I.	Pea I.	North Beach	South Beach	Ocracoke I.	2 sites	>2 sites
Bodie I.	62.6	8.0	1.1	0	0	26.2	2.1
Pea I.	7.5	52.5	7.5	2.5	0	25.0	5.0
North Beach	2.9	2.6	52.2	11.9	1.1	27.0	2.3
South Beach	0	0	6.3	50.0	0	12.5	31.2

Sanderlings showed high inter-annual site fidelity. Fifty-eight percent (380/655) of the birds marked during 1992 were resighted in 1993. A significant proportion of the birds returned to their banding site. The proportions returning were 0.89 for North Core Banks (χ^2=102.9, $\underline{P}$<0.01, 2 d.f.), 0.82 for Bodie Island (χ^2=174.7, $\underline{P}$<0.01, 2 d.f.), and 0.69 for North Beach (χ^2=74.2, $\underline{P}$<0.01, 2 d.f.).

DISCUSSION

The 21 species detected in this study were representative of shorebirds commonly found on barrier island beaches along the Atlantic Coast. Sanderlings were the most abundant species, followed by Red Knot and Willet. Because sampling was done only in outer beach habitat, it is possible that some shorebirds were not counted because they used other habitats, namely tidal flats and mudflats at freshwater impoundments. However, these habitats were very localized on the Outer Banks, and only small numbers of species using outer beach habitat were missed as a result of the habitat surveyed. The patterns of abundance contrast markedly with those at Delaware Bay, one of the most important stopovers for shorebirds along the Atlantic Coast (Myers 1983). At Delaware Bay, Semipalmated Sandpipers were the most abundant species, followed by Ruddy Turnstones, Red Knots, and Sanderlings (Clark et al. 1993). Differences in abundance between these sites are likely due to the differences in habitats surveyed. This study focused on outer beach habitat, while the Delaware Bay study sampled other habitats including beaches adjacent to tidal flats and salt marshes (Clark et al. 1993).

Two species of shorebirds examined in this study (American Oystercatcher and Willet) are common breeders on the Outer Banks, which explains their abundance in the study area. Two other species (Black-bellied Plover and Ruddy Turnstone) are common migrants on the Outer Banks, with the greatest numbers recorded at North Beach, South Beach, and North Core Banks. All four of these species winter on the Outer Banks in smaller numbers.

By examining patterns of distribution for species of local and regional significance, the importance of the Outer Banks to the conservation of shorebirds is better understood. The abundance of Piping Plovers using the Outer Banks highlights the importance of the area to this endangered species. In addition to a breeding population of around 40 pairs, the area is an important staging site, especially in fall. Censuses recorded a peak of 89 during September 1992, most on North Core Banks. However, single-day counts of 128 on 29 August 1992, 110 on 25 September 1992, and 136 on 20 August 1993 on North Core Banks were made independently of censuses. These counts included large numbers of plovers using tidal flats at Ocracoke and New Drum inlets. North Core Banks is probably one of the most important staging areas for the Atlantic Coast population of Piping Plovers (see Haig and Plissner 1993). The 1991 International Piping Plover Census recorded 1,975 adult plovers along the Atlantic Coast of Canada and the United States (Haig and Plissner 1993). Based on these numbers and assuming no turnover, a minimum of 7% of the Atlantic Coast population of Piping Plovers uses North Core Banks during migration.

The Outer Banks may also be important as a stopover for migrant Whimbrel. Howe et al. (1989) reported a significant decline in Whimbrel numbers during 1972-1983 using International Shorebird Survey data, though their conclusions were based on a small sample size. Peak numbers on the Outer Banks were found during May and July-August. Large numbers use the Cape Romain-Santee Delta region of South Carolina (Marsh and Wilkinson 1991), including single-day counts of >400 in April and >200 in August. Comparisons to other ISS sites revealed that substantial numbers of Whimbrel used the Outer Banks. Information about critical staging areas for this species is scant, and the numbers found on the Outer Banks are probably indicative of the importance of this area to Whimbrel.

This study documents that moderate numbers of Red Knot use the Outer Banks during migration and in winter. Morrison and Harrington (1992) estimated the North American population of Red Knots at 180,000. The vast majority of these birds stage in Delaware Bay during spring (Clark et al. 1993), with small concentrations noted at other sites along the Atlantic Coast (Hicklin 1987, Marsh and Wilkinson 1991). On the Outer Banks, over 4,700 knots were counted in May and June 1992, with 73% on North Core Banks. Not accounting for turnover, the Outer Banks host 2-3% of the estimated North American Red Knot population during spring. The importance of the Outer Banks as a wintering area is less understood. Censuses indicated that >500 knots wintered each year, the northernmost sizeable wintering aggregation on the Atlantic Coast. The largest known wintering group in North America is on the Gulf Coast of Florida, where a mean of 6300 ± 3400 were detected in 1980-82 (Harrington et al. 1988). In South Carolina, no sizeable winter concentrations of knots were noted in the Cape Romain-Santee Delta region (Marsh and Wilkinson 1991).

Sanderlings were the most abundant species detected during censuses. They were present every month of the year, though peak numbers were detected in May and from July to October. The relative abundances of Sanderlings reported here are similar to those reported by Walters (1984) for fall (50 birds/km) on the Outer Banks. Comparative data for the Atlantic Coast are limited to Delaware Bay in New Jersey, a site of hemispheric importance to this species (>200,000 during migration) (Myers et al. 1990). Concentrations of up to 30,000 birds/km have been reported at this site. Other comparative data come from the Pacific Coast. From California to Washington, concentrations of 40 birds/km were reported in winter (Myers et al. 1984). Concentrations of

185 birds/km were reported in coastal Oregon and Washington during spring, with a peak of 472 birds/km at Clatsop Beach, Oregon in early May (Myers et al. 1984). Myers et al. (1988) reported abundances of 46, 41, and 22 birds/km in California during fall, winter, and spring, respectively. Differences in abundance between the Outer Banks and western sites might be attributed to differential habitat quality, though some might be related to the availability of beach habitat. The relative abundances in North Carolina might be lower because outer beach is not as limited as in coastal California (see Connors et al. 1981, Myers et al. 1984).

Sanderlings were most abundant on North Beach and North Core Banks, which collectively hosted more than 60% of all Sanderlings counted during this study. Sanderlings tended to be sedentary during migration periods. Most birds (69%) remained at their banding site during a given season. This total might have been much higher, but since sites were not isolated, many birds moved to adjacent sections of a nearby site. For example, North Beach and South Beach were adjacent to each other, and small numbers of Sanderlings fed on North Beach but roosted on the nearest portion of South Beach. These distributional patterns may result from differential food availability between sites. Observations of food items captured by Sanderlings ($\underline{n}$>1000) and limited work on food availability (see Appendix 2) suggest that Sanderlings prey almost exclusively on mole crabs (*Emerita* *talpoida*) along the beaches of the Outer Banks. This is consistent with other sites where Sanderlings and mole crabs co-occur (Myers et al. 1980, Connors et al. 1981, Maron and Myers 1985). Comparisons between North Beach (high Sanderling abundance) and Ocracoke Island (low Sanderling abundance) indicate that the abundance of mole crabs was significantly higher ($F_{1,56}$=4.52, P=0.0380) on North Beach (see Appendix 2). Variations in food supply are thought to influence seasonal variation in Sanderling numbers in North Carolina (Walters 1984). At Pea Island National Wildlife Refuge, Dolan et al. (1993) found considerable seasonal variation in mole crab numbers. Mole crab numbers there peaked in May to July and in October. Few were detected from December to March.

This pattern of mole crab abundance matches very closely the seasonal trends in the numbers of Sanderlings on the Outer Banks. The late fall exodus of Sanderlings is a pattern not found in California, where the Sanderling population remains fairly stable after early October until it begins to decline in February (Myers 1980). On the Outer Banks, the Sanderling population quickly increased in late July and early August and remained somewhat stable through October. There was some turnover during this period, with late-arriving juveniles replacing adult birds that departed. It is likely that Sanderlings remain on the Outer Banks as long as possible, departing only when the food supply crashes.

The drastic reduction in mole crab numbers after October may explain the drop in Sanderling numbers in November.

The Outer Banks appear to be an important staging area for Sanderlings. It ranked as the site with the highest peak count during fall migration when compared to seven other sites along the Atlantic Coast. Delaware Bay in New Jersey is the only site to record higher peak counts than those on the Outer Banks. The importance of the Outer Banks to migrant Sanderlings becomes clearer when turnover is considered. Information on the turnover of Sanderlings indicates that the number using this area is much greater than indicated by peak counts (Chapter 2). An estimated 35-40,000 Sanderlings use the Outer Banks annually, most during fall migration. These data suggest that the Outer Banks are an area of regional importance to Sanderlings under the guidelines of the Western Hemisphere Shorebird Reserve Network, supporting 20-40,000 birds annually during migration (Myers et al. 1987). The dependency of many migrant Sanderlings on the Outer Banks is confirmed by the strong inter-annual site fidelity reported in this study. The 1993 return rate of Sanderlings banded on the Outer Banks in 1992 was 58%. Philopatry of Sanderlings during winter has been demonstrated in California (Myers et al. 1988, Myers 1988) and in southern Africa (Summers et al. 1987). Other studies have made similar findings during migration and in winter (Evans et al. 1980, Myers 1980, Myers et al. 1988, Myers et al. 1990). At Bodega Bay, California, the annual return rate of

Sanderlings was 72% for adults and 50% for first-winter birds (Myers 1980). In Norway, the adult and first-winter annual return rate was estimated as 56% and 38%, respectively (Boyd 1962). Return rates provide a conservative estimate of annual survival since they do not account for birds which may have survived but did not return to the site they were banded.

The demographic implications of these results are clear. The Outer Banks of North Carolina provide a critical link in the migratory path of several shorebird species. Significant portions of the Atlantic Coast populations of some species may depend on the Outer Banks to complete their annual migrations. Several species such as the endangered Piping Plover depend on the Outer Banks for breeding habitat. This detailed study of Sanderlings hints at the implications of habitat loss or alteration on the Outer Banks. If such losses were to occur, a significant portion of the Atlantic Flyway population of Sanderlings would be negatively impacted, causing possible population declines. Other shorebird species could be similarly affected. Given the regional significance of this area, further protection for shorebirds under the guidelines of the Western Hemisphere Shorebird Reserve Network is necessary.

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CHAPTER 2

TURNOVER RATES AND POPULATION ESTIMATES OF MIGRANT SANDERLINGS ON NORTH CAROLINA'S OUTER BANKS.

Many shorebirds undergo lengthy annual migrations from their Arctic breeding grounds to wintering areas in the tropics (Myers et al. 1987). The distance each species migrates is dependant upon trade-offs between overwinter survival and the costs of migration (Greenberg 1980, Gauthreaux 1982, Alerstam and Lindstrom 1990). How shorebirds invest time and energy during migration is of critical importance to their fitness (Gudmundsson et al. 1991). Regardless of the distance traveled, south and northbound migrants are under different time constraints. Southbound migrants are pressured to reach a migratory terminus that maximizes overwinter survival. Time constraints during this part of the annual cycle are not as tight (Gudmundsson et al. 1991). Generally, sites furthest from the breeding grounds have better resources and can be exploited for longer time periods. Northbound migrants are under different constraints. Individuals must meet nutritional requirements for migration and reproduction under the constraints of reaching the breeding grounds on time to compete successfully for territories and mates (Morrison 1984, Gudmundsson et al. 1991).

Alerstam and Lindstrom (1990) and Gudmundsson et al. (1991) proposed two hypotheses to account for the selection of and time spent on stopover sites. The time-selected hypothesis states that shorebirds seek to minimize the time spent on migration, by-passing lower quality sites in favor of sites where potential energy gains are greater. The energy-selected hypothesis states that shorebirds migrate to the next stopover site as soon as their fat reserves allow them to cover the distance safely, regardless of the quality of the next site. In both cases, departure from an area (i.e. turnover rates) is a function of body mass. Thus, regardless of the strategy followed by shorebirds, birds with greater body mass should depart from stopover sites at a faster rate than birds of lower body mass.

Knowledge of turnover rates is of practical importance. Identification of important stopover areas relies heavily on population estimates (Myers et al. 1987). Counts of shorebirds at stopover areas, collected as part of the International Shorebird Survey (ISS) program, are the basis of population trend analyses (Howe et al. 1989). Analysis of data from the period 1972-83 revealed significant ($P<0.05$) declines for Whimbrels, Sanderlings, and Short-billed Dowitchers. While such data are sensitive to general population trends, their accuracy depends on untested assumptions about turnover rates. A better understanding of the factors affecting population estimates of many shorebirds is necessary (Howe et al. 1989). Factors such as age, sex, body condition, and food availability may differentially affect timing of migration and the rates with which shorebirds depart an area. Knowledge of how these factors influence the dynamics of migrant shorebirds at a staging area can be used to improve population monitoring efforts, and thus, improve the sensitivity of trend analyses to gauge the status of shorebird populations.

Despite their intimate relationship to the ecology and population dynamics of stopover areas, turnover rates have been documented for few shorebird species. Turnover of wintering Sanderlings in California was investigated by Myers (1984). Baseline information is available on the length of stay of Western Sandpipers in British Columbia (Butler et al. 1987) and Semipalmated Sandpipers in Maine (Dunn et al. 1988). The relationship between body mass and length of stay has been reported for few species of shorebirds (Page and Middleton 1972, Post and Browne 1976, Butler et al. 1987, Dunn et al. 1988). In western Europe, departure rates as a function of body mass have been studied for Ruddy Turnstones, Red Knots, and Sanderlings (Gudmundsson et al. 1991) and for Dunlin (Holmgren et al. 1993). In most cases, departure rates have been estimated for small segments of the migratory period and with limited sample sizes.

An essential requirement to test either the time- or energy-selected hypothesis is that body condition be a factor influencing turnover rates. In this study, explicit tests were made to determine if residence probabilities differed between migratory Sanderlings of different body condition classes (heavy and light). It was assumed that every bird was capable of gaining weight to a threshold or minimum level permitting departure to the next destination regardless of the weight at capture. Residence probabilities were estimated using mark-resight techniques. Unlike other studies where this parameter has been reported

(Myers 1984, Butler et al. 1987, Dunn et al. 1988, Holmgren et al. 1993), the underlying theoretical basis, assumptions, and robustness of the analytical approach are well-developed and tested (see Pollock et al. 1990).

In this study, mark-resight techniques (Pollock et al. 1990) were used to estimate the turnover rates of migratory Sanderlings (Calidris alba) in spring and fall 1993. Mark-resight data were also used to estimate the population size and mean length of stay of Sanderlings. Population estimates (±SE) were used to evaluate biases and limitations of beach censuses conducted during this study (Chapter 1). It is hoped that information presented here will aid in the understanding of the dynamics of migrant shorebirds on the Outer banks, provide a basis to assess the importance of the Outer Banks as a staging area for the Atlantic Flyway Sanderling population, and help improve sampling designs to monitor migratory shorebirds.

METHODS

Study Area

The Outer Banks are located along the east-central coast of North Carolina (see Chapter 1, Figure 1). The area consists of a series of narrow barrier islands of approximately 228 km in length, stretching from just south of Nags Head in Dare County to Beaufort Inlet in Carteret County. Much of the area is included in

Cape Hatteras and Cape Lookout National Seashores. Because of accessibility, this study was restricted to the northern portions of the Outer Banks north of New Drum Inlet. The topography is typical of barrier islands, with a low elevation and flat relief. Outer beach habitat occupied by shorebirds was devoid of vegetation. Mean tidal amplitude is approximately 1 m.

Beach censuses

From March 1992 to December 1993, five outer beach sites ranging from 9-34 km in length were surveyed. These were Bodie Island, North Beach, South Beach, Ocracoke Island, and North Core Banks. Additionally, a stretch of Pea Island National Wildlife Refuge (19 km), extending from the Oregon Inlet jetty south to Rodanthe, was surveyed for color-marked Sanderlings during the 1993 fall season. A total of 142 km of beach were surveyed during this study.

Surveys were conducted twice per month by vehicle. All surveys were begun 1.5 h before low tide, except for two counts on North Core Banks in July and August 1992 that were begun 1.5 h before high tide. Numbers of all shorebirds present on the outer beach were recorded. Outer beach is defined as the area from the base of the dune line to the ocean edge, including that portion of the intertidal zone exposed at low tide. Outer beach did not include soundside tidal flats at inlets or other tidal flat habitats. Flying birds were not recorded, unless they were clearly disturbed by the person(s) conducting the census. Since large shorebird concentrations (>500 birds) were rare, data here represent actual counts and not estimates. Abundance was expressed as the mean of two monthly censuses. For a few sites, there was only one count in a given month and this was treated as the value for that month. Monthly counts were summed across sites to obtain seasonal and annual counts.

Capture and marking of birds

The capture of Sanderlings was described in detail earlier (Chapter 1). All birds were fitted with an aluminum U.S. Fish and Wildlife Service leg band and a series of either four (1992) or three (1993) color bands arranged in a unique combination. The color bands were U.V. stable PVC bands (A.C. Hughes, London, England). Combinations were derived from six and ten possible colors during 1992 and 1993, respectively. Color band seams were melted together to reduce the possibility of band loss. Before release, each bird was weighed (to nearest 0.5g) and aged as juvenile or adult by plumage (Prater et al. 1977). Birds were released at the capture site within three hours.

Surveys for marked birds were done by four-wheel drive vehicle. Resighting efforts were restricted to North Core Banks in spring and to the five sites on Cape Hatteras National Seashore in fall. The study area was sampled every five days during spring (22 April-11 June) and during a two- to four-day period every seven days during fall (26 July-8 December), except that the first week of September was missed because of a hurricane. These periods are referred to as resighting periods. During surveys, complete and partial color band combinations were recorded, as well as the number of unmarked birds examined for color bands. Very large (>500 birds) concentrations of Sanderlings were rare, which increased the ease of examining birds for color bands.

Residence probability estimation

Residence probabilities (survival rates) were estimated using the Jolly-Seber models for open populations (Pollock et al. 1990). Program JOLLY was used to generate the parameter estimates. The assumptions and robustness of this approach were reviewed by Pollock et al. (1990). Careful consideration of several of the assumptions is relevant for this study. Residence probability is equal to 1-(mortality+emigration). Since this was estimated for periods of less than two weeks, mortality was assumed to be zero. The Jolly-Seber model assumes emigration is permanent. The extensive coverage of the study area and information about the site fidelity of Sanderlings suggest this assumption was met, though temporary emigration may have introduced a slight bias. Temporary emigration may have occurred when birds fed on tidal flats in nearby inlets, since these sites were not searched for marked birds. No band loss was detected among the 2,830 marked birds examined. Temporary trap response may bias the precision of the survival estimates. It is possible that the handling and stress associated with capture temporarily altered the resighting probabilities and survival of newly-marked birds, but it was assumed this response was negligible and was not permanent. Therefore, the survival estimates generated were assumed to be representative of the entire Sanderling population on the Outer Banks.

The data were tested under the general model for open populations (Model A; Jolly 1965, Seber 1965) and a model that allowed for a temporary marking effect (Model 2; Brownie and Robson 1983). Residence probability ($\hat{\phi}_i$) is defined as the probability a bird alive in sampling period i will remain to sampling period i+1. Turnover is defined as ($1-\hat{\phi}_i$) and is the estimated rate at which birds departed the area. Differences in residence probabilities due to age or sex were not tested because of limited sample sizes. Residence probabilities ($\hat{\phi}_i \pm$ SE) were estimated at nine five-day intervals from 22 April to 6 June, and at eighteen intervals of 1.5-14 days from 26 July to 30 November. Because marking was done between capture periods, the first resighting was treated as the initial capture (except for birds marked at the onset of each season). To correct for the unequal interval length between resighting periods, daily residence probabilities ($\hat{\phi}_d$) were calculated. The daily residence probability is the n^{th} root of the period residence probability ($\hat{\phi}_i$), where n is the number of days in the interval.

Residence probabilities were modeled as a function of body condition. To account for differences in body size, the ratio of body mass at capture to exposed culmen length (bill length) was calculated and used as an indicator of body condition. Wing chord was not used because birds were molting their primaries, making this measurement unreliable. All birds were assigned to a cohort for the spring (n=4 cohorts) and fall (n=8 cohorts) seasons. A cohort consisted of a group of birds banded during the same interval between two consecutive resighting periods. Each bird was then categorized as heavy (upper 40%) or light (lower 40%) based on within-cohort bill length to body mass ratios. Heavy birds were considered to be in good body condition, while light birds were in poor body condition. Birds with mean bill length to body mass ratios ± 10% were excluded in an effort to make body condition classes more distinct, while still retaining adequate sample sizes. Under these criteria, 42 birds were excluded from the spring data set and 128 birds were excluded from the fall data set. Small numbers of birds that were never resighted also were not included since the first resighting was treated as the initial capture. The number of individuals falling in each category may have been biased towards light birds since some birds were released almost 3 hours after capture. Those individuals may have lost up to 2.3 g during that time (Schick 1983). Such weight loss is uniform, regardless of the initial weight of the bird, and probably results from dehydration (Schick 1983). However, weight loss was small (<5% of the weight of the average bird) and was believed to have little effect on residence probabilities.

A series of goodness-of-fit tests were then performed to compare resightings of heavy and light birds in spring and fall. For each period, a 2x2 matrix was compiled which compared numbers of newly-released birds of both body condition classes that were resighted in some later period versus those never resighted.

Output from JOLLY also included resighting probabilities for each sampling period. A chi-square test comparing resighting probabilities of heavy and light birds was performed. For each period, a 2x2 matrix was compiled which compared numbers of newly-released birds of both body condition classes that were resighted in the next sampling period versus those not resighted in the next sampling period.

To obtain an estimate of the residency time of Sanderlings during the spring and fall seasons, a variation of the formula for mean life expectancy given by Brownie et al. (1985) was used. The mean length of stay (MLS, in days) was estimated as $MLS = \frac{1}{-\ln(\hat{\phi}_d)}$, where $\hat{\phi}_d$ is the mean daily survival rate from JOLLY.

Population estimation

Population size was estimated with a simple Lincoln-Peterson Index (see Pollock et al. 1990). The output from JOLLY provided estimates of the number of marked birds ($\hat{M}_i$) in the population during each resighting period. Using the output from JOLLY and counts of marked and unmarked birds from each resighting period, the total population ($\hat{N}_i$) for each resighting period was estimated as $\hat{N}_i = \hat{M}_i \times \frac{\text{Total number of birds}}{\text{Number of marked birds}}$. Population size was estimable for all but the first and last resighting periods in each season.

Population estimates ($\hat{N}_i \pm$ SE) were used to determine if actual monthly beach counts from spring (May and June) and fall (August to November) fell within the 95% confidence limits. Using census data, the number of Sanderlings in the study area each month was calculated as the sum of the monthly counts for each site. For mark-resight data, there were 2-6 population estimates ($\hat{N}_i$) within each month. These population estimates were log-transformed and a mean and standard error were calculated from the transformed estimates. The estimates were then back-transformed to provide comparable monthly estimates. The relationship between beach censuses and mark-resight population estimates was examined using linear regression through the origin.

By combining information from population estimates and estimates of turnover, the numbers of Sanderlings moving through the study area were estimated. The number of Sanderlings departing during period i is $(1-\hat{\phi}_i)(\hat{N}_i)$, where $\hat{\phi}_i$ is the turnover rate for the interval from period i to i+1 and $\hat{N}_i$ is the population estimate for that period. The sum of departing birds across all resighting periods estimates the number of Sanderlings moving through the area. This estimate is obtained for periods 2 through i-2 for each season.

RESULTS

A total of 964 Sanderlings was marked during the study. From these, 759 capture histories were generated to estimate residence probabilities. Weights varied seasonally, with the heaviest birds present during late spring and early fall (Table 1). During fall, mean weight for Sanderlings was 63.4g. Weights were high in July and August then decreased and stabilized somewhat after September. Heavy birds had a mean weight >80g in early fall (July-August), then dropped to 60-73g thereafter. During spring, mean weight was 55.4g, being highest during late May. Heavy birds were roughly 10g heavier than light birds.

Residence probability estimation

Data were insufficient to estimate residence probabilities under Model 2. The fit to Model A was significant (spring: $\chi^2=26.76$, $P=0.005$, 11 d.f., fall: $\chi^2=96.66$, $P<0.0001$, 42 d.f.). Despite the overall significance, Model A was selected for these data because the lack-of-fit was due to low numbers of resightings in a few periods. In spring, period 4 contributed 46% of the chi-square value. In fall, five periods (8,9,13,14,17) contributed 65%

Table 1. Weights (mean ± SE), overall and by body mass class, of Sanderlings captured during spring and fall on the Outer Banks of North Carolina, 1993.

Cohort	N	Weight	N	Light birds	N	Heavy birds
		Spring				
22-25 April	99	52.81 ± 0.35	45	49.81 ± 0.19	33	56.94 ± 0.40
30 April	55	56.69 ± 0.74	26	51.90 ± 0.53	23	62.04 ± 0.61
18-21 May	34	59.21 ± 1.39	18	52.89 ± 0.77	13	67.88 ± 1.37
23 May	16	59.19 ± 1.64	4	51.25 ± 2.85	4	66.88 ± 2.16
Spring Total	204	55.42 ± 0.42	93	51.05 ± 0.28	73	61.04 ± 0.62
		Fall				
26 July	53	70.63 ± 1.29	20	61.40 ± 1.19	21	79.76 ± 1.20
29 July-2 August	96	72.59 ± 1.30	38	62.37 ± 0.96	41	87.41 ± 1.01
6 August	97	78.92 ± 1.33	37	64.97 ± 1.31	44	90.59 ± 0.73
Early Fall Total	246	75.72 ± 0.80	95	63.18 ± 0.70	106	87.22 ± 0.67
9-10 September	116	57.24 ± 0.55	37	51.78 ± 0.39	47	61.64 ± 0.90
16 September	83	57.58 ± 0.43	29	53.33 ± 0.51	37	60.92 ± 0.31
29 September-1 October	211	55.38 ± 0.32	87	51.24 ± 0.24	85	59.71 ± 0.35
21 October	55	60.19 ± 0.70	24	55.83 ± 0.50	22	65.14 ± 0.82
4 November	49	64.30 ± 1.07	23	58.13 ± 0.85	16	73.03 ± 1.00
Late Fall Total	514	57.52 ± 0.26	200	52.99 ± 0.25	207	61.97 ± 0.37
Fall Total	760	63.41 ± 0.44	295	58.62 ± 0.31	313	70.52 ± 0.75

of the chi-square value, and were also due to low numbers of resightings.

Mean period residence probability ($\hat{\phi}_i$ ± SE) for spring was 0.79 ± 0.02, with a mean daily residence probability ($\hat{\phi}_d$ ± SE) of 0.94 ± 0.01 (Table 2). Mean resighting probability ($\hat{p}_i$) was 0.46 (SE not estimable). Daily residence probability was relatively high (>0.96) through 27 May, but declined sharply thereafter. Mean period residence probability ($\hat{\phi}_i$ ± SE) for fall was 0.81 ± 0.01 with a mean daily residence probability ($\hat{\phi}_d$ ± SE) of 0.96 ± 0.01 (Table 3). Mean resighting probability ($\hat{p}_i$) was 0.41 ± 0.02. Daily residence probability was slightly lower (0.82-0.97) from late July to early September, but relatively constant (0.95-1.00) from mid-September through late November.

In spring, light and heavy birds had the same residence probabilities (Table 4) (χ^2=14.61, $\underline{P}$>0.05, 9 d.f.). During fall, light and heavy Sanderlings had different residence probabilities (χ^2=43.20, $\underline{P}$<0.01, 18 d.f.). Differences in fall were significant in periods 4,6,13, and 19, when light birds had higher residence probabilities than heavy birds (Table 5). The resighting probabilities of heavy and light birds did not differ in spring (χ^2=4.87, $\underline{P}$>0.05, 8 d.f.) or fall (χ^2=18.21, $\underline{P}$>0.05, 18 d.f.).

Mean length of stay (MLS) was estimated for the spring and fall seasons. During spring, Sanderlings remained an average of 15.5 days (95% C.I. 13.0-19.1), while in fall they stayed an average

Table 2. Residence probabilities ($\hat{\phi}_i$) of Sanderlings at North Core Banks on the Outer Banks of North Carolina, spring 1993. (interval length in days)

Resighting Period	Interval length	Interval $\hat{\phi}_i$ (±SE)	Daily $\hat{\phi}_i$ (±SE)
22-27 April	5	0.84 ± 0.05	0.97 ± 0.01
27 April-2 May	5	1.00 ± 0.08	1.00 ± 0.01
2-7 May	5	0.83 ± 0.07	0.96 ± 0.02
7-12 May	5	0.91 ± 0.08	0.98 ± 0.02
12-17 May	5	1.00 ± 0.13	1.00 ± 0.02
17-22 May	5	0.78 ± 0.11	0.95 ± 0.03
22-27 May	5	1.00 ± 0.25	1.00 ± 0.05
27 May-1 June	5	0.33 ± 0.15	0.80 ± 0.07
1-6 June	5	0.20 ± 0.09	0.72 ± 0.06
Mean	-	0.79 ± 0.02	0.94 ± 0.01

Table 3. Residence probabilities ($\hat{\phi}_i$) of Sanderlings at five sites[1] on the Outer Banks of North Carolina, fall 1993. (interval length in days)

Resighting Period	Interval length	Interval $\hat{\phi}_i$ (± SE)	Daily $\hat{\phi}_i$ (± SE)
26-28 July	1.5	0.74 ± 0.07	0.82 ± 0.05
28 July-3 August	7	0.85 ± 0.11	0.98 ± 0.02
4-10 August	7	0.81 ± 0.10	0.97 ± 0.02
11-17 August	7	0.86 ± 0.11	0.98 ± 0.02
18-25 August	7.5	0.56 ± 0.09	0.93 ± 0.02
25 August-8 September	14	0.62 ± 0.10	0.97 ± 0.01
8-14 September	6.5	0.97 ± 0.10	0.99 ± 0.02
15-21 September	7	1.00 ± 0.05	1.00 ± 0.01
22-28 September	6.5	0.90 ± 0.04	0.98 ± 0.01
28 September-5 October	7	0.96 ± 0.06	0.99 ± 0.01
5-12 October	7	0.83 ± 0.04	0.97 ± 0.01
12-19 October	7	0.94 ± 0.05	0.99 ± 0.01
19-27 October	8.5	0.89 ± 0.09	0.99 ± 0.01
28 October-2 November	6	0.81 ± 0.10	0.96 ± 0.02
3-9 November	7	0.81 ± 0.15	0.97 ± 0.02
10-16 November	6.5	0.70 ± 0.14	0.95 ± 0.03
16-23 November	7	0.89 ± 0.32	0.98 ± 0.05
23-29 November	6.5	0.39 ± 0.17	0.87 ± 0.06
Mean	-	0.81 ± 0.01	0.96 ± 0.01

[1] The five sites are Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island.

Table 4. Daily residence probabilities of Sanderlings by body condition on North Core Banks on the Outer Banks of North Carolina, spring 1993. (NE=not estimable) (Residence probability is the probability a bird alive in resighting period i will survive to the next period).

	Body Condition	
REsighting Period	Poor	Good
22 April	0.96 ± 0.04	1.00 ± 0.01
27 April	1.00 ± 0.03	1.00 ± 0.02
2 May	0.96 ± 0.03	0.96 ± 0.03
7 May	1.00 ± 0.04	0.96 ± 0.03
12 May	1.00 ± 0.07	1.00 ± 0.03
17 May	0.86 ± 0.06	0.98 ± 0.03
22 May	1.00 ± 0.10	0.97 ± 0.05
27 May	0.71 ± 0.09	0.82 ± NE
1 June	0.76 ± NE	NE
Mean	0.93 ± NE	0.96 ± NE

Table 5. Daily residence probabilities of Sanderlings by body condition at five sites[1] on the Outer Banks of North Carolina, fall 1993. (NE=not estimable) (Residence probability is the probability a bird alive in resighting period i will survive to the next period).

	Body Condition	
Resighting Period	Poor	Good
26 July	0.77 ± 0.08	0.79 ± 0.11
27-28 July	0.99 ± 0.03	0.96 ± 0.04
3-4 August	0.95 ± 0.02	0.98 ± 0.04
10-11 August[2]	1.00 ± 0.01	0.93 ± 0.05
17-18 August	0.94 ± 0.02	0.98 ± 0.11
24-26 August[2]	0.98 ± 0.01	0.85 ± NE
7-9 September	0.99 ± 0.02	NE
14-15 September	1.00 ± 0.01	0.99 ± 0.01
2--23 September	1.00 ± 0.01	0.99 ± 0.01
27-29 September	0.98 ± 0.02	1.00 ± 0.01
4-6 October	0.97 ± 0.01	0.98 ± 0.01
11-13 October	0.99 ± 0.01	1.00 ± 0.02
18-20 October[2]	0.99 ± 0.02	0.98 ± 0.03
26-29 October	0.94 ± 0.03	0.95 ± 0.04
2-3 November	0.97 ± 0.03	0.96 ± 0.05
9-10 November	0.96 ± 0.04	0.95 ± 0.05
15-17 November	0.98 ± 0.07	0.92 ± 0.06
22-24 November	0.83 ± 0.07	1.00 ± NE
Mean	0.96 ± 0.01	0.95 ± NE

1 The five sites are Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island.

2 Differences in survival of heavy and light birds were significant ($P<0.05$) for these resighting periods.

of 24.5 days (95% C.I. 21.0-30.8). Mean length of stay was lower in early fall (mean=18.5 days) than in late fall (mean=31.9 days).

Population estimation

A total of 2,830 sightings of marked birds were made during spring (491) and fall (2,339). An additional 138,140 birds (12,495 in spring and 125,645 in fall) were examined and found to be unmarked. Population size was estimated for nine of eleven resighting periods during spring (Table 6). Peak numbers were present on 27 April and 12,17 May when >3000 Sanderlings were estimated to be on North Core Banks. There was high variability in the spring population estimates, though they generally declined through early June, when <500 birds were present. Population size was estimated for eighteen of twenty resighting periods during fall (Table 7). Peak numbers were present on 24-27 August and 7-9 September when an estimated 19,415-20,460 Sanderlings were at the five sites on Cape Hatteras National Seashore. Numbers dropped sharply in mid-September, then declined slowly through late November.

Using estimates of turnover and population size, the total number of Sanderlings migrating through selected portions of the Outer Banks was estimated. During spring, an estimated 3,566 Sanderlings used North Core Banks (Table 6). During fall, an estimated 28,744 Sanderlings used the five sites at Cape Hatteras National Seashore (Table 7). These estimates are conservative since they do not account for birds present in the first or last two

Table 6. Population estimates ($\hat{N}_i$) and the number of Sanderlings that departed $[(1-\hat{\phi}_i)(\hat{N}_i)]$ from mark-resight data for nine of eleven resighting periods at North Core Banks on the Outer Banks of North Carolina, spring 1993. (NE=not estimable; $\hat{\phi}_i$ is the residence probability rate from resighting period i to i+1)

Resighting Period	$\hat{N}_i$	Departures
27 April	4,003	0
2 May	1,528	260
7 May	2,353	220
12 May	3,179	0
17 May	3,214	699
22 May	1,924	0
27 May	2,399	1,607
1 June	975	780
6 June	499	NE
Total		3,566

Table 7. Population estimates ($\hat{N}_i$) and the number of Sanderlings that departed $[(1-\hat{\phi}_i)(\hat{N}_i)]$ from mark-resight data for eighteen of twenty resighting periods at five sites[1] on the Outer Banks of North Carolina, fall 1993. (NE=not estimable; $\hat{\phi}_i$ is the residence probability rate from resighting period i to i+1)

Resighting Period	$\hat{N}_i$	Departures
27-28 July	10,460	1,572
3-4 August	4,445	849
10-11 August	5,656	797
17-18 August	9,742	4,305
24-26 August	19,415	7,465
7-9 September	20,460	706
14-15 September	2,837	0
20-23 September	5,192	500
27-29 September	8,327	367
4-6 October	5,234	914
11-13 October	8,193	527
18-20 October	8,181	891
26-29 October	8,706	1,685
2-3 November	6,333	1,178
9-10 November	8,516	2,560
15-17 November	4,047	456
22-24 November	6,552	3,972
29-30 November	4,040	NE
Total		28,744

[1] The five sites are Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island.

resighting periods, or those birds that may have migrated through prior to the first resighting period. Assuming 1,000 Sanderlings used each of these sites not surveyed in spring (Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island) and the single site not surveyed in fall (North Core Banks), a conservative estimate of the annual number of Sanderlings using the Outer Banks is 35-40,000. The assumption of 1,000 birds using each site not included in population estimates is valid, given that beach censuses documented greater numbers at each of these sites.

Numbers of Sanderlings varied considerably between sites within months (Table 8). Some of the greatest variability was during the peak migration, when mean counts for the five sites were 1,140 ± 225 in May and 2,251 ± 1,841 in July. During spring, mean monthly population estimates from mark-resight data were 2,352 for May and 698 for June, compared to census counts of 1,407 in May and 213 in June (Table 9). During fall, mean monthly population estimates from mark-resight data were 8,304 for August, 7,078 for September, 7,435 for October, and 5,655 for November. Only in November did the census count fall outside the confidence limits for the mark-resight population estimate (Table 9). In both seasons, beach censuses provided consistently lower estimates of the Sanderling population. There was a significant relationship between beach censuses and the mark-resight population estimates ($F_{1,5}$=88.9, P<0.01). Estimates of

Table 8. Sanderling numbers obtained from beach censuses at five sites on the Outer Banks of North Carolina, 1993.

	Site					
Month	Bodie Island	North Beach	South Beach	Ocracoke I.	N. Core Banks	Mean ± SE
January	224	79	328	106	475	242 ± 73
February	295	80	540	360	438	343 ± 77
March	20	11	178	434	333	195 ± 84
April	395	416	638	978	870	659 ± 117
May	290	1,594	1,198	1,213	1,407	1,140 ± 225
June	2	27	438	26	213	141 ± 83
July	28	9,552	11	325	1,341	2,251 ± 1,841
August	1,135	2,354	2,097	1,114	1,700	1,680 ± 250
September	896	1,500	580	802	1,506	1,057 ± 189
October	172	2,663	982	683	-	1,125 ± 539
November	18	570	774	317	468	429 ± 127
December	15	251	448	474	620	362 ± 105

Table 9. Mean monthly number of Sanderlings on the Outer Banks of North Carolina from mark-resight data ($\hat{N}_i \pm$ 95% C.I.). Counts derived from beach censuses at five sites[1] on the Outer Banks are given for comparison. (the number of estimates used to generate each estimate of $\hat{N}_i$ are given in parentheses).

Month	Mean $\hat{N}_i$		95% C.I. of $\hat{N}_i$	Census count
May	2,352	(6)	1,161-4,764	1,407
June	698	(2)	91-5,347	213
August	8,304	(4)	3,355-20,554	7,743
September	7,078	(4)	2,231-22,454	5,555
October	7,435	(4)	5,364-10,306	5,865
November	5,655	(5)	3,774-8,472	2,140

[1] The five sites are Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island.

the number of Sanderlings present on the Outer Banks are obtained by multiplying beach counts by 1.235.

DISCUSSION

Turnover rates as a function of body mass

Residence probabilities were more variable during spring than in fall, indicating that spring birds were departing almost continuously. Spring birds stayed at North Core Banks about a week less, on average, than birds remained at the five sites on Cape Hatteras National Seashore during fall. Significant differences in residence probabilities as a function of body mass were found only during four periods in fall. No significant differences were found during spring. These findings, particularly in spring, suggest that differences in body condition did not always explain patterns of Sanderling departure from the Outer Banks. These results and several confounding factors are discussed below and illustrate the need to carefully design studies of shorebird population dynamics at stopover sites.

Age is known to influence the timing of migration. Adults depart the breeding grounds prior to juveniles for many species (Morrison 1984). In this study, birds captured during the early fall period (late July to early September) were all adults. During that period, residence probabilities of birds in good and poor body condition differed significantly in two of seven periods. Since samples were homogeneous in age composition at this time, the influence of body condition on departure rates was tested in the absence of a known confounding factor. It can be assumed (Gudmundsson et al. 1991) that the mean weight of birds with the highest turnover rates (e.g. ≥80g) met or exceeded the threshold level to trigger departure.

After mid-September, the Sanderling population was comprised of adults from early in the season and new arrivals (of both age classes). Differences in residence probabilities of heavy and light birds from mid-September to late November were detected in two of eleven periods. Lower turnover rates during this period could have been an artifact of mixed age classes or may have reflected the inability of later birds, irrespective of age, to put on the necessary fat reserves as some early birds did. Mean weights after September were below the adhoc threshold of ≥80g, and weights of both body condition classes were more similar (converged) than those earlier in the season. The latter contention may explain the spread between resighting periods before detecting significance (about 6-7 weeks). Periods of significance early in the season were detected soon after the arrival of birds (about 4 weeks) and 2 weeks apart (periods 4 and 6).

This study, though, continued to document departures of Sanderlings post-September, albeit not as fast as early season birds. This undermines the confidence of arbitrarily selecting a threshold level (≥80g) that triggers departure. Birds of both body condition classes continued to depart at similar rates even though mean body mass had dropped by as much as 13g for light birds and 30g for heavy birds. It is hard to tell whether the lower turnover of post-September birds was because they were unable to rapidly build up body fat levels (assuming adequate resources were available) or because their fall migration schedule, coupled with suitable weather and resource levels (Dolan et al. 1993), facilitated a longer stay than predicted by body mass alone. It is also possible that some birds may overwinter if suitable conditions prevail, but are forced to migrate south when food resources declined in late fall (see Chapter 1). Southbound migrations of shorebirds are often considered more leisurely because birds are not as pressured to reach their migratory terminus as they are to reach the breeding grounds in spring (Morrison 1984, Myers et al. 1985, Gudmundsson et al. 1991).

During spring, residence probabilities of Sanderlings of different body condition classes were not significantly different. Birds in poor condition seemed to be departing at slightly faster rates than those in good condition, and mean body masses of heavy spring birds were lower than those of heavy fall birds. This is opposite to the pattern that was used as evidence to support the time-selected hypothesis (Gudmundsson et al. 1991). Several factors may explain these patterns. Fewer Sanderlings used the Outer Banks in spring than fall (Chapter 1). Sanderlings may be bypassing the Outer Banks during spring in favor of more suitable stopover sites. Sanderlings are known to add large amounts of fat reserves at Delaware Bay just prior to departure for the breeding grounds (Myers 1983). At this site, consistently higher spring weights might be expected (Gudmundsson et al. 1991). Alternately, birds may be stopping on the Outer Banks, but only for a short time. In either case, birds present on the Outer Banks may be departing to sites where the expected rate of energy gain is higher (Alerstam and Lindstrom 1990). Under this strategy, turnover rates of birds of both body condition classes would not be expected to differ in a predictable pattern. This explanation hints at the possibility that Sanderlings operated under the time-selected hypothesis. Rigorous testing of this hypothesis would require knowledge of regional movements, body condition information, and assessments of habitat quality along the migration route. Alternatively, the strong selective pressures of spring migrants to reach the breeding grounds may have contributed to the similar turnover rates of the two body mass classes. Time and energy constraints during spring probably interact strongly, making it difficult to partition their individual effects.

The period of time with the fewest confounding factors was probably the early fall migration period. Captured birds were new arrivals comprised entirely of adults, resources were assumed to have not been overexploited, and there was no strong selective pressure to depart quickly. During this period, overall departure rates were higher than later in the season, and significant periods in which heavy birds departed at higher rates occurred soon after arrival and close to each other. This suggests that body condition might influence departure rates during certain, perhaps brief, periods in a given migratory season. Still it is possible that early season birds represented a unique segment of the population. These results raise several unanswered questions that are relevant for future studies investigating the importance of within-season turnover rates. Early fall Sanderlings could be under an inherently different migration schedule than later birds. The higher body masses of early Sanderlings could represent evidence of overloading of fat reserves (see Gudmundsson et al. 1991), not fat reserves indicating a threshold level for departure. The lack of seasonal relationships between body condition and departure rates is not evidence to refute the time- or energy-selected hypothesis. Rather, it simply emphasizes the number of factors influencing migrant birds at stopover sites and the need to partition their effects before explicit tests of some hypotheses dealing with the evolution of migration are possible.

Population estimates

The importance of obtaining accurate estimates of shorebird numbers is critical for their conservation (Myers et al. 1987). The influence of age and sex, an understanding of turnover rates, and the timing and frequency of censuses all affect the accuracy of coastal shorebird counts (Howe and Collazo 1989, Colwell and

Cooper 1993). This study provides information that can be used to improve on current shorebird censusing techniques. Current shorebird censusing techniques, such as the International Shorebird Survey (Howe et al. 1989), do not specifically account for turnover. Counts derived from these surveys may greatly underestimate the number of birds using an area.

A comparison of census counts and population estimates derived from mark-resight information on the Outer Banks revealed that the census counts were consistently lower. Census counts were 55% lower in spring and 26% lower in fall. Estimates derived from mark-resight information incorporated estimates of turnover, and thus may have provided more accurate population estimates. The timing and frequency of counts, and local movements, may have contributed to the discrepancy between estimates. Censuses were conducted monthly in this study, and span the peak migration periods for Sanderlings. In some cases, peak counts were averaged with lower counts within months, and may have biased the estimates low. For example, in July 1993 counts were conducted at three of five sites early in the month when few (<500 per site) Sanderlings were present. Counts at the other two sites were done late in the month when >9,000 Sanderlings were counted at one of the sites. Despite these problems, beach censuses were found to be a useful index of the Sanderling population size. When beach counts were multiplied by a factor of 1.235, they provided reasonable estimates of the actual number of Sanderlings present, based on information from the mark-resight study.

Other studies of Sanderlings (Evans et al. 1980, Myers 1983) have found considerable variability in local movement patterns of individual birds. Myers (1983) noted that at Bodega Bay, California, a census of the local Sanderling population underestimated the true population by up to 50%. Birds not detected on a particular census were temporarily using nearby beaches. On the Outer Banks, some of the discrepancy between population estimates may have resulted from local movements that were not detectable on beach censuses. Individual birds were not always present on the beach, but instead used nearby tidal flats at inlets or temporarily moved outside the study area. A study of the site-faithfulness of Sanderlings (Chapter 1) provides evidence that local movements regularly took place. Sixty-nine percent of the birds remained where they were banded. The remaining birds wandered to nearby beaches, usually no more than 20 km from the banding site. Some birds used up to three or four sites within the fall season. The time scale of such movements was not specifically examined, but may prove useful when designing appropriate survey methods.

Peaks counts have been suggested as an alternative to multiple beach censuses to avoid problems brought about by high variability (Colwell and Cooper 1993). Peak counts could be an useful population estimate to assess the relative importance among areas or for trend analyses. To be useful, counts must be standardized throughout the area or range of interest. Also, its functional relationship with estimates of total population numbers needs to be explored. Qualitative comparisons among sites (Chapter 1) assume that the relationship is positive. Peak counts, on the other hand, are inappropriate as an estimate of total population numbers. The peak fall count, derived by summing monthly mean counts across sites, was 11,257 birds in July. Detailed mark-resight information revealed that nearly all of these birds (>80%) had departed by early September. However, small numbers of Sanderlings continued to arrive through September, with moderate numbers eventually overwintering. The estimated number of Sanderlings using the area during fall (28,744) was more than twice as high as the peak count.

To generate more precise estimates, temporal replication of counts must be conducted on a scale that fits within the length of stay of a given species. For Sanderlings on the Outer Banks, the 10-day sampling interval of the ISS seems adequate, given the length of stay estimates ranging from 15-32 days from this study. This protocol should intercept the peak migration intervals for Sanderlings on the Outer Banks. As turnover dropped in late fall, Sanderlings remained on the Outer Banks for an average of one month. During that period, sampling once per month might suffice. However, as suggested by Colwell and Cooper (1993), the average of several counts replicated over a short period of time will provide reasonable estimates when count variability is low, such as the late fall and winter period on the Outer Banks. If the Outer Banks are representative of other sites along the Atlantic Coast, the trend analyses performed by Howe et al. (1989) for Sanderlings were probably sensitive enough to have detected population declines. If Sanderling declines continue, researchers may have to rely on numeric counts, rather than ISS estimates, to monitor population changes. The results of this study may help in the design of such counts, which incorporate mark-resight studies to estimate population size and turnover rates and the corresponding precision levels.

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APPENDICES

Appendix 1. Seasonal numbers (mean ± SE), total numbers, and month of peak count of shorebirds on the Outer Banks of North Carolina, 1992-93. (Seasonal numbers are means of the monthly counts within each season; peaks are given by month with the number recorded in parentheses)

Species[1]	Seasonal Numbers Spring[2]	Seasonal Numbers Fall[2]	Total Numbers[3] Spring	Total Numbers[3] Fall	Month of peak count
All species	5,684±2,421	7,760±1,118	17,051	38,798	May (11,540)
Black-bellied Plover	194±113	282±76	582	1,408	October (472)
Wilson's Plover	2±1	1±1	6	7	May, July, August (3)
Semipalmated Plover	28±27	27±10	82	134	May (81)
Piping Plover	13±2	31±9	39	155	September (58)
American Oystercatcher	114±22	79±26	342	397	July (152)
Willet	369±52	1,034±452	1,108	5,168	July (2,750)
Whimbrel	175±150	100±60	526	500	May (474)
Marbled Godwit	0	2±1	0	8	October (4)
Ruddy Turnstone	176±125	116±58	527	581	May (419)
Red Knot	1,363±725	267±27	4,088	1,334	May (2,764)
Sanderling	3,222±1,796	5,692±907	9,667	28,458	August (8,194)
Semipalmated Sandpiper	21±18	24±13	63	120	September (70)
Western Sandpiper	1±1	17±8	4	84	September (43)
Least Sandpiper	2±2	5±4	5	26	September (19)
Dunlin	1±1	53±38	4	263	November (196)
Short-billed Dowitcher	1±1	29±22	4	146	July (117)

[1] Five species were recorded <5 times (killdeer, greater yellowlegs, lesser yellowlegs, spotted sandpiper, and white-rumped sandpiper)

[2] Seasons are defined as Spring (April to June) and Fall (July to November)

[3] The sum of the monthly means over the season

Appendix 2. Availability of mole crabs (Emerita talpoida) at two sites on the Outer Banks of North Carolina, fall 1993.

In October and November 1993, mole crabs were sampled at two sites (North Beach and Ocracoke) on Cape Hatteras National Seashore. The two sites were selected to contrast areas of high and low sanderling abundance, respectively. Baseline survey data support these claims (Chapter 1). At each site, a transect of 15 stations, each 0.1 mile apart, was established. Each transect was sampled three times, once in October and twice in November. Each time, two scoops of sand were taken from the swash zone at each station, for a total of 30 scoops per transect. The volume of the scoop was 0.5 gallon, and the opening was approximately 15 cm in diameter. Samples were placed in a large shallow pan and all mole crabs were removed and counted.

For analysis, the mean of the two samples at each station was calculated. This resulted in 15 counts per sampling date for each site. The effects of date and site on the variability of mole crab numbers were tested. Station, a repeated measure, was nested within site in the ANOVA model. The whole model test was significant ($F_{33,56}$=2.85, P=0.0003) and fit the data well (model R^2=0.63). The effect of date was significant ($F_{4,56}$=14.26, P<0.0001). Mole crabs were most abundant in October and numbers declined sharply in November. The two sites differed significantly in the number of mole crabs detected ($F_{1,56}$=4.52, P=0.0380). Mole crabs were three times as abundant on North Beach as on Ocracoke.

Mole crabs are a primary prey item of sanderlings, and their abundance is probably related to the distribution of sanderlings on the Outer Banks (Walters 1984). Census data show that sanderlings were consistently more numerous on North Beach than on Ocracoke.

Appendix 3. Morphometric data for Sanderlings banded during 1992 on North Carolina's Outer Banks.

During 1992, 655 Sanderlings were captured on the Outer Banks of North Carolina. Measurements of weight (to nearest 0.5 g), natural wing chord (bend in wing to tip of longest primary, to nearest mm), and exposed culmen length (bill tip to proximal end of frontal shield, to nearest 0.1 mm) were taken from each bird. Means (± SE) for the three measurements are presented here by cohort for the spring and fall seasons.

Cohort	N	Mean weight ± SE	Mean wing ± SE	Mean bill ± SE
			Spring	
28 Apr-17 May	56	58.94 ± 1.08	118.86 ± 0.40	24.78 ± 0.22
27 May	70	63.49 ± 1.72	121.39 ± 0.43	25.54 ± 0.18
Spring total	126	61.47 ± 1.09	120.26 ± 0.32	25.21 ± 0.14
			Fall	
29 Jul-7 Aug	28	60.80 ± 1.79	121.36 ± 0.71	25.55 ± 0.27
5-7 Sep	146	56.03 ± 0.58	122.68 ± 0.30	26.18 ± 0.12
20 Sep	83	54.08 ± 0.41	122.36 ± 0.52	26.27 ± 0.15
27-28 Sep	69	52.18 ± 0.50	120.80 ± 0.65	26.29 ± 0.18
3 Oct	114	54.29 ± 0.50	121.48 ± 0.45	25.90 ± 0.12
16 Oct	89	61.13 ± 0.71	121.36 ± 0.52	25.82 ± 0.16
Fall total	529	55.96 ± 0.29	121.84 ± 0.20	26.05 ± 0.06

Appendix 4. Morphometric data for Sanderlings banded during 1993 on North Carolina's Outer Banks.

During 1993, 964 Sanderlings were captured on the Outer Banks of North Carolina. Measurements of weight (to nearest 0.5 g), natural wing chord (bend in wing to tip of longest primary, to nearest mm), and exposed culmen length (bill tip to proximal end of frontal shield, to nearest 0.1 mm) were taken from each bird. Means (± SE) for the three measurements are presented here by cohort for the spring and fall seasons.

Cohort	N	Mean weight ± SE	Mean wing ± SE	Mean bill ± SE
			Spring	
22-25 Apr	99	52.81 ± 0.35	122.21 ± 0.28	24.43 ± 0.10
30 Apr	55	56.69 ± 0.74	125.05 ± 0.37	24.93 ± 0.18
18-21 May	34	59.21 ± 1.39	122.03 ± 0.42	24.48 ± 0.19
23 May	16	59.19 ± 1.64	121.50 ± 0.81	24.71 ± 0.27
Spring total	204	55.42 ± 0.42	122.89 ± 0.22	24.59 ± 0.08
			Fall	
26 Jul	53	70.63 ± 1.29	125.45 ± 0.45	25.95 ± 0.19
29 Jul-2 Aug	96	72.59 ± 1.30	125.54 ± 0.34	25.92 ± 0.15
6 Aug	97	78.92 ± 1.33	126.32 ± 0.31	26.48 ± 0.12
9-10 Sep	116	57.24 ± 0.55	124.62 ± 0.43	25.67 ± 0.12
16 Sep	83	57.58 ± 0.43	122.18 ± 0.73	25.95 ± 0.12
29 Sep-1 Oct	211	55.38 ± 0.32	121.80 ± 0.39	25.59 ± 0.10
21 Oct	55	60.19 ± 0.70	124.13 ± 0.43	25.13 ± 0.20
4 Nov	49	64.30 ± 1.07	126.63 ± 0.41	26.20 ± 0.20
Fall total	760	63.41 ± 0.44	124.06 ± 0.18	25.83 ± 0.05

Appendix 5. Parasites found on Sanderlings on the Outer Banks of North Carolina, fall 1992.

On 27-28 September 1992, several captured Sanderlings were examined for external and internal parasites and assessed for general body condition.

Ten Sanderlings were examined externally for parasites. Three species of lice were collected; Carduiceps zonarius, Lunaceps holophaeus, and Actornithophilus umbrinus. Additionally, three mortalities from a rocket net firing were examined internally. Several large tapeworms of the genus Hymenolepis were noted, possibly representing 2-3 species.

The Sanderlings were in very good condition. They were in good flesh with the pectoral muscles even with the keel, there were moderate amounts of subcutaneous and abdominal fat, and there were no gross lesions on any of the major organs. Additionally, the parasite burden of the birds seemed fairly low, a further indication that the birds were in good health.

Effects of human disturbance on shorebird populations on the Outer Banks of North Carolina.

Chapter III

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INTRODUCTION

Little detailed information is available concerning effects of human use of oceanfront beach on shorebirds. Studies in the northeastern United States have observed human disturbance and its effects on shorebird behavior (Burger 1981, 1986). This study was conducted in an effort to determine the impact of human recreational use of barrier-island beaches on shorebirds along North Carolina's Outer Banks. The barrier beaches of the Outer Banks face mostly east to southeast with sandy, gentle slopes. They usually experience moderate wave action in spring and summer with heavy wave action in fall and winter that can move large quantities of sand, drastically altering beach faces. The Outer Banks are not as heavily developed as many Atlantic coast beaches, providing substantial feeding and roosting habitat for large numbers of migratory shorebirds each year (Fussel and Lyons 1990). With human access to these islands greatly increased in recent years through bridge construction and ferry service, recreational use of these beaches has steadily increased (Parnell et al. 1992). Helmers (1992) found human disturbance energetically expensive to colonially nesting waterbirds as they increased attempts to avoid beachcombers, off-road vehicles (ORV's), and pets. Reduced fertility and fecundity, severe changes in social and individual behavior, increased mortality, population declines, and range reductions of colonially nesting waterbirds have been related to human disturbance along North Carolina's Outer Banks (Buckley and Buckley 1976). Because shorebirds are more susceptible to human disturbance than other coastal birds such as gulls, terns, and waterfowl (Burger 1981), there is increasing concern about shorebirds throughout their ranges.

METHODS

Impacts of human activities on shorebird numbers and behavior were measured by comparing shorebird use of paired beach plots. Six paired plots were established: four on Hatteras Island, two on Ocracoke Island, and one on North Core Banks (Fig. 1). Within each pair, 1 plot was closed to all human activities (pedestrians, vehicles, fishing, swimming, etc.) and one plot was left open to human activity. All pairs of plots, except Cape Point (open) and North Core Banks (closed), were adjacent to each other and each measured approximately 0.5 km from end to end. Each included the beach area from dune to ocean edge. We were unable to place the plots randomly because of legal and political constraints within the national seashore. The National Park Service (NPS) designated segments of beach that were already closed to vehicular traffic as available for our study. These areas were subsequently closed to all pedestrian traffic as well and were posted with closure signs from the dune line to the high tide line. One site, at Hatteras Inlet (Fig. 1), did not have a previous closure. Here a closure was posted from the high-tide line to a point 70 m above the high-tide line. Pedestrian and vehicular access was permitted around this plot between the closure and the dune line. There was no prior knowledge or consideration of bird use or disturbance levels among the available sites so we think that site placement was random in relation to those factors. The limits of our site selection and dynamic nature of the barrier beach environment did not allow for physically identical plots.

Three different types of data were collected during each sampling period: 1) Species composition and abundances were gathered through census scans in which all species of birds in the plot were identified and counted. 2) Behavior was determined by focal scans during which a single bird was observed and all behavior changes recorded for 5 minutes or until the bird left the plot. Target species for focal scans were Sanderling (*Calidris alba*), Black-bellied Plover (*Pluvialis squatarola*), Whimbrel (*Numenius americanus*), and Red Knot (*Calidris canutas*), chosen as relatively common species that regularly used the outer beaches during migration. 3) Disturbances were measured by scans during which all disturbance events, human or otherwise, within the plot were recorded along with species responses. Disturbances were classified as stationary vehicles, moving vehicles, stationary humans, moving humans, and other which included disturbance events such as aircraft, boats, swimmers, surfers, and pets.

Each pair of plots was sampled three times each month; once at high tide, once at low tide, and once during an intermediate tide phase. The order of sampling between open and closed plots was determined randomly prior to the sampling period. Samples were begun 1 hour before the appropriate tide phase and concluded 1 hour following the same tide phase. Although many species forage at night, most shorebird species in the northern hemisphere forage during the day (Puttick 1984). Sampling was limited to tide phases occurring during daylight hours.

Census scans were conducted twice during each sampling period, once at the beginning of the hour and once at the end of the hour. After each census scan, a disturbance scan was conducted, followed immediately by a focal scan. Focal scans and disturbance scans were alternated for approximately 50 minutes with a different bird observed during each focal scan. If there were not enough birds present for all 8 scans, some individuals were observed more than once. After a maximum of 8 focal and disturbance scans, the final census scan was conducted and sampling was shifted to the next plot.

Sampling was conducted from April 1992 through July 1993. During that period, 600 census scans, 2600 disturbance scans, and 2600 focal scans were conducted. Data were not collected from October 1992 - December 1992 due to the low numbers of shorebirds in the area during those months.

We expected that disturbance levels in the closed plots would be lower than in the open plots. In response to different disturbance levels, we anticipated that bird numbers, time spent foraging, and time spent resting would be different between open and closed plots. Three-way ANOVA's were used to test for significance of seasonal effects on average per scan values for census data, disturbance values, time spent resting, and time spent foraging. To nullify seasonal effects, which masked other significant trends, deviations from monthly averages were used in subsequent three-way ANOVA's testing for treatment, site, and tide effects. Student-Newman-Keuls tests were used to determine when differences between treatments, seasons, tide phases, and sites were significant.

RESULTS

Disturbance levels in open plots varied by season ($F = 8.92$, $P < 0.002$, $df = 2$) with nearly 10 times more disturbance events in fall than in spring and winter (Table 1, Figs. 2 and 3). Disturbance levels in closed plots were much lower and showed little seasonal variation (Fig. 2). A significant interaction occurred between treatment and season ($F = 8.01$, $P < 0.003$, $df = 2$). Although bird numbers were higher in fall than winter and spring ($F = 3.90$, $P < 0.04$, $df = 2$), the time shorebirds devoted to feeding ($F = 0.55$, $P < 0.58$, $df = 2$) and resting ($F = 2.58$, $P < 0.10$, $df = 2$) did not change with respect to season (Fig. 4).

Disturbance was consistently higher in open plots than in those closed to human activity ($F = 327.77$, $P = 0.0001$, $df = 1$) (Figs. 2 and 3). There were also variations in disturbance levels between sites ($F = 27.69$, $P < 0.0001$, $df = 5$). Disturbance events increased in number from low to high tide but those differences were not statistically significant (Fig. 3).

Shorebird numbers were always significantly higher in closed plots than in open plots ($F = 5.81$, $P < 0.03$, $df = 1$). The number of shorebirds per scan ranged between 15 and 20 in open plots (Fig. 2). Bird numbers were higher in the closed plots, with fall numbers of 35 to 40

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shorebirds per scan. These were nearly 4 times larger than winter values (Fig. 2). Differences in the number of individuals seen per scan also varied among sites ($F = 9.26$, $P < 0.0001$, $df = 5$). Tide effects were not significant although more birds were usually present at low tide than at high or intermediate stages (Fig. 3).

Shorebird foraging times were not significantly different ($F = 2.06$, $P = 0.1663$, $df = 1$) between open plots and plots closed to people, nor were they significantly different with regard to season (Fig 4). Time spent foraging did, however, vary significantly ($F = 13.24$, $P < 0.0002$, $df = 2$) with tide cycle (Fig. 5). Shorebirds spent more time feeding during intermediate and low tides than at high tide. There were no significant differences in foraging times among sites.

Shorebirds spent nearly twice as much time resting in closed plots than in open plots ($F = 13.42$, $P < 0.002$, $df = 1$) (Figs. 4 and 5), and significantly more time was spent resting ($F = 7.66$, $P < 0.003$, $df = 2$) at high tide than during intermediate or low tides. Resting times were similar among all sites ($F = 1.52$, $P < 0.22$, $df = 5$).

Seven species of shorebirds were regularly recorded within the study plots (Table 2). Sanderlings were the most abundant species during winter, spring and fall. Only Willets (*Catoptrophorus semipalmatus*) and American

DISCUSSION

Closing the beach to human traffic significantly reduced disturbance levels. Even at sites with the most human activity, disturbance levels in the closed plots were always much lower than in the adjacent open plots. Closed plot disturbance values averaged less than 2 events per scan for all sites, and these often represented the research assistants who needed to sit in the center of the plots in order to conduct scans. There was a significant 10:1 difference in average disturbance events per scan between open and closed plots.

Disturbance levels in open plots increased during spring and peaked in fall with disturbance levels nearly 10 times higher than winter values (Fig. 6). Fall data were collected in July, August, and September to coincide with fall shorebird migration (Fussel and Lyons 1990) and to allow for equal sample sizes among seasons. Our findings agreed with Burger (1986) who found disturbance levels in Jamaica Bay, New York, to peak between May and August. During these peak disturbance times along the Outer Banks, it was not unusual to record up to 400 individual sources of human disturbance, including vehicles, pedestrians, fishermen, swimmers, and dogs, during a single disturbance scan in an open plot. The most disturbed plots were at

Frisco and Cape Point, which were grouped together by SNK testing as having significantly higher disturbance levels than all other sites. These beaches were adjacent to campgrounds and had several nearby off-road vehicle (ORV) ramps. They were constantly used by tourists and residents because of their accessibility and proximity to the towns of Buxton and Frisco. The Avon site had the least disturbance. The nearest ORV ramp was about 2 km north of the site and there was limited pedestrian access. These differences in disturbance levels likely accounted for higher bird numbers seen at the Avon site. In Raritan Bay and Delaware Bay in the northeastern United States, Burger (1986) saw fewer birds on beaches with high levels of disturbance than on beaches with low disturbance, indicating that high disturbance levels reduced shorebirds' use of beach habitat. During winter, when disturbance levels in open plots were about the same as in closed plots, more shorebirds were observed in open areas (Fig. 2). They may have been exploiting foraging and roosting habitats that were unavailable to them during spring and fall when human activity kept them out of those areas.

Most species of shorebirds seen along the Cape Hatteras National Seashore were using those beaches as stopovers between breeding and wintering grounds. Our data reflected this with higher numbers of shorebirds observed during spring and fall migrations than in winter (Fig. 2). Shorebird numbers increased significantly during spring migration and peaked in the fall with as many as 526 shorebirds per census scan in the 0.5-km-closed study plots. Higher numbers of shorebirds were observed during fall migration than during spring. This may have been due to some species' use of different migration routes for spring and fall. Shorebirds also tend to migrate slower during fall and may have spent more time in the study area than during spring migration.

Overall, average bird numbers were significantly higher in the closed plots than in the disturbed plots agreeing with Burger (1986); however, sites at Hatteras Inlet and Ocracoke North did not conform to that pattern (Table 1). Although recorded disturbance levels for the Hatteras Inlet site were low in comparison to other sites (Table 1), there were regular trespasses into this closed plot. Tire tracks through the plot and broken sign posts were observed at almost every sampling period. Beach visitors were seemingly less likely to drive or walk through closed plots when researchers were present. There were also notable differences in the physical characteristics of the beach itself. A steep scarp was formed in the closed plot at Hatteras Inlet during a winter storm. This steep beach gradient reduced the amount of usable beach for shorebirds providing little intertidal beach for foraging. The amount of foraging area is related to the number of shorebirds one can expect to see in any given area (Recher 1966, Burger 1977, Puttick 1984). The upper beach area, usually used for roosting, was bordered on 3 sides by open beach with fairly heavy vehicle traffic. The open plot at Hatteras Inlet had a broad gentle slope with more intertidal foraging area and more uninterrupted roosting space. These physical conditions were likely responsible for higher shorebird numbers in the open plot than in the closed plot at the Hatteras Inlet site.

The Ocracoke North site had a wide beach in the open and closed plots and both experienced relatively little disturbance. An area between the open and closed plots had been previously closed to vehicles but not to pedestrians. Large numbers of shorebirds were regularly observed feeding and roosting in the area between the 2 plots. The birds may have utilized that section of beach prior to our study due to its lower disturbance level. A general trend was seen for birds to forage northward toward the open plot then fly back south into the closed area to forage the same section of beach repeatedly. This may have been the result of higher prey densities in that area or could have been to avoid human activities in the open plot.

Analyses of variance showed no significant differences in bird numbers or disturbance levels among tide phases. There was however, a pattern of increasing numbers of birds present from high tide to low tide as seen in other studies (Burger et al. 1977, Meyers 1984, Puttick 1984, Helmers 1992) and decreasing average disturbance levels from high to low tide (Fig. 3). The increase in bird numbers may be attributed to lower disturbance levels (Burger 1986) or to increased feeding opportunity the birds encountered at low tide (Recher 1966, Burger et al. 1977, Meyers 1984, Puttick 1984, Maron and Meyers 1985, Swennen et al. 1989, Helmers 1992) or most likely a combination of the two.

Feeding time did not vary significantly between closed plots and open plots. In open plots, however, feeding areas in the intertidal zone were often divided into small, irregularly spaced sections between groups of humans. This division of the foraging habitat did not allow shorebirds to congregate into large feeding flocks as they normally would, likely resulting in reduced feeding efficiency. In closed plots, we observed that birds were spending up to 70 percent of their time feeding in both large multispecies and single species flocks along the intertidal zone. Advantages of foraging in flocks may include enhanced feeding efficiency and increased safety from predators. In mixed species flocks, individuals may be able to expand their foraging niches and exploit the time and energy of other birds with minimal competition for food items (Recher 1966, Meyers 1984, Barnhard and Thompson 1985).

Most species concentrated feeding efforts in the wet sand at the water's edge. In open plots, this zone of intertidal beach was also heavily used by vehicle and pedestrian traffic. When interrupted by human activities, flocks would often take wing and move to a new location. When disturbed several times in succession, shorebirds were likely to abandon an area completely, as was also found by Burger (1986). It is possible that shorebirds left areas of high prey concentrations to forage less profitable habitat in an effort to avoid human disturbances. Even if shorebirds remained in areas of human activity, foraging behavior may have been adversely affected. Burger (1991) found that human disturbance negatively affected foraging activities of the Piping Plover (*Charadrius melodius*) resulting in a decrease in foraging time and an increase in time devoted to alertness. She suggests that this loss of foraging time caused a decrease in Piping Plover fitness.

Tides influence shorebird feeding habits directly through effects on the amount of time and space available for foraging (Burger 1977, Puttick 1984). Shorebirds along the Outer Banks spent nearly 80 percent of their time during low tide foraging (Fig. 5). That was an increase of 20 to 30 percent when compared to high tide. SNK grouping showed that foraging times during low and intermediate tide phases were significantly higher than foraging times during high tide. Shorebirds were taking advantage of increased foraging habitat resulting from lower water levels. In the northeastern United States, prey items found lower on the beach were found to be more abundant, larger, and may have provided more energy per item than at other tide phases (Puttick 1984). Since prey items exposed at lower tide levels were only available for a short time, shorebirds rarely ceased feeding during low tide phases and were less likely to fly away from disturbance. When disturbed, they usually ran a short distance but were quick to resume foraging with little time spent in alert postures. When foraging under time-stressed conditions, shorebirds tend to maximize foraging time by decreasing search time and handling time per prey item, which increases the overall intake of food (Swennen et al 1989).

Large, multispecies flocks of shorebirds used upper beach areas in undisturbed plots primarily for roosting. Those areas provided broad, flat beaches with little vegetation. Presumably the birds preferred those areas due to the reduced likelihood of predators approaching roosting flocks unobserved (Helmers 1992). In open plots, resting flocks were nonexistent or were split into smaller groups that were more susceptible to disturbance than larger flocks as was also seen by Burger (1986) along beaches of the northeastern United States. Smaller flocks were constantly running and flying to avoid humans and vehicles. With reduced resting times in disturbed plots and no changes noted in foraging times, shorebirds were expending more energy in disturbed areas to avoid pedestrians and vehicles on the beach at the expense of resting time.

Shorebirds had more resting time during high tide than at intermediate or low tide (Fig. 5). With their foraging habitat reduced by incoming tides, feeding efficiency was reduced (Helmers 1992). We observed that almost 60 percent of the shorebirds' time was still devoted to foraging, but it was done in small increments with frequent rest breaks. Often birds would stop foraging and walk to the upper beach, joining roosting flocks for several minutes before resuming foraging. It was probably more profitable for the birds to rest and wait for a falling tide that would expose more abundant prey (Helmers 1992).

Overall, we saw that the main impacts of human beach use on shorebirds in the Cape Hatteras National Seashore were displacement of shorebirds from beach habitat and interference with normal resting and foraging behaviors. The highest impacts seemed to occur during spring and fall seasons when human beach traffic was at its peak. These times coincided with the spring and fall migrations when shorebird numbers were also highest.

Different human activities had different effects on shorebird behavior. Faster, erratic events such as running pets and children, seemed to upset birds more than slower, regular events such as people walking, or slow moving vehicles. This was very similar to Burger's (1986) findings in New York. Along North Carolina's Outer Banks, many shorebirds seemingly ignored stationary humans and stationary vehicles on the beach, often foraging within a few feet of sunbathers and parked vehicles. Beach closures reduced impacts of other human activities by allowing shorebirds to forage and roost in undisturbed habitats.

This project was not designed to compare different parts of the outer banks relative to disturbance and shorebird behavior. The five pairs of plots were used as replicates to provide adequate sample size for statistical tests. It is possible, however, to make some observations about different sites that may be useful for management purposes.

Disturbance levels in the open plot at Avon were comparable to disturbance levels in closed plots at other sites (Table 1). As discussed earlier, the lower levels of human activities observed at the Avon site were likely due to limited access to that section of beach. Most disturbances were fishermen and stationary vehicles. There were observations of people walking and jogging, but pedestrian traffic was not heavy. With beaches adjacent to the Avon site closed to ORVs by the National Park Service, vehicular traffic was minimal. Overall, human activities on this section of beach were very low in comparison to the rest of the study sites within the Cape Hatteras National Seashore.

Cape Point was one of the most heavily disturbed study sites at Cape Hatteras (Table 1, Fig. 8). This site had several access points for pedestrians and vehicles. Cape Point is a popular recreational beach for residents and visitors alike. Most beachgoers were fishing but many were sunbathing, swimming, and walking. Proximity to the town of Buxton and several other points of interest provides for high levels of human activities. At any time during our study we were likely to see between 25 and 30 stationary people and 8 to 10 stationary vehicles within our study plot. On several occassions we counted the total number of vehicles at Cape Point regardless of plot boundaries. During these estimates it was not unusual to see more than 300 vehicles and nearly 1000 people lining the water's edge around the point. As a result, shorebirds were not observed in large numbers at Cape Point, as they were at the Avon site. Shoreirds that were present were constantly running and flying in efforts to avoid moving vehicles, pedestrians, and dogs. As Cape Point is also a valuable nesting area for several species of colonial waterbirds (see the report on colonial waterbirds), the high levels of human activities are of concern.

Disturbance levels in the open plot at Frisco were very similar to those at Cape Point (Figs. 8 and 9). Again the higher levels of human activities were likely due to easy accessibility and the proximity of the Frisco Campground. The Frisco site was used more as a pedestrian beach than Avon and Cape Point. There were still large numbers of stationary vehicles and a steady flow of ORV traffic, but people were using that area more for swimming, surfing, volleyball, and other beach activities rather than sport fishing. As a result, human traffic along the beach, especially near the water line, was generally higher at Frisco than at other sites. As stated earlier, human foot traffic is often more disruptive to shorebird behavior than moving vehicles. On several occassions we observed dogs off-leash running the length of the study plot. This usually resulted in most shorebirds leaving the area. We also regularly saw groups of people on horseback. The horses had the same effect as dogs on shorebirds. Overall, Frisco was one of the most disturbed sites in this study.

The Hatteras Inlet site was mostly used by sport fishermen, as access was difficult except for ORVs. The overall level of disturbance events recorded there were intermediate relative to other sites (Table 1). Vehicular traffic was fairly constant through the Hatteras Inlet site, presumably fishermen heading toward the inlet (Fig. 10). During surf fishing tournaments, the numbers of fishermen in the Hatteras Inlet area increased dramatically. At those times, we observed several hundred people and vehicles along the water stretching out of sight in both directions.

At Hatteras Inlet the closed plot did not extend to the dune line as in the other plots. Space was left to allow for the passage of vehicles above the plot, between the posted area and the dunes. This was done to ascertain whether or not such a closure design would allow birds to utilize the area without blocking all pedestrian and vehicular traffic. Birds did not utilize the closed plot to the extent we observed at other sites (Table 1), but differences between open and closed plots were clearly visible (Table 1, Fig. 10). We also noticed that there was a greater incidence of human intrusion into the closed plot at the Hatteras Inlet site. While results cannot be statistically tested, it appeared that closing the entire beach controls disturbance better than allowing access above the plot.

The site at Ocracoke North had relatively low disturbance levels in comparison to other sites at Cape

Hatteras except Avon (Table 1). Our records averaged less than 10 disturbances for any given time (Fig. 11). The reduced disturbance levels may be attributable to lower accessibility as at the Avon site. There was only one point of access to the Ocracoke North site and no development within several miles. Most sources of disturbance there were stationary vehicles and stationary humans (Fig. 11). It was a popular spot for fishing and sunbathers. There were regular observations of walking and swimming humans within the plot, but almost no joggers or surfers. Shorebirds utilized the open plot there in similar numbers to those seen in the closed plot (Table 1).

Ocracoke South was busier than the Ocracoke North site in terms of human activities (Table 1, Figs. 11 and 12). It was closer to areas of development and a campground but was still buffered by a large expanse of undeveloped land. The primary disturbances there were stationary humans and stationary vehicles. It was a popular site with sport fishermen and sunbathers. There was regular pedestrian traffic along the water line but vehicular traffic was low. The reduced vehicular flow was due to areas of beach closed to ORVs both north and south of the study plot. With only one point of access and limited development nearby, the heavily disturbed Ocracoke South site would appear to be an exception to the trend of lower disturbance levels seen at other sites with reduced access.

North Core Banks was the least disturbed of all the study sites (Table 1, Fig. 8). As there are no permanent residents of the island and access is only by car ferry or boat, human activity is very limited. Bird numbers and behavior were assumed to be as close to unimpacted as possible at this site.

This site was paired with Cape Point, which represented a very heavily impacted section of beach (Fig. 8), As disturbance levels in this open plot at North Core Banks were very similar to those in the closed plots within the Cape Hatteras National Seashore, North Core Banks may make an acceptable control site for future studies at Cape Hatteras where human use of the beach is much greater.

SUMMARY

1. Impacts of human use of barrier island beaches on shorebirds along North Carolina's Outer Banks were determined during a 16-month period (April 1992 - July 1993) by observing shorebird numbers and behavior relative to human activities in six pairs of beach plots.

2. Within each pair, one plot was open to human use and the other was closed to all human traffic.

3. Human beach use peaked in the fall, coinciding with shorebird migration and highest shorebird numbers.

4. Human disturbance levels decreased from time of high tide to low tide.

5. More shorebirds were observed within plots closed to humans than in open areas. Shorebirds were also more abundant during intermediate and low-tide phases than high tide.

6. Shorebirds spent more time foraging during periods of low and intermediate tide than at high tide. Although time spent foraging did not differ significantly between open and closed plots, high levels of human activity may have reduced shorebirds' feeding efficiency by disrupting flocking behavior along the intertidal beach.

7. More time was spent resting on upper beach areas during high tide than during other tide phases. Resting time was reduced by nearly 50 percent in areas open to human activity.

8. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for shorebirds.

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APPENDICES

Appendix A: Monthly summaries of disturbance data.

Within each month, disturbance data are broken down to type of disturbance, total number of disturbances recorded, average number of disturbances per scan, and tide phase for open and closed plots.

Appendix B: Monthly summaries of bird census data.

All species recorded in open and closed plots with regard to site and tide phase. Total numbers of individuals, total numbers of species, numbers of shorebirds and percentages shorebirds represent of all recorded species are given.

Appendix C: Monthly summaries of shorebird behavioral data.

All focal scans conducted on shorebirds are given in seconds with regard to tide phase for open and closed plots at all sites. Observations are grouped by species. Species are abbreviated as follows:

American Oystercatcher	Amoy	Semipalmated Plover	Sepl
Piping Plover	Pipl	Black-bellied Plover	Bbpl
Ruddy Turnstone	Rutu	Whimbrel	Whim
Willet	Will	Dunlin	Dunl
Short-biolled Dowitcher	Sbdo	Sanderling	Sand
Marbled Godwit	Mago	Red Knot	Rekn

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Table 1. Disturbance events , shorebird numbers, time spent foraging, and time spent resting for open and closed plots at all sites. (Numbers are averages per scan.)

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Avon	High	2.58	0.92	16.33	50.34	69.33	58.00	11.11	31.11
	Int	3.86	1.07	34.06	67.89	61.22	81.89	6.11	13.33
	Low	3.33	1.94	23.44	67.22	72.67	70.78	5.22	19.44
Cape Point and	High	17.17	0.78	7.56	15.25	50.67	76.17	5.11	26.20
North Core Banks	Int	15.86	0.98	6.00	17.38	43.89	92.00	22.44	7.60
	Low	11.79	1.09	9.28	20.88	72.22	79.67	6.78	9.60
Frisco	High	16.17	0.97	7.50	12.78	51.44	57.11	0.22	21.44
	Int	16.89	1.10	20.83	20.79	57.33	78.33	7.56	13.22
	Low	20.54	1.10	28.91	56.28	72.67	82.00	4.56	11.67
Hatteras	High	6.31	1.15	4.22	2.44	38.00	35.67	15.11	13.44
Inlet	Int	5.70	0.92	21.89	13.91	68.78	65.11	12.56	3.78
	Low	6.49	1.60	9.22	9.67	76.44	69.78	18.89	8.44

Table 1. Continued

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Ocracoke	High	5.15	1.31	34.72	8.44	63.89	52.89	7.33	21.56
North	Int	5.52	1.65	10.39	9.28	79.11	86.89	12.22	17.56
	Low	3.25	1.19	12.50	9.39	86.78	80.22	10.22	6.89
Ocracoke	High	9.43	0.98	19.33	24.50	70.56	64.44	7.56	30.22
South	Int	13.00	1.06	19.72	32.22	77.67	68.78	11.22	15.78
	Low	10.35	1.06	19.56	18.78	77.89	84.11	77.89	7.56

Table 2. Average numbers of shorebirds per scan in open and closed plots with respect to tide.

Species	High Tide		Int Tide		Low Tide	
	Open	Closed	Open	Closed	Open	Closed
Sanderling	10.27	14.69	13.93	19.33	13.07	24.88
Red Knot	0.25	0.18	0.01	0.61	0.13	0.88
Black-bellied Plover	0.55	0.42	0.53	0.47	0.92	0.39
Whimbrel	0.84	1.76	1.51	3.18	0.60	1.46
Willet	0.83	2.99	1.89	6.16	2.89	5.08
Ruddy Turnstone	0.14	0.38	0.24	0.09	0.26	0.44
American Oystercatcher	0.17	0.44	0.33	0.83	0.31	0.60

Table 3. Average numbers of shorebirds per scan in open and closed plots with respect to tide.

Species	High Tide		Int Tide		Low Tide	
	Open	Closed	Open	Closed	Open	Closed
Sanderling	10.27	14.69	13.93	19.33	13.07	24.88
Red Knot	0.25	0.18	0.01	0.61	0.13	0.88
Black-bellied Plover	0.55	0.42	0.53	0.47	0.92	0.39
Whimbrel	0.84	1.76	1.51	3.18	0.60	1.46
Willet	0.83	2.99	1.89	6.16	2.89	5.08
Ruddy Turnstone	0.14	0.38	0.24	0.09	0.26	0.44
American Oystercatcher	0.17	0.44	0.33	0.83	0.31	0.60

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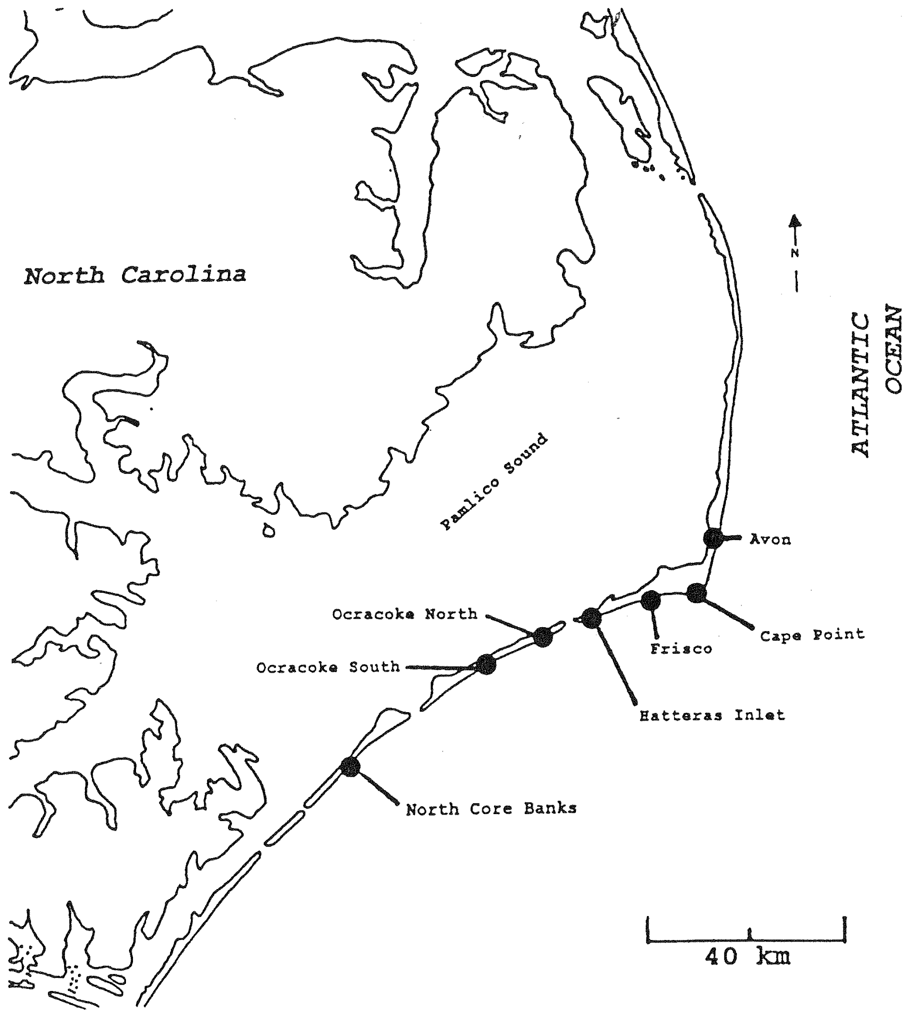

Figure 1. Study sites along North Carolina's Outer Banks. Each site consisted of two paired beach plots, one open to human use and one closed to all human activities. The open plot at Cape Point was paired with the closed plot at North Core Banks.

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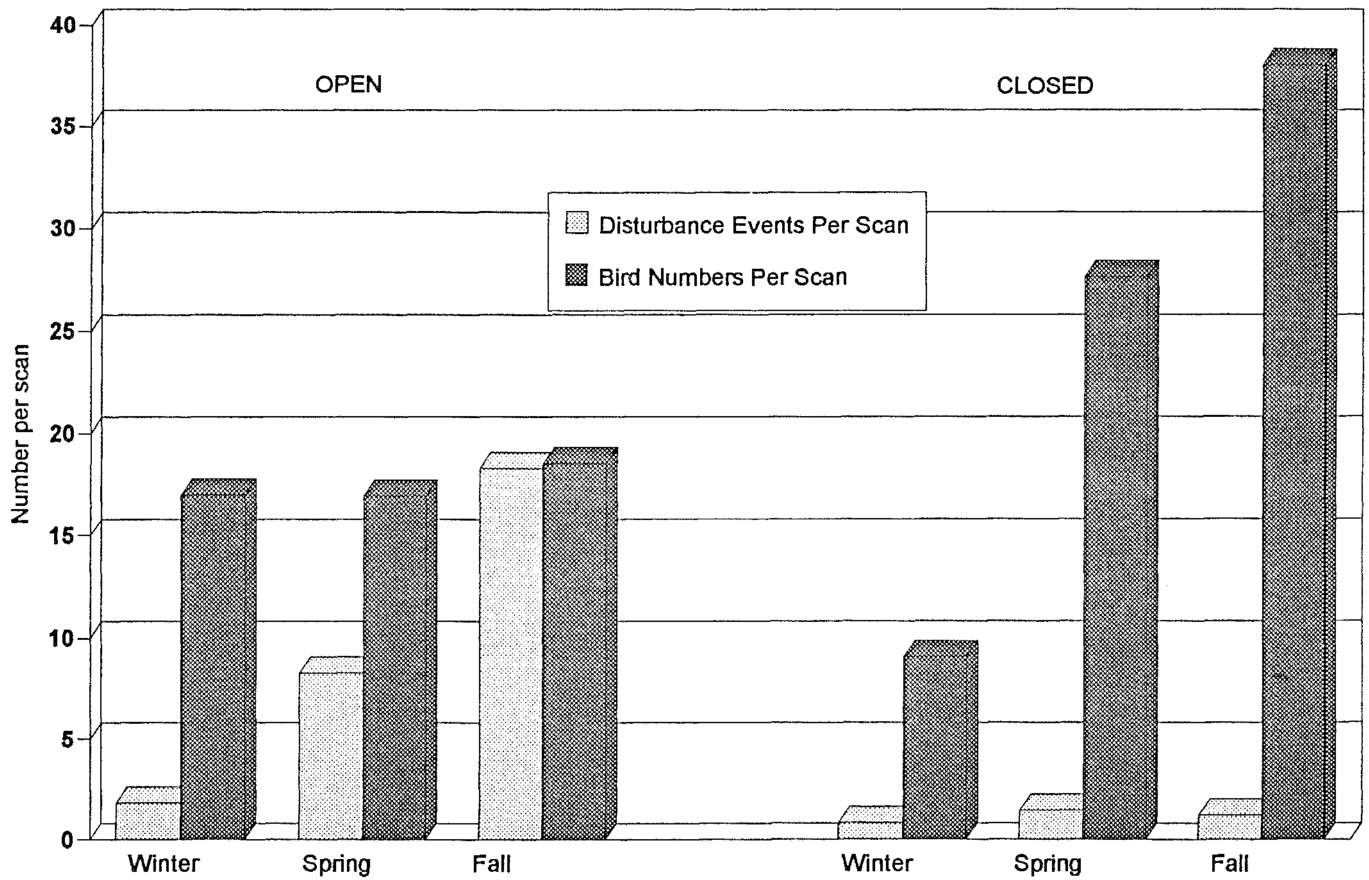

Figure 2. Average disturbance events per scan and average shorebird numbers per scan during winter, spring, and fall.

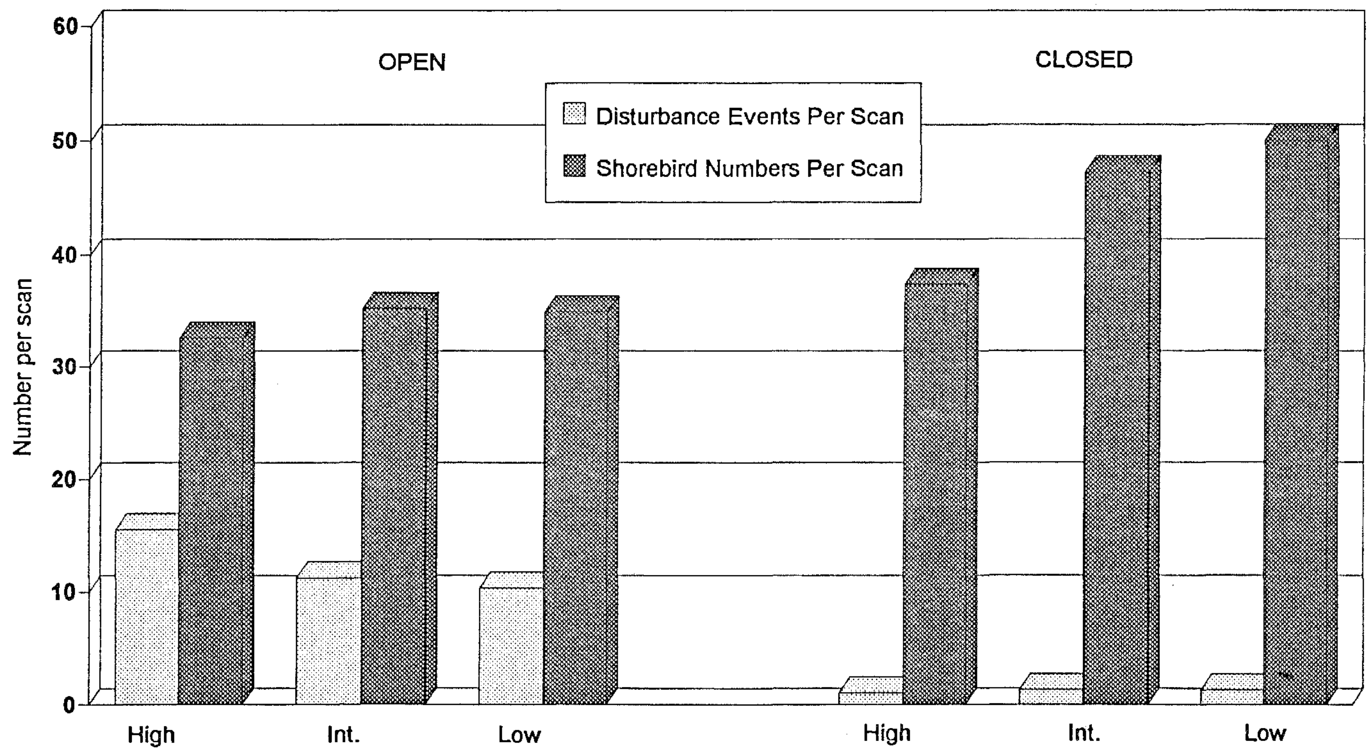

Figure 3. Average disturbance events per scan and average bird numbers per scan at high, intermediate, and low tides.

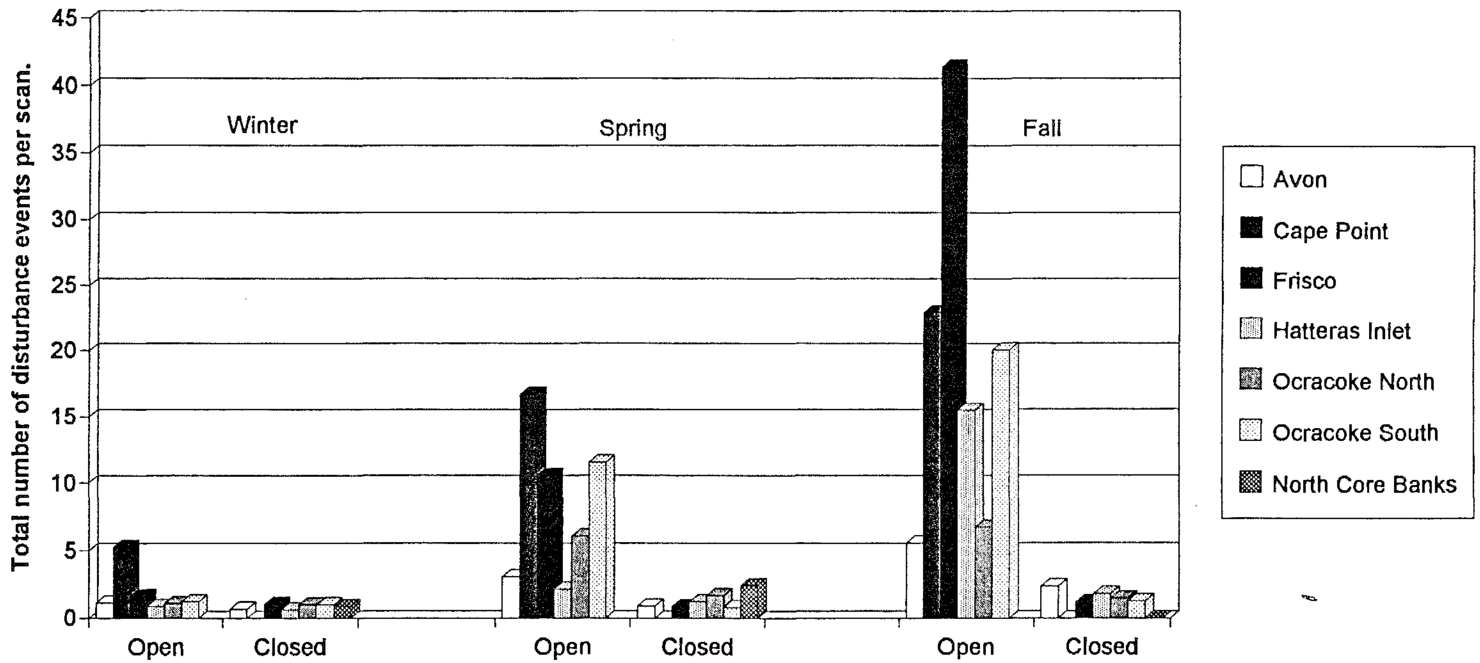

Figure 6. Disturbance events at study sites by season.

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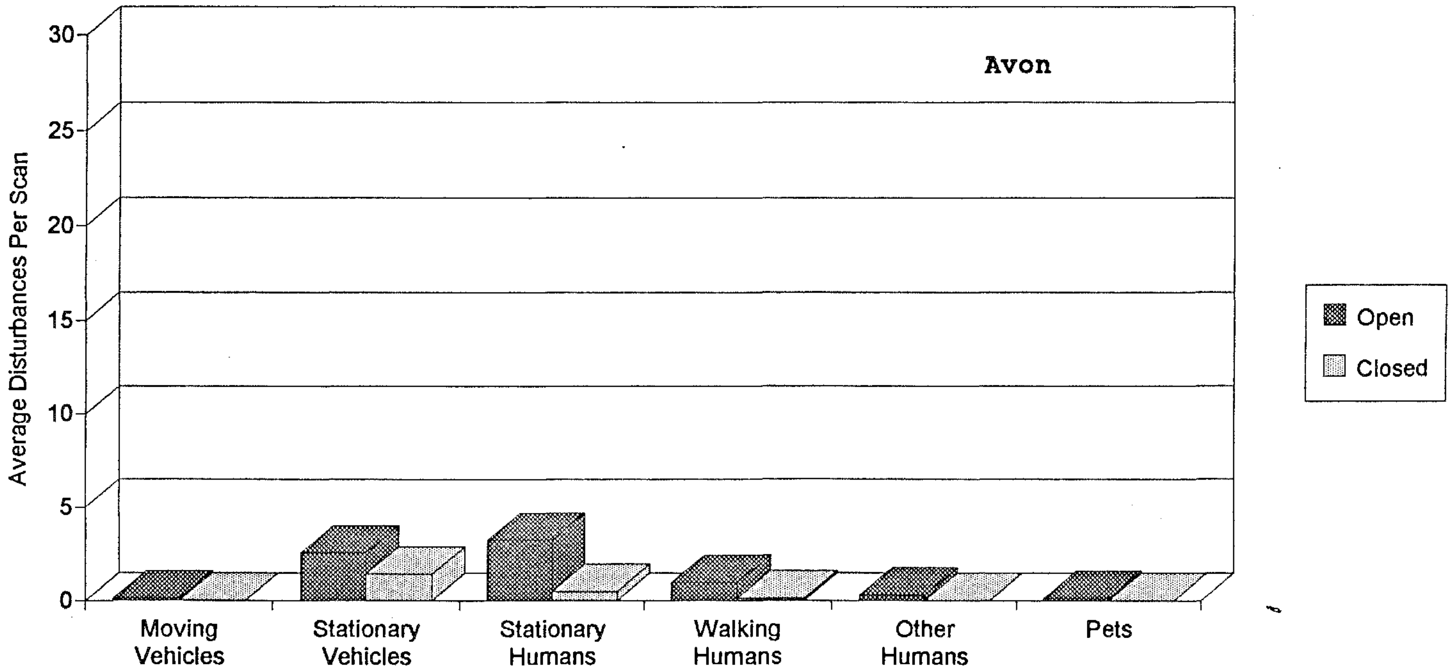

Figure 7. Kinds of disturbance and disturbance levels at the Avon site

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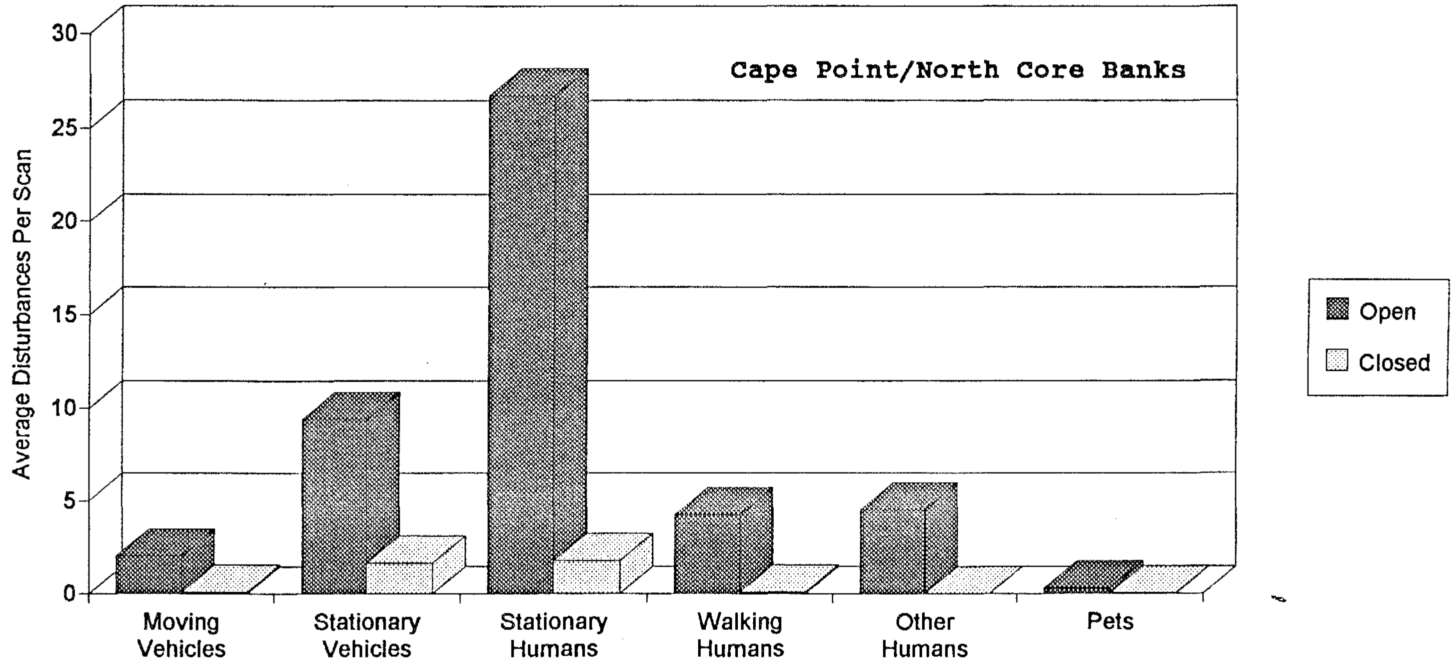

Figure 8. Kinds of disturbance and disturbance levels at the Cape Point/North Core Banks study site

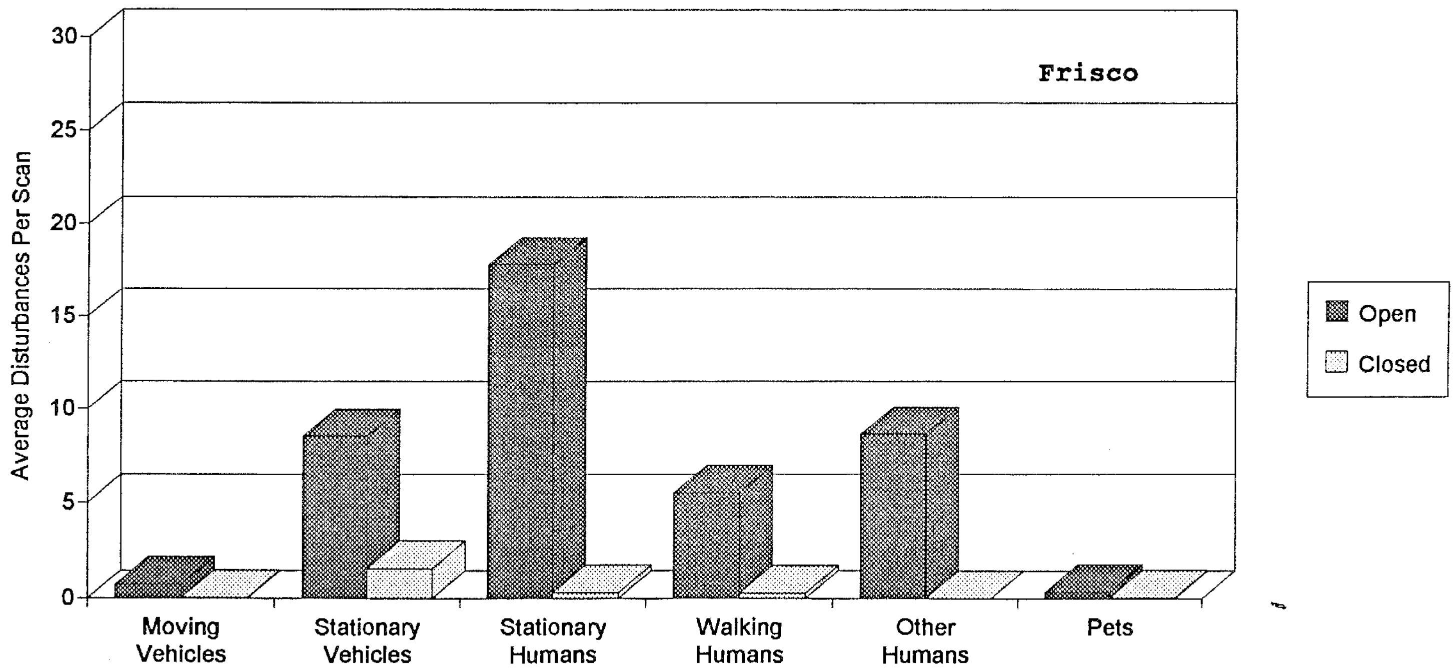

Figure 9. Kinds of disturbance and disturbance levels at the Frisco study site

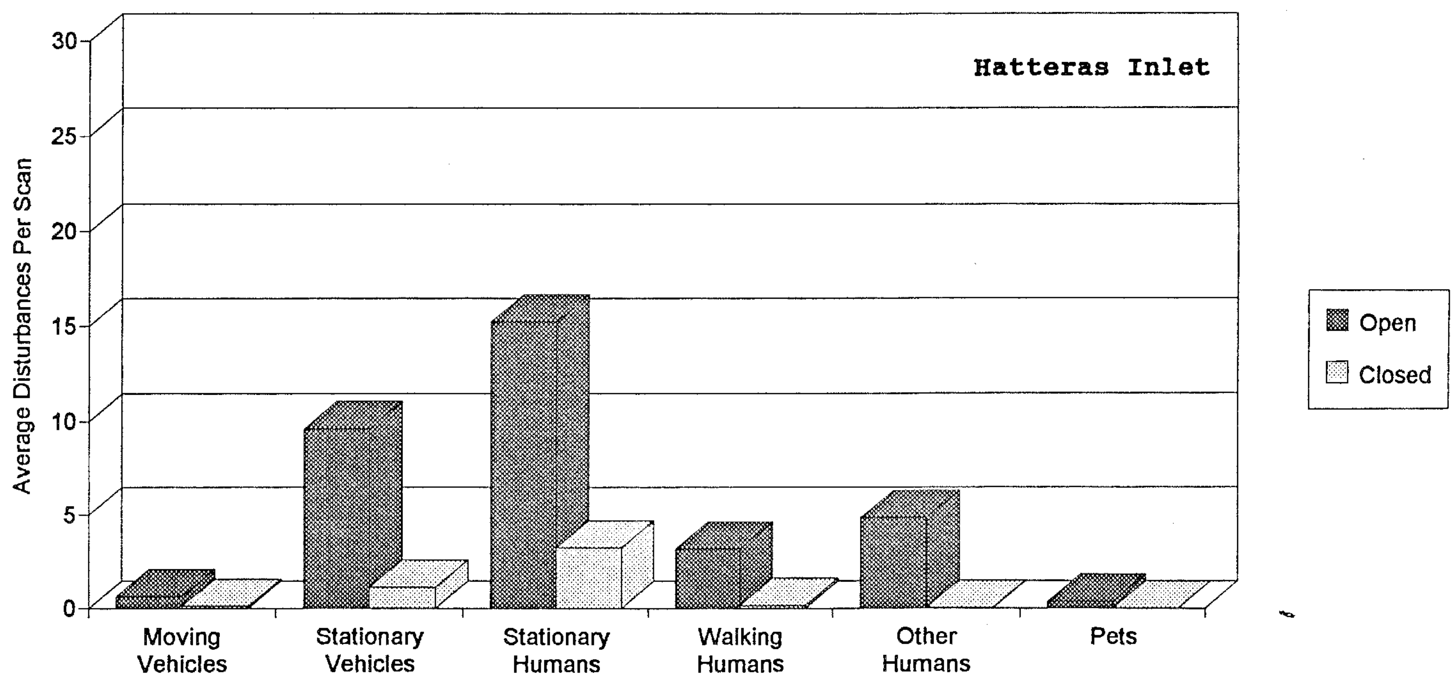

Figure 10. Kinds of disturbance and disturbance levels at the Hatteras Inlet study site

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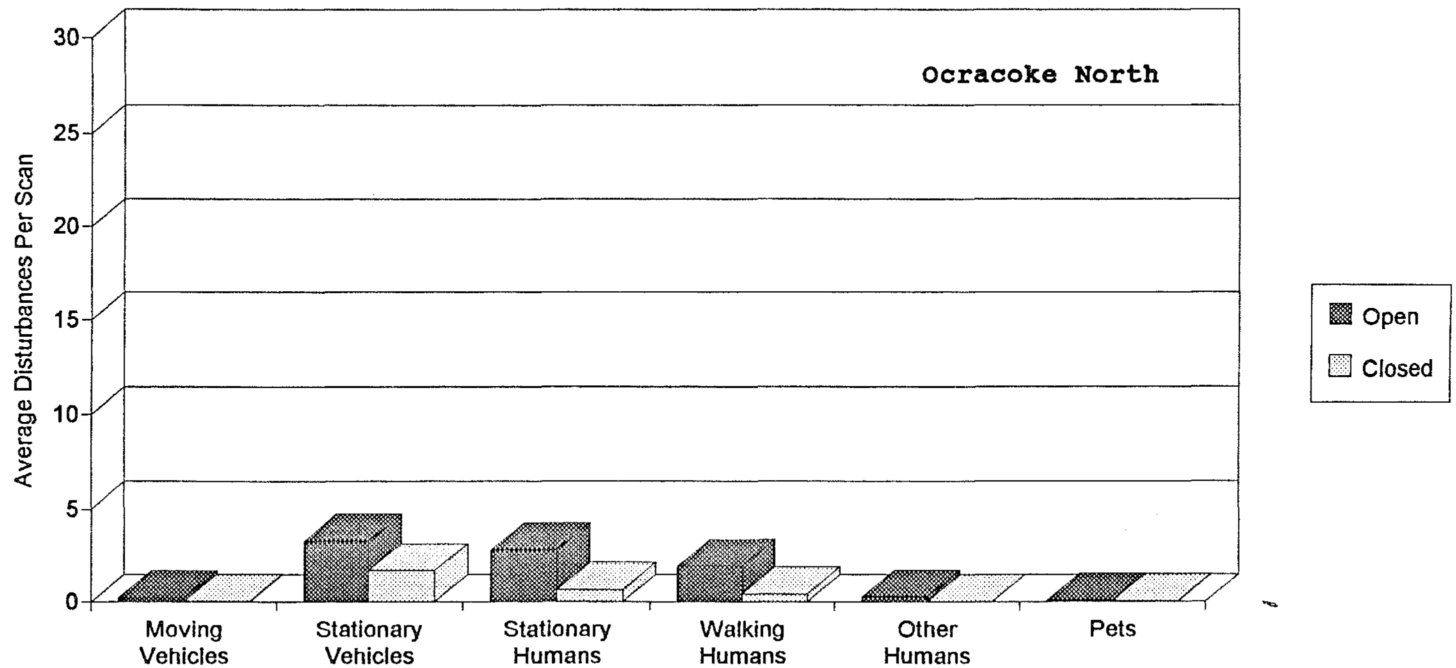

Figure 11. Kinds of disturbance and disturbance levels at the Ocracoke North study site

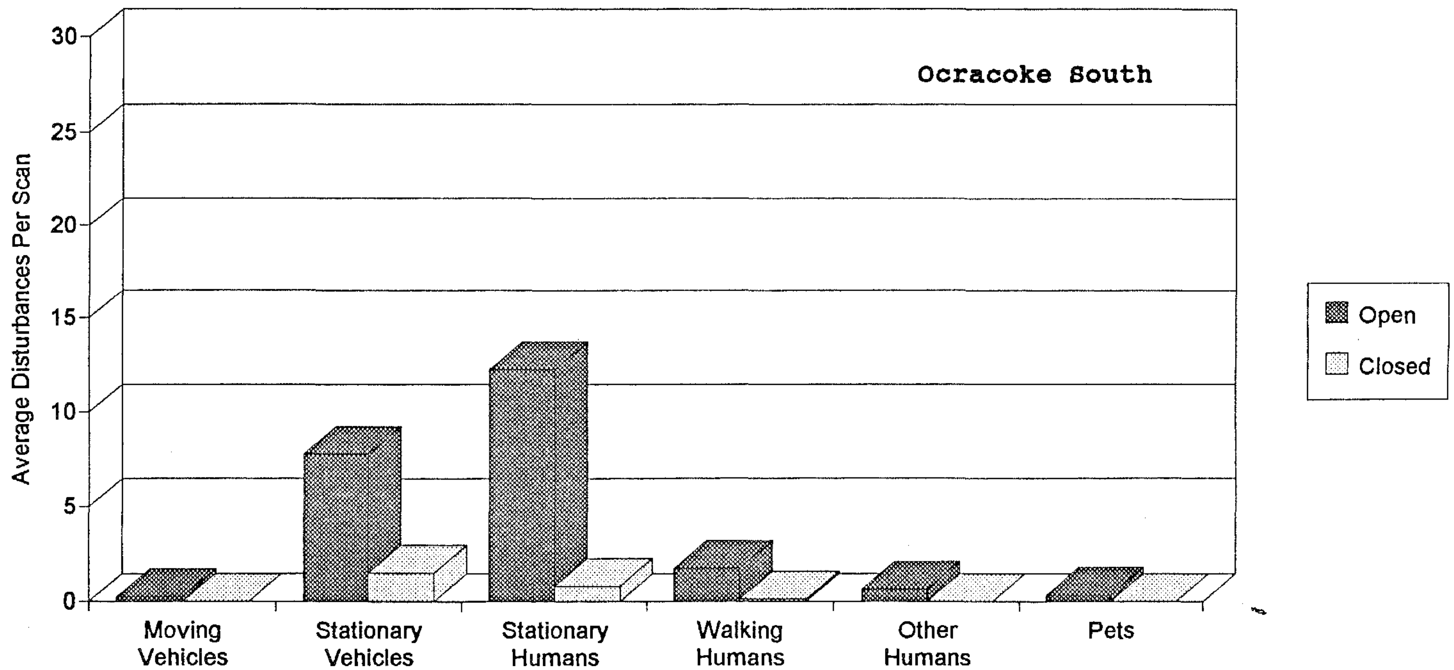

Figure 12. Kinds of disturbance and disturbance levels at the Ocracoke South study site

Breeding colonial waterbird studies on the Outer Banks of North Carolina.

Chapter IV

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INTRODUCTION

The primary goal of this phase of the project was to determine nesting populations at all nesting colonies of gulls, terns, skimmers, herons and egrets within the Cape Hatteras and Cape Lookout seashores during 1992 and 1993 and to relate present populations to historical levels and to regional populations outside of the Seashores.

METHODS

All colonies of nesting waterbirds were surveyed during the peak of the breeding seasons of 1992 and 1993. Colonies were located by driving the beaches of the two Seashores and by visiting all offshore islands by boat. When colonies of nesting birds were located, nest counts were made during the period of incubation. Counts usually involved a team of several workers walking slowly through the colony counting all nests within prescribed strips. Personnel from the University of North Carolina at Wilmington, the North Carolina Wildlife Resources Commission, the National Audubon Society and the National Park Service assisted with the colony surveys. These surveys provided total counts of active nests present at the time of the census. This is the same technique that has been used for the past several years by workers censusing colonial waterbird nests along the North Carolina coast (Parnell and Soots 1979, Parnell and McCrimmon 1984, Parnell and Shields 1990).

RESULTS AND DISCUSSION

Spring and early summer of 1992 were unusually cold and wet, and nesting data were not suitable for determining the current status of several species of nesting birds. The 1993 breeding season was more normal, being generally warm and dry, and data gathered was expected to be representative of a reasonably normal season.

Cape Hatteras: There are three sites within the Cape Hatteras National Seashore where beach nesting waterbirds have nested in good numbers during recent years--Ocracoke Flats, Hatteras Flats and Cape Point. Numbers of nesting terns and skimmers have declined at all three sites in recent years. Ocracoke Flats was the earliest site to be heavily utilized, with good numbers of nesting birds from 1977 through 1989 (Fig. 1). It was abandoned soon after stabilization of the interior road from Highway 12 to the inlet. This area had been maintained as an open sand flat by heavy ORV use, and the habitat was appropriate for nesting terns and skimmers. After traffic was limited to a fixed roadway, the flats rapidly grew up to marsh, and appropriate nesting habitat for this group of birds disappeared. It appears that the new natural spit developing at Ocracoke Inlet will again provide nesting habitat for terns and skimmers in that region if it is properly managed. Small numbers of Common Terns (*Sterna hirundo*) and Black Skimmers (*Rhynchops niger*) attempted to nest there in 1992 but were unsuccessful (Table 1). I suggest that this spit be left open to ORV traffic except during the nesting season. Post the colony sites that are utilized by the birds as is now being done at Cape Point and Hatteras Inlet.

Both the Hatteras Flats (Fig. 2) and Cape Point (Fig. 3) colonies grew rapidly after the sites were provided protection from unrestricted vehicular traffic, but nesting at Hatteras Flats has declined recently in spite of continued protection. Heavy use of these sites coincided with the deterioration of habitat on offshore dredged-material islands, specifically those islands just to the east of the ferry channel from Hatteras to Ocracoke. The decline in use of the beach site at Hatteras Inlet appears to be due to vegetation encroachment occurring as a result of the absence of vehicular traffic. Hatteras Flats was not used at all in 1992 but had a small colony in 1993. The Cape Point colony has declined somewhat in recent years but remains a very important nesting site for Least (*Sterna albifrons*) and Common Terns with some Black Skimmers and Gull-billed Terns (*Sterna nilotica*) as well. This colony moves each year into the most open areas available in this vicinity (Table 2).

Least Terns usually nest in small colonies at several sites along Seashore beaches. During 1992, several small colonies were initiated but were always abandoned before chicks hatched. This appeared to be due primarily to the cold rainy weather of spring and early summer. It is likely that most of these birds ended up in the large colony at Cape Point in 1992. In 1993 colonies occurred at Pea Island and near ramp 30 in addition to Cape Point and Hatteras Flats (Table 2).

In 1992, there was a total of 3,327 nests of 13 species counted within the Cape Hatteras National Seashore, if the Ocracoke Village Heronry (located on private property within the Seashore) is included. In 1993, numbers rose to 4,324 nests of 14 species (Table 3). The primary increase was in numbers of White Ibis (*Eudocimus albus*) and Least Terns, although numbers of nests of several other species also were up.

The heronry at Ocracoke Village is developing into the largest heronry in the region. It was first discovered in 1989 when it contained over 600 nests of 10 species. By 1993 it contained nearly 900 nests of 9 species and was the largest nesting assemblage of White Ibis north of Southport. It is likely that this colony developed and has thrived due to the newly developing marsh between Ocracoke Village and Ocracoke Inlet. The conditions that made this site less suitable for nesting terns and skimmers may have provided good feeding habitat for waders, thus stimulating the development of a nearby nesting site.

It is likely that beach sites within the Cape Hatteras National Seashore will continue to be important for the ground nesting terns and skimmers for many years. Dredging practices are not maintaining islands adjacent to ferry channels, primarily due to problems of dumping in estuarine waters containing sea grass beds, and the dredged-material islands that were prime nesting sites in the 1970s are either gone or are growing up into dense grasslands or thickets. This, for example, is happening on the large island between Hatteras and Ocracoke islands.

Oregon Inlet may continue to be an exception, as the heavy boat use and shoaling there appear to continue to dictate that much dredged material be deposited on islands in and to the westward of the inlet. Most colonial waterbirds utilizing the northern portion of the Seashore, for example the herons and egrets using Bodie Island, apparently nest outside of the Seashore on these man-made islands.

Cape Lookout Nesting skimmers and terns on Cape Lookout beaches appear to move more frequently and to be less likely to nest for several years at the same site than at Cape Hatteras. This is probably due to the availability of more open, overwashed beach habitat in this Park. There are, however, several places where good numbers of birds frequently nest--Shackleford Point, Power Squadron Spit and New Drum Inlet (Table 4). The west end of Shackleford Island was occupied by sizeable numbers of nesting birds in 1992 and in 1993 (Table 4). Populations at Power Squadron Spit were lower in 1993 than in 1992 with many birds moving to Lookout Point in 1993. Numbers at New Drum Inlet were low in both 1992 and 1993, apparently due to overwash of this very low site.

Several colonies of Least Terns attempted to initiate nesting along the beaches of Core Banks in 1992 and in 1993. The colony at Swash Inlet was successful in 1992, but most of these birds apparently moved further south along the beach in 1993 (Table 4). Rain and wind apparently resulted in the failure of most other beachfront colonies.

Islands in the estuary behind Core and Shackleford banks are regularly used by nesting colonial birds. Nesting sites and numbers for 1992 and 1993 are found in Tables 5 and 6. Morgan Island, a large dredged-material island adjacent to the channel from Harkers Island to Lookout Bight, has been used for many years. In 1993 a heronry containing 905 nests of 9 species was present. This was more than double the 1992 numbers. This site appears to be attracting birds that are leaving the declining heronry at Phillips Island near Beaufort. Morgan Island also contained over 3,900 Laughing Gull (*Larus atricilla*) nests in 1993. This island appears to be strategically located for the birds and has been used frequently since it was constructed by dredged-material deposition.

Several marsh islands in Core and Back sounds are utilized each year by nesting Forster's (*Sterna forsteri*) and Common terns. Sites used shift from year to year depending on the presence of wrack in the marsh. Numbers of nesting birds appears to be relatively constant (Tables 5 and 6). An apparent trend in this region is the increasing use of these marsh islands by nesting Laughing Gulls. Laughing Gulls traditionally nest in *Spartina patens* meadows on upland sites, as on Morgan Island. In Core and Back sounds in recent years they have begun building elevated nests in *Spartina alterniflora* stands on marsh islands. This may be in response to problems on the nearby upland sites, such as Morgan, or to other unknown factors. In New Jersey, biologists are seeing the same trend and have attributed it to competition with Herring Gulls on the upland sites. Herring Gulls (*Laraus argentatus*) appear too infrequent in summer here to be a factor. Nutria (*Myocaster coypus*) are abundant in the region and are known to disturb nesting Laughing Gulls by grazing near nests at night. It may be that they are less likely to disturb birds nesting in saltmarsh vegetation.

There was a dramatic increase in the overall number of nests present within the Cape Lookout National Seashore from 1992 to 1993 (Table 7). In 1992, a total of 3,912 nests of 16 species were recorded. The most abundant species was the Laughing Gull with 625 nests. In 1993, 8,747 nests of 17 species were counted. Most of the increase was due to the presence of 4,227 Laughing Gull nests, but several other species also showed increases. The new species was the Sooty Tern (*Sterna fuscata*). A single nest was found among the Laughing Gulls on Morgan Island.

Colonial Waterbirds nesting in the Cape Lookout region will likely continue to use the natural beach sites, as bare dredged-material sites are likely to decrease in the region in the future. Use of marsh islands is likely to continue at present levels or to increase.

SUMMARY AND RECOMMENDATIONS

Indications are that colonial waterbirds are doing well at both Cape Hatteras and Cape Lookout. Both parks provide nesting habitat for significant regional populations of nesting colonial waterbirds. Reproductive success appears to be good, and the management strategy of posting colony sites and providing patrol of these sites appears to be effective.

Protection of nesting sites has allowed beach nesters to be successful most years in spite of heavy use of beaches by people. This strategy is now being copied by the State of North Carolina at Ft. Fisher and is allowing nesting to be successful there as well.

Primary threats to beach nesting within the national seashores appear to be overwash and vegetative encroachment. Predation, especially by mammals such as feral cats (*Felis domesticus*) and raccoons (*Procyon lotor*) may also be important occasionally. Overwash may destroy colonies when it occurs during the nesting season, but will likely be beneficial in the long run, as it helps to maintain the open sandy beach that is used by nesting terns and skimmers. Encroachment of beach nesting sites by plants is a normal part of the succession of overwash communities. Growth is slowed by frequent overwash and now by the action of ORVs. When colony sites are posted throughout the year, vegetation may grow rapidly and the period of use by nesting terns and skimmers will be shortened. Under natural conditions the birds would be expected to move to a new bare area elsewhere up or down the beach or to offshore dredged-material islands. This is much more difficult now that much beachfront is developed and dredging practices no longer result in the regular deposition of new surfaces on islands along dredging channels.

To assure that important sites where nesting birds are successful and where management is possible, we recommend that ORV traffic be allowed in such key colony sites as Cape Point, Hatteras Inlet, Power Squadron Spit, and the west end of Shackleford Island during the fall and winter to assist in maintaining the bare or nearly bare upper beach habitat necessary for nesting terns and skimmers.

Terns and skimmers that nest on bare or nearly bare sites need the most assistance. Laughing Gulls, nesting is dense Spartina patens meadows on islands along the sound are in habitat that is abundant and that will persist for relatively long periods. These are also areas little used by people and so human disturbance is less frequent. We do recommend that such sites be posted and visited occasionally by park personnel.

Herons and egrets usually nest in dense thickets along the back side of the barrier island or on old offshore islands where thickets have developed. There appears to be sufficient habitat, and such sites may be utilized for many years by nesting birds. Human disturbance is most unlikely as such places are decidedly inhospitable. Such sites should, however, be posted. The exception to the natural safety of such sites is when a site is a potential target for development as is the case for the colony near Ocracoke Village.

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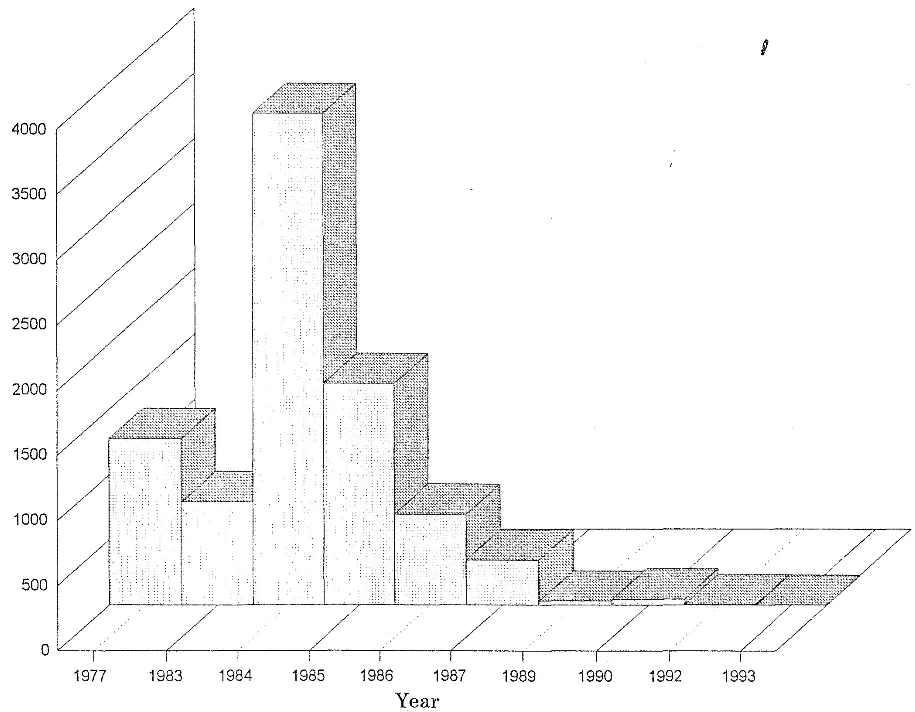

Fig. 1. Total Nests at Ocracoke Flats

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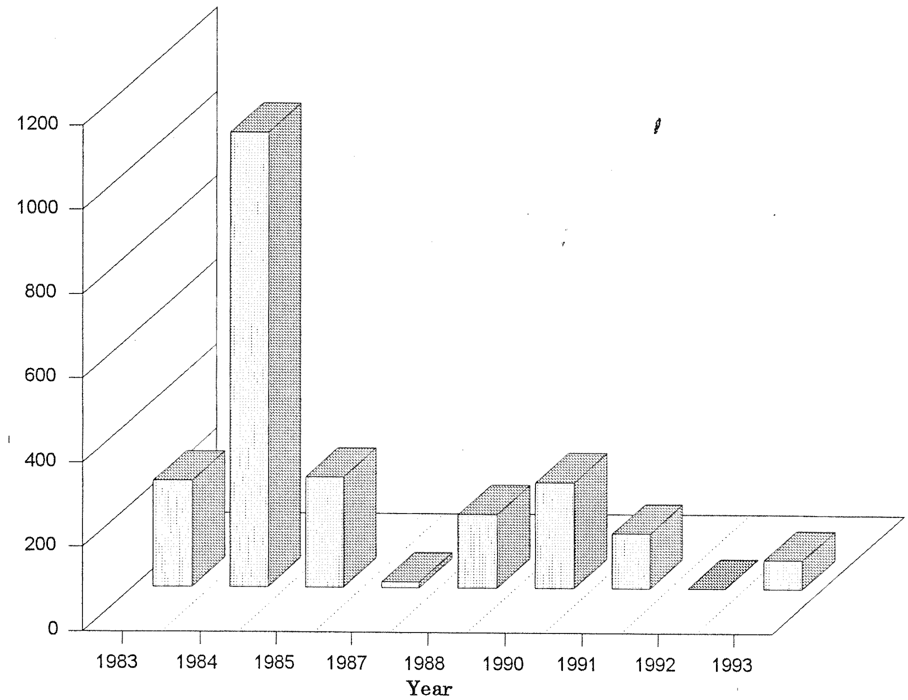

Fig. 2. Total Nests at Hatteras Flats

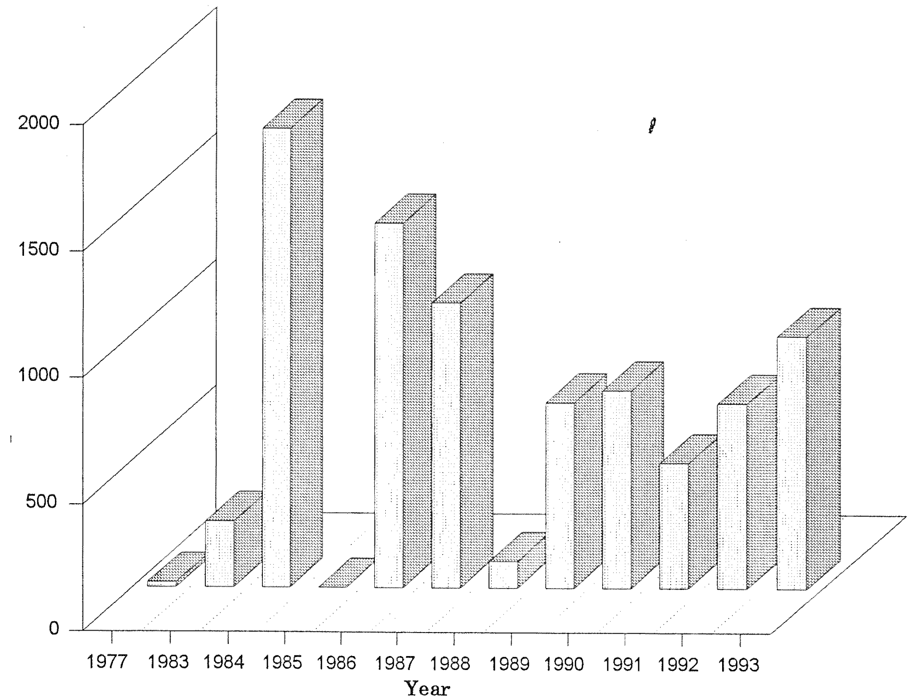

Fig. 3. Total Nests at Cape Point

Table 1. Nesting sites and nest numbers of colonially nesting waterbirds on Ocracoke Island in 1992 and 1993.

	Ocaracoke North		Ocracoke Village		Ocracoke Flats		Pony Pen South	
	1992	1993	1992	1993	1992	1993	1992	1993
Green-backed Heron	0	0	1	0	0	0	0	0
Little Blue Heron	0	0	54	83	0	0	0	0
Cattle Egret	0	0	16	16	0	0	0	0
Great Egret	0	0	17	96	0	0	4	14
Snowy Egret	0	0	77	24	0	0	0	0
Tricolored Heron	0	0	58	39	0	0	0	0
Blk-cr. Night-Heron	0	0	36	13	0	0	0	0
Yl-cr. Night-Heron	0	0	7	17	0	0	0	0
Glossy Ibis	0	0	41	37	0	0	0	0
White Ibis	0	0	262	570	0	0	0	0
Common Tern	0	0	0	0	5	0	0	0
Least Tern	1	0	0	0	0	0	0	0
Total	1	0	569	895	5	0	4	14

Table 2. Nesting sites and numbers of nests of colonially nesting waterbirds on Hatteras Island in 1992 and 1993.

	Pea Island		Ramp 30		Avon		Cape Point		Hat. Inlet	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Gull-billed Tern	0	1	0	0	0	0	0	11	0	0
Common Tern	0	46	0	0	0	0	273	376	0	9
Least Tern	0	151	13	58	0	0	440	502	0	50
Black Skimmer	0	0	0	0	14	0	16	206	0	10
Sooty Tern	0	0	0	0	0	0	0	1	0	0
Total Nests	0	198	13	58	14	0	719	1096	0	69

Table 3. Trends in numbers of nests of colonially nesting waterbirds in the Cape Hatteras National Seashore during the period 1977 to 1993.

	1977[1]	1983[2]	1988	1992	1993
Green-backed heron	0	0	0	1	0
Little Blue Heron	62	58	8	54	83
Cattle Egret	5	1	147	16	16
Great Egret	14	65	17	21	110
Snowy Egret	87	111	8	77	24
Tricolored Heron	50	91	16	58	39
Black-cr. Night-Heron	50	46	5	36	13
Yellow-cr. Night-Heron	2	7	12	7	17
Glossy Ibis	35	20	160	41	37
White Ibis	0	1	12	262	570
Laughing Gull	22	0	0	0	0
Gull-billed Tern	27	7	26	0	12
Forster's Tern	382	63	0	0	0
Common Tern	802	763	678	278	422
Least Tern	121	508	450	454	761
Sooty Tern	0	0	0	0	1
Black Skimmer	286	296	144	30	226
Total	3922	4020	3671	3327	4324

[1] Parnell and Soots 1979

[2] Parnell and McCrimmon 1984

Table 4. Nesting sites and numbers of nests of colonially nesting waterbirds on Cape Lookout National Seashsore beaches in 1992 and 1993.

	Swash Inlet		New Drum Inlet, South		Lookout Beach		Lookout Point		Power Squad. Spit		Shackleford West End	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Gull-billed Tern	0	0	0	0	0	0	0	0	16	0	43	37
Common Tern	0	0	4	2	0	0	4	78	27	0	120	391
Least Tern	200	0	10	3	1	225	10	242	47	61	95	7
Black Skimmer	0	0	0	10	0	68	0	18	42	0	62	157
Total	200	0	14	15	1	293	14	338	142	61	320	592

Table 5. Nesting sites and numbers of nests of colonial waterbirds nesting in the Core Sound area of the Cape Lookout National Seashore 1992 and 1993.

	New Drum Inlet		Big Deep Marsh Isl.		Cockle Marsh Isl.		Whitehurst Island		UNI, Bard. Inlet	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Laughing Gull	0	0	100	81	0	0	125	278	0	40
Gull-billed Tern	0	1	0	0	0	0	0	0	0	0
Forster's Tern	85	23	0	9	23	0	0	0	0	0
Common Tern	85	96	0	0	0	0	0	0	0	0
Sooty Tern	1	0	0	0	0	0	0	0	0	0
Black Skimmer	7	54	0	0	0	0	0	0	0	0
Total	178	174	100	90	23	0	125	278	0	40

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Table 6. Nesting sites and nest numbers of colonial waterbirds nesting in the Back Sound area of the Cape Lookout National Seashore in 1992 and 1993.

	Bottle Run Pt. Isl		UNI, Back Sound # 1		UNI, Back Sound # 4		Sheep Island		Unnamed Isl. CR-018-[1]		Morgan Island	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Green-backed heron	0	0	0	0	0	0	0	0	0	0	0	1
Little Blue Heron	0	0	0	0	0	0	0	0	0	0	40	121
Cattle Egret	0	0	0	0	0	0	0	0	0	0	200	462
Great Egret	0	0	0	0	0	0	0	0	0	0	30	138
Snowy Egret	0	0	0	0	0	0	0	0	0	0	15	23
Tricolored Heron	0	0	0	0	0	0	0	0	0	0	40	132
Black-cr. Night-Heron	0	0	0	0	0	0	0	0	0	0	22	18
Glossy Ibis	0	0	0	0	0	0	0	0	0	0	24	9
White Ibis	0	0	0	0	0	0	0	0	0	0	2	0
Laughing Gull	0	0	0	0	0	0	0	0	0	0	500	3909
Herring Gull	0	0	0	0	0	0	0	0	0	0	2	1
Gull-billed Tern	0	19	0	0	0	0	0	0	0	0	0	0
Forster's Tern	0	0	0	6	0	11	18	34	19	0	0	10
Common Tern	7	14	0	0	0	0	0	0	0	0	0	1
Sooty Tern	0	0	0	0	0	0	0	0	0	0	0	1
Total	7	33	0	6	0	11	18	34	19	0	875	4826

[1] Small unnamed and unnumbered marsh island southwest of sheep island.

Table 7. Numbers of nests of colonially nesting waterbirds in the Cape Lookout National Seashore 1992 - 1993.

	1992	1993
Green-backed heron	0	1
Little Blue Heron	40	121
Cattle Egret	200	462
Great Egret	30	138
Snowy Egret	15	23
Tricolored Heron	40	132
Black-cr. Night-Heron	22	18
Glossy Ibis	24	9
White Ibis	2	0
Laughing Gull	625	4227
Herring Gull	2	1
Gull-billed Tern	59	57
Forster's Tern	145	93
Common Tern	242	582
Least Tern	363	583
Sooty Tern	0	1
Black Skimmer	111	307
Total	3912	8748

Breeding biology and effects of human disturbance on Piping Plovers (Charadrius melodus) on the Outer Banks of North Carolina.

Chapter V

by

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Due to its threatened status on the East Coast, the piping plover and its breeding success was of special interest to our study of shorebirds in CAHA and CALO. North Carolina's seashores represent the southern edge of the piping plover's breeding range, and plover productivity here historically has been low. Habitat and conditions for piping plovers breeding in North Carolina are different than those experienced by birds in northern regions, where most previous piping plover research has been conducted. Factors that affect reproductive success in northern regions involve human disturbance, habitat loss and predation. A major goal of our study was to determine how these and other factors may be influencing production by piping plovers on North Carolina seashores.

In addition to general monitoring of piping plover breeding activity, observations of breeding pairs were conducted to better understand the interaction of disturbance, foraging habitat use and predation in affecting productivity. We investigated the nature of interactions between adults and chicks during brood rearing in detail, in order to better understand the determinants of successful reproduction. These studies included examination of possible indirect effects, such as temperature, on chick survivorship. We will first present a brief summary of population dynamics, including reproductive success, during our study. Additional details were provided in project annual reports. We will then present and discuss our intensive studies of breeding biology.

Unlike other parts of our project, data collection for the piping plover study continued through the summer of 1994. The two students involved in other parts of the project have written and defended their theses, whereas the student conducting the piping plover work is still analyzing data and writing her thesis. What is reported here represents the final product of other components of the project, but for the piping plover study an additional product, a Ph.D. thesis, will be forthcoming at a later date. In this report we indicate additional analyses to be provided in this thesis, as well as results of analyses already completed. Although not included in our project, we present some additional data from the 1995 breeding season on CALO.

Summary of Population Dynamics

Population numbers of breeding piping plovers increased slightly over the duration of our study (Table 1). The slight growth comes from increases at CALO, whereas numbers at CAHA were steady. The reported increase from 1992 to 1993 on CALO may represent increased accuracy of censusing due to experience of researchers rather than actual population increase, but gains from 1993 to 1994 almost certainly are real. Distribution of pairs among different nesting areas of the parks remained fairly consistent (Table 1). The number of pairs nesting at Ocracoke declined with each year, and pairs increased at New Drum Inlet on both NCB and SCB, but declined in 1995. These two nesting areas at New Drum Inlet contained the highest density of pairs.

Reproductive success for the two seashores was quite low (Table 2) and was lower than the average for Atlantic coast plovers (1.33 chicks per breeding pair from 1988-1994, USFWS 1995). Plover productivity varied between years, locations and management strategies. Reproductive success on CAHA remained relatively constant, whereas success on CALO was markedly greater in 1993 than in the other two years. Use of predator exclosures and weather conditions were major determinants of productivity. On CAHA number of fledglings per nesting pair increased from 0.67 for the first two years to 0.82 in 1994 when predator exclosures were used (Table 2). Productivity was highest in 1993 on CALO when exclosures were used and storms were few. Frequent storms resulted in low productivity in 1994, in spite of use of exclosures. On CALO in 1995 when exclosures were used on all nests and storms were few, the highest hatching success (63%) was attained.

A total of 196 nests were monitored on CAHA and CALO from 1992-1994. Of these nests, 132 (67%) did not hatch, 47 (24%) produced fledglings, and 17 (9%) hatched but fledged no chicks. Of all hatched nests, 73% fledged at least one chick. These general statistics illustrate that on CAHA and CALO, piping plover reproductive success is most strongly affected by factors acting during the incubation period. Among shorebirds, rates of nest loss tend to be lower in Arctic regions and higher in the tropics compared to temperate areas. The proportion of chicks that fledge varies similarly, but less dramatically. Rates of loss of piping plover chicks in North Carolina are typical of what one expects of a shorebird at this latitude, but hatching success appears somewhat lower than expected. There is some evidence that beach-nesting species have lower hatching rates than other species, so whether the rates we observed are lower than they were historically is unclear. Predation and storm overwash are the primary causes of nest loss (Table 3). Frequent loss of nests to storms is a factor in which piping plovers and other beach-nesting species differ from other shorebirds, one which may have led evolutionarily to other, compensating differences in breeding biology, such as extended nesting seasons and frequent renesting. This factor might even restrict breeding range. High rates of nest predation, on the other hand, could be a more recent phenomenon linked to human influences.

There was consistently higher hatching success in some nesting areas (such as Cape Point and Power Squadron Spit) than in others (such as Ocracoke (CAHA), Ocracoke Inlet (CALO) and New Drum Inlet (Table 4). These differences may be due to variation in predator pressure or overwash frequency. Predation is high at Ocracoke, where 50% to 100% of nests are predated. Predators usually take a third to a half of the nests at Hatteras Spit. Predation frequency varies on NCB. Nests on Portsmouth Flats, Kathryn-Jane Flats and New Drum Inlet have had up to 40% predation rate during different years. Most flooding of nests occured on NCB. Flooding was prevalent on Portsmouth Flats, where 40% to 44% of nests failed from flooding each year. Nests along Portsmouth Flats are adjacent to expansive flats that are promptly flooded from Core Sound during northeast winds. About a third of nests (25% to 44%) at Kathryn-Jane and New Drum Inlet (NCB) flooded during stormy years. These two areas do not receive sound water as readily as Portsmouth Flats, yet the areas lie low and collect rainwater.

During the duration of our study, reproductive success has been generally low (Table 1) while population size has increased slightly (Table 2). This pattern is a curious one, and begs the question of how North Carolina populations are regulated. Individuals may continually immigrate from more productive populations to maintain the North Carolina population, or adult and/or juvenile survivorship may be substantially better for North Carolina populations than for others so that they maintain themselves with relatively low reproductive rates. Higher rates of survival and lower rates of productivity are typical of more southern bird populations compared to more northern ones. That an increase in population numbers occurred after a successful year of reproduction in North Carolina (1993) and that population numbers decreased on NCB after a poor year of reproduction (1994) illustrates that the population might be self-sustaining rather than dependent on immigration. It also suggests that population size might be limited by productivity. Yet whether the population is below carrying capacity due to low productivity or is limited by habitat availability is far from clear. If the former is the case, one expects population size to vary with previous productivity. The required level of productivity for stability must be quite low, given recent population behavior. Alternatively, if habitat is limiting one expects population levels to fluctuate as habitat changes due to losses to vegetative growth and gains from storm overwashes, rather than with variation in productivity. Determining how the population is regulated, including and understanding of differences in biology related to an extreme southern and peripheral location, is the key to devising appropriate management. We will return to this theme at the end of the piping plover section.

Factors affecting reproductive success on CAHA and CALO

Human disturbance:- With continuing increases in human activity at CAHA and CALO, study of the consequences of these activities on piping plovers breeding in these parks is critical. Humans and vehicles can flush adults from eggs or young, prevent access to preferred nesting or foraging habitat, crush eggs or young, and attract predators to areas that plovers utilize. Although we were unable to investigate the question of human disturbance directly through experimentation, observations of nesting adults and broods revealed the magnitude of human disturbance on our study sites.

During observations, records of intrusions and disturbance events were taken through "all-events" samples (Altmann 1974). All instances of intrusions were indicated during a ten-minute sampling period. Intruder type, behavior and distance from plovers were recorded, as well as any reaction by plover adults and chicks. Samples were taken at various time of day, breeding stage and chick age on CAHA and CALO. Further details of the methodology of our intrusion study are given in the 1994 project annual report.

Data from 73 "intense" ten-minute sampling periods were used to determine intrusion rate. During intense samples all intrusions within 50 meters of the focal bird(s) were recorded, as well as any birds flying high directly over the focal bird(s). Number of intrusions during these periods ranged from zero to 268, with a mean of 9.37 and median of two. The median is a more accurate depiction of average intrusion rate as the frequency distribution of number of intrusions per sample period is clearly skewed (Figure 1). Twelve samples had no intrusions, and 44 samples had three or fewer intrusions. Four samples with large numbers of intrusions (over 30) were obtained from groups located near tern colonies, and most intrusions consisted of nesting or flying terns. There were only three instances of human disturbance during intense samples, each involving one or more moving vehicles. There was no response to any of these intrusions.

Data from 708 intense and non-intense 10-minute sampling periods (118 hours) were used to analyze reactions of piping plovers to intrusions. In almost half of the samples (322) no intrusions were observed during the ten minutes. Of 687 intrusion episodes (which may include one or a group of intruders) 86 (13%) were considered human disturbance (aircraft, vehicles, humans, researchers) and 601 (87%) were "natural" intrusions (terns, gulls, shorebirds, crows, etc.). Most types of human intrusions (84%) consisted of passing vehicles or planes that elicited little or no response. There were 18 human intrusions that evoked a response (3% of all intrusion episodes). There were seven intrusions of planes, helicopters or boats to which plovers responded with calls or became alert. There were six intrusions of vehicles to which plovers responded with alert behaviors. The most extreme case involved a chick feeding at the ocean shore that was nearly hit by a passing truck. There were four instances of an observer evoking calls or defensive behaviors. In the final instance a group of five people standing over 50 meters away caused the tending adult to lead chicks away from the disturbance.

Most intrusions that elicited responses were by potential predators or competitors. Adult plovers were usually alert to crows and great black-backed gulls, and were aggressive towards other plovers, ghost crabs, gull-billed terns, great black-backed, herring and laughing gulls. Tables 5 and 6 provide detailed and consolidated summaries of the various types of intrusion encounters and reactions of piping plovers. Although only a few encounters with ghost crabs were recorded during disturbance sampling periods, observations of adult plovers with chicks indicate that adults will commonly leave chicks in order to chase away crabs.

Data from our intrusion samples indicate human disturbance is not a significant factor affecting reproductive success of piping plovers on CAHA and CALO within the areas the birds currently use. With the present rate and nature of human disturbance on these beaches, there is no need to terminate beach access to visitors. It is possible, however, that areas that might be used are avoided due to human disturbance, namely the ocean intertidal zone. We will return to this possibility later.

Further analyses of disturbance effects are presently being conducted. Scan sample data taken during observations of incubation and brood rearing will be used to compare behaviors of plovers breeding on CAHA (higher level of disturbance) and CALO (lower level of disturbance). This analysis will estimate time diverted from essential activities as a result of nesting in areas used heavily by humans compared to those used little. This analysis is part of the intensive time budget studies described below.

<u>Predation</u>:-Over the three years of our study, predation accounted for 34% of nest losses on CAHA and CALO (Table 3). Since nest predation is rarely witnessed directly, determination of causes of nest loss unfortunately requires inferences from evidence remaining at the nest

site. We kept guesswork to a minimum. Losses that could not be reliably determined were designated as "unknown loss". By this method, the data on known losses serve as the best sample possible of causes of nest loss. We determine primary predators to be raccoons and crows. Predation by crows was witnessed on CALO in 1992. Since predator exclosures virtually eliminated predation on nests (see below), primary nest predators are likely those that can be physically barred from the nest with exclosure. Thus grackles, mice, crabs, and other small animals are probably not primary predators. Raccoon prints are commonly seen regularly in nesting areas on both CAHA and CALO, as well as cat and nutria prints. Mink tracks are regularly seen at the north end of Ocracoke, and mink have entered an exclosure to take eggs.

Although mink predation is limited to a small area (north end of Ocracoke), it is intense within that area, and appears to almost preclude successful reproduction. Mink are known to have similarly large effects on nesting success of other shorebirds, for example spotted sandpipers. Spread of mink within the seashores could be devastating to the piping plover population. The situation needs to be monitored, and management action may become necessary if the mink spread.

Predation of chicks is even more difficult to reliably determine than predation of eggs, as it normally occurs at night. A Herring gull was seen to eat two newly-hatched chicks at Portsmouth flats. There was some evidence of mink predation on chicks at the north end of Ocracoke in 1994. Cat tracks are seen commonly at Cape Point, Hatteras Spit and Ocracoke on CAHA, and Portsmouth Flats, Kathryn-Jane Flats and New Drum on CALO. Gull-billed terns were seen to take chicks on CAHA in 1995 (M. Lyons, pers. com.). Crows are likely to take piping plover chicks since crow predation on least tern chicks nesting near piping plovers was witnessed repeatedly at High Hills on CALO. There is unfortunately little information regarding activity, such as foraging, of piping plovers at night. Poor foraging habitat or restriction of foraging time by high daytime temperatures or storms may increase nighttime foraging and vulnerability to predation. Since chick mortality rates of piping plovers are not abnormal when compared to closely related and ecologically similar species, effective management measures to curb predation during incubation likely are more realistic than efforts to reduce chick mortality.

We can use reactions of plovers recorded during focal sampling and intrusion sampling (outlined previously) to indicate what species are considered to be a threat. Plovers with eggs or chicks normally react to crows with calling, alert behaviors and crouching over eggs. Gull-billed terns and great black-backed gulls were generally ignored during incubation, yet were chased in flight by adults tending chicks while the chicks crouched. Ghost crabs elicited unique chasing behaviors by adults that functioned to drive the crabs away from chicks. Herring and laughing gulls evoked chasing or alert behaviors from adults incubating or tending chicks, but only at close distances.

Placement of exclosures around some nests on CAHA and CALO allowed us to experimentally manipulate vulnerability of nests to predation. Details of the methodology for our exclosure study is given in the 1994 project annual report. Nests with exclosures experienced significant increases in hatching success ($X2 = 18.88$, $p<.0001$, $df=1$; exclosed $N = 46$, control $N = 76$), confirming that predation is a major factor affecting reproductive success on CAHA and CALO. Exclosures are recommended for both the parks to increase piping plover productivity. Since losses during incubation comprise the largest portion of reproductive failures and hatching success without exclosures is low, the use of exclosures is one of the most effective and most easily implemented possible methods to increase piping plover productivity on North Carolina seashores. In light of washover and predation probabilities and chick mortality rates, we can extrapolate the productivity to be expected when exclosures are used. On CAHA, about 10 chicks should be produced for every 10 exclosed nests. On CALO, about 4.5 chicks should be produced for every 10 exclosed nests.

These estimates will be lower if effectiveness of exclosures decreases with subsequent years, which would occur if predators learn to associate prey with exclosures. There is some preliminary indication that this is occuring on NCB. During the present breeding season (1995), raccoons have circled exclosures. This behavior has been evidenced at different nesting areas on the island, which would suggest it to be a general response among the raccoon population. A raccoon entered one exclosure by climbing the fence and crawling under the netting. Fixing the netting much more tightly to the exclosure fencing would alleviate this type of predation, yet the attraction of raccoons to nests no doubt harasses the plovers and may cause abandonment.

Weather:-Breeding success of plovers nesting on CALO fluctuated with weather. Hatching success in 1993, a year of relatively good weather, was markedly greater than in 1992 and 1994, years that had storms and flooding during May (Table 4). Accordingly, nest losses due to flooding or winds are greater in 1992 and 1994 on CALO (Table 3). On CALO, strong northeast winds raise tides in Core Sound and cause water to flow from the sound towards the sand flats where piping plovers nest. Contrary to the normal weather pattern, colder northeast winds continued to blow in early May of 1992, and caused the flooding of five nests and delayed many first nest attempts until late May. In 1994 a combination of northeast winds and a storm on May 21st caused the loss of 14 first nests.

In addition to its direct effects, adverse May weather has other deleterious effects. Cold and stormy weather will delay initiation of nests and force renesting. Nests initiated later in the breeding season appear to have diminished success compared to early nests. This is a common pattern in birds. Comparing nests during 1993, when losses to flooding did not occur, of 28 nests initiated in May, six nests fledged a total of 13 chicks (21% fledging success, 2.17 chicks per fledged nest). Of 16 nests initiated in June, four nests fledged a total of four chicks (25% fledging success, 1 chick per fledged nest). It is more likely for large broods to fledge if they hatch earlier in the breeding season. So it appears that on NCB a successful year requires favorable weather so that early nests hatch.

While weather effects can certainly be harmful, they cannot easily be managed and are little different than they were historically. Since severe storms are more prevalent along North Carolina shores than in other breeding areas along the east coast (D. Bartoff of NOAA weather, pers. com.), weather effects may have always limited productivity in North

Carolina compared to more northern areas, and may even limit the species' breeding distribution.

Temperature:-Piping plovers breeding at the southern end of the range presumably experience higher ambient temperatures than those in northern regions. When temperatures are high during incubation eggs must be shaded by adults to prevent death of embryos from overheating. In Wilson's plovers once temperatures rose above 31o C (87.8o F), incubation rates increased in order to shade eggs (Bergstrom 1982). Beach temperatures on CAHA and CALO frequently rise above this temperature starting in Mid-May. Increased time spent on incubation would likely decrease time available for foraging (Walters 1984) at a time when heat stress demands more energy resources. When precocial chicks such as those of piping plovers first hatch, they are unable to thermoregulate and depend on their parents to warm and cool them (Ricklefs 1983). During extremely high temperatures chicks may spend little time foraging and instead are brooded or crouch in the shade. In one instance at CALO when temperatures were above 90o F, two one-day old chicks and one egg were shaded constantly by both adults during observations in the heat of the day. The chicks were brooded continually for 5.5 hours and only foraged sporadically during the final half hour of an observation after temperatures declined. The adults foraged only briefly at the nearby ocean. During the next day, no chicks were found with the pair.

High temperatures encountered by piping plovers in the southern portions of the breeding range therefore are likely to have many indirect effects on chick foraging time, and perhaps consequently on mortality rate. On NCB, mortality rate increased for chicks hatched later in the breeding season (Figure 2). It is possible that high temperature shortens the effective breeding season of piping plovers nesting on North Carolina seashores. Mortality may be caused directly by insufficient foraging time, or indirectly by higher predation rates due to increased foraging at night.

Correlational analyses of temperature and time spent foraging by chicks are currently in progress. These analyses are a component of time budget studies described below. We will use our data to estimate the amount of foraging time available at favorable temperatures as a function of season.

Habitat:-A factor crucial to piping plover reproductive performance is the availability of suitable foraging habitat. Chicks foraging in habitats rich in resources travel less, forage more and have increased growth (Loegering 1992). We sought to identify habitats on CAHA and CALO that

In general, dry sand flats and interdunal areas (used for nesting) were widely available, yet were uncommonly used for foraging. These two habitat types were used by newly hatched chicks during their first foraging attempts near the nest site. Once all chicks were mobile, groups foraged at mudflats or wet flats. Mudflats were located at the west end of a pond at Cape Point, along the sound on Hatteras Spit, at the north end of NCB, behind wet flats on Portsmouth Flat and along the sound at New Drum Inlet. On CAHA, wet flats were located on the east end of the pond and within the interior of Cape Point, near the drain pond at the South Beach, along a tidal pond and within the interior of Hatteras Spit and on the north end of Ocracoke. On NCB, wet flats were generally located towards the sound from the nesting areas on Portsmouth Flat, Kathryn-Jane Flat, and Old Drum Inlet, and in the interior of New Drum Inlet. Access to the sound shore is limited; Hatteras Spit on CAHA and New Drum and Ocracoke inlets on CALO are the only sound shores available to plover groups.

During behavioral observations, habitat use by foraging piping plover adults and chicks was recorded with scan samples. If any plovers were foraging during the scan, the habitat type, distance from vegetation, density of vegetation and other distance estimates were noted. The 1994 project annual report provides more detail of methods. Initial analyses of

1993 data indicate that plovers foraging on CAHA use either wet or mud flats, and CALO plovers forage primarily on wet flats. On CAHA, there were 38 instances (51%) of use of mudflats and 31 instances (42%) of use of wet flats (N = 74). On CALO, there were 252 instances of wet flat use (or wet flat habitat in combination with other habitats such as dry or mud flats) (90%, N = 279). These differences between CAHA and CALO may be due to differing availability of habitats in the two parks. Mudflats on CALO are only available at Portsmouth flats and small areas of New Drum Inlet. Samples from CAHA were taken from groups located in various areas, but were mainly taken at either Hatteras Spit or Ocracoke. Samples from CALO tended to come from groups in New Drum or Kathryn-Jane Flats. On CAHA, plovers tended to forage less than five meters from dense or moderately dense vegetation. Plovers foraging on CALO tended to be either within sparse vegetation or less than five meters from dense vegetation.

Data from other years will be entered and analyzed, and a more definitive assessment of foraging habitat selection will be provided in the thesis. Also, we intend to link foraging data from scan samples to peck rate data from chicks collected during focal samples in order to gain some understanding of foraging rates in different habitat types. Finally, data from focal samples and scan samples will be used to compare time spent foraging and traveling by chicks in different habitats. These analyses will enable us to assess habitat quality in greater detail than reported here.

Use of ocean intertidal zone by plover chicks is of special interest because of possible conflicts with park visitor use. Although mudflats and wet flats are more commonly used, chicks were seen at the ocean shore at Hatteras Spit, Cape Point and Ocracoke on CAHA during our study. Chicks seen at the ocean were usually around fledging age. On CALO, most frequent use of the ocean shore by chicks occurred at Kathryn-Jane Inlet and Portsmouth Flats after the chicks had fledged. Some use by young chicks at Portsmouth Flats also was witnessed, and in one instance a chick was nearly struck by a vehicle. Chicks at New Drum have very rarely fed along the ocean shore. More often older chicks feed at the sound. Thus slightly more use of the ocean intertidal zone was observed at CALO compared to CAHA, but use was still infrequent.

Since vehicles are frequent along the shores of CAHA and infrequent along CALO, and use of the ocean intertidal zone by young chicks was observed more at CALO, one might conclude that human disturbance reduces use of this habitat. This idea can best be tested experimentally by closing portions of outer beach to visitors. Without such a study, only a very general comparison of highly used (CAHA) and infrequently used

(CALO) habitats is possible. Since use of the ocean intertidal zone by piping plover broods on CALO, where there are more breeding pairs than CAHA, is not substantially more frequent than on CAHA, it can be concluded that reduced human disturbance does not greatly alter habitat use. Either adults have little inclination to bring their broods to the shore, or even minimal disturbance is sufficient to discourage them from doing so. This suggests that the ocean intertidal zone is not highly preferred habitat for brood rearing in North Carolina. The preferred habitat appears to be mudflats and wet sandflats, habitats that are much more prevalent on CALO due to the absence of dune stabilization measures.

Geographic location:-Our brief study of piping plover breeding biology has revealed that factors affecting reproductive success in North Carolina are different than those in northern regions. Being along the edge of the piping plover's breeding range, the environment at North Carolina seashores is likely to have more unfavorable conditions for reproduction (e.g. predators, diseases and weather conditions). Storms in the early part of the breeding season cause breeding losses and delays, and high temperatures, especially late in the breeding season, impose heat stress that may indirectly cause chick mortality. For these reasons, productivity goals set in the recovery plan (1.5 fledged chicks/pair/year), established from studies of more northern populations, are probably unrealistic for

North Carolina. Still, productivity can be improved over current levels, especially through use of predator exclosures. The little information that exists suggests that more realistic productivity levels may be sufficient to increase the population.

To provide additional perspective on piping plover reproductive success within the seashores, we provide comparative data we collected from Wilson's plovers. Wilson's plovers are an ecologically similar species and North Carolina is in the middle of their breeding range. We estimate hatching success of Wilson's plovers to be 23%-50%, compared to 33% for piping plovers. The two species appear to be experiencing similar, high levels of nest loss within the seashores.

Nesting habitat

On CAHA and CALO, piping plovers nest in the vicinity of the wet sandflats and mud flats in which their broods forage. Nest locations tend to be in drier areas, often on dry sandflats or even interdunal area adjacent to wet flats or mud flats. One of our objectives was to provide the Park Service with locations of nests and foraging areas in a form that could be used both to locate sites in the field and incorporate locations into GIS data bases. We previously provided nest locations and foraging area locations plotted on copies of aerial photographs in our project annual reports. Unfortunately aerial photos, while ideal for mapping exact nest locations, have not proven suitable for digitized mapping for GIS, and GIS maps suitable for field use are not yet available. The locations plotted on aerial photography provided previously are the best source of precise information for field use currently. We have mapped nest locations and foraging area locations onto topographic maps of portions of CAHA and CALO. Unfortunately, due to the age of the maps, locations could not be exactly mapped. Some nesting areas (such as the overwash area at Kathryn-Jane Inlet on NCB) were not present on the topographic maps, making accurate mapping difficult. We feel that these maps are inadequate for input of GIS data, and attempts to plot locations on GIS habitat maps currently available were equally imprecise. We recommend using a GPS (global positioning system) unit to obtain locations for use in GIS data bases.

Intensive studies of breeding biology

A total of about 1000 hours of observational data has been collected: 270 hours from CAHA, and 665 hours from CALO. The data consist of: 1) scan samples indicating adult and chick behavior, distances between adults and chicks, and foraging locations; 2) all-events samples recording type and behavior of intruders, distances between plovers and intruders and reactions of plovers to intruders; 3) focal samples of chick and adult behavior measuring time budgets and peck rates of chicks, and providing additional information concerning interactions with intruders and competitors. In association with these samples we recorded general information such as temperature, wind speed, tide, weather, age of chicks, number of chicks, date and time of day.

These observational data will allow us to examine interactions of adults with their broods in detail. We will determine how time budgets and distance relationships (which determine how well adults can protect their chicks) vary with factors such as brood size, habitat and temperature. A goal of these analyses is to better understand determinants of chick survival. These analyses will comprise the bulk of the material to be reported later in Susan Philhower's dissertation.

Conclusions

Most frequently cited causes of the decline of piping plovers are habitat loss or degradation and human disturbance. Human development has replaced former nesting and foraging habitat of plovers throughout their breeding range, especially in the northeastern United States (USFWS

1995). Dune stabilization inhibits the formation of washover areas, and causes the loss of wide flats for nesting and foraging. Plovers nesting in degraded habitat are usually closer to human activity. With no access to sound or moist flats, the only foraging habitat available in many areas is along ocean intertidal zone.

In CAHA and CALO, nesting areas are usually adjacent to wet flats, mud flats or sound flats and these areas are favored for foraging by adults and chicks. Because of the availability and protection of these wide flats, plovers are not generally near human activity. Indeed, our observations suggest human disturbance does not significantly affect piping plover breeding activity. An important conclusion is that conditions in North Carolina are very different than those in other areas, notably the northeast, in which piping plovers have been studied, and based on which the species recovery plan has been structured (USFWS 1995). Effective management likely will differ between North Carolina and other areas as a result. For example, beach closures, which are effective in other areas, likely will have little impact in North Carolina. It is not clear that ocean intertidal zone will be used much even if such habitat is closed to humans. At the very least, experimental closures should be conducted before adopting closure as a general policy.

There are very few breeding areas for the species in which habitat is as little altered, or little disturbed, by humans as CALO. Yet here, in the absence of the problems to which the decline of the species generally is attributed, the dynamics of the population appear less favorable than in areas to the north, and no better than those observed at CAHA, where habitat alteration and human presence are greater. We must search for other factors to explain the exceptionally low productivity of the North Carolina populations.

There is a critical need to understand the population dynamics of piping plovers in North Carolina, both in terms of how they differ from historical dynamics on site, and from the dynamics of populations in other areas. There are two important reasons to suspect that population dynamics in North Carolina are different than those observed in the northeast, (1) the southern location of the North Carolina population and (2) the fact that the North Carolina population represents the limit of the species' range. It is likely that due to the first factor productivity will be lower and survival higher in North Carolina, and from the second factor that conditions will be less favorable for the species in North Carolina. Presumably whatever factors limit the range of the bird impact them much more on the edge of the range than elsewhere.

The most critical step in understanding population dynamics will be to determine how the population is regulated, specifically whether the small population reflects limited habitat, or is due to poor productivity, such that the population is below carrying capacity. This can be assessed by closely tracking whether populations fluctuate according to variation in productivity, or according to changes in availability of habitat. Without this knowledge, it will be difficult to set reasonable population objectives, or formulate effective management strategies.

We suspect that productivity is limited in North Carolina by the relatively high frequency of storm overwash in nesting areas. This is the type of factor, since it varies in a clinal fashion, that could limit the breeding distribution. High temperatures, by restricting foraging time during the day, could directly or indirectly limit productivity, and breeding range, as well. Such factors may constrain the potential for positive impacts of management. That is, it may be unreasonable to expect to increase productivity as much, or increase populations as fast, as can be accomplished elsewhere. However, we also suspect, based on the population increases observed despite very low levels of productivity, that mortality rates of adults may be lower in North Carolina, and thus that a small increase in productivity in North Carolina may have as big an effect on population size as a larger increase elsewhere. We can only hypothesize about survival rates, though, because relevant data on survival of North Carolina birds do not exist. Equally important is the lack of data on return rates. Without these data, one can not determine whether the North Carolina populations are self-sustaining, or represent sinks dependent on immigration from elsewhere for their continued existence.

We conclude that the most effective means to influence population dynamics in a favorable way is to reduce predation. Predation on chicks is more difficult to affect, and the data do not indicate predation rates to be abnormally high during the chick stage. We therefore favor attempts to reduce predation during the egg stage, and have shown that this can readily be accomplished with predator exclosures. We also recommend that mink be prevented from spreading to other plover nesting areas. The major predators of piping plover eggs appear to be crows and raccoons, species whose abundance clearly has increased due to human presence. This fact is another reason to suspect that if piping plover populations in North Carolina are suffering from reduced productivity compared to historical levels, that it is predation on eggs that has increased, rather than other sources of nest loss.

A major difference between the two seashores is that dune stabilization characterizes one (CAHA) but not the other (CALO). Dune stabilization reduces availability of nesting habitat, and this is probably the reason the population on CALO is so much larger than that on CAHA. On the other hand, dune stabilization probably also accounts for reduced levels of nest loss to flooding on CAHA. That the population trend on CALO is more positive than that on CAHA argues for habitat availability being limiting on CAHA rather than productivity. On CALO the number of breeding pairs on NCB from 1993-1995 (28, 32, 29, respectively) is to some extent related to reproductive success of the previous year (.27, .68, .19, respectively), which suggests that the population may be limited by productivity.

In conclusion, the conservation of piping plovers in the North Carolina seashores is more complicated than it at first appears. A simple view is that the population is small because productivity is so much lower than elsewhere. There is no doubt that productivity is extremely low, yet the population currently is increasing. Two explanations are possible. First, the dynamics of the North Carolina populations might be very different from those of more northern populations, so that only low levels of productivity are necessary to maintain fairly closed populations. Second, the North Carolina populations might depend on immigration from better areas elsewhere for their continued existence, thus acting as sinks that drain birds from healthier source populations. If this is the case, these dynamics may be recent, arising from greatly reduced levels of productivity that have produced a problem that needs to be fixed through management. Or North Carolina, at the limits of the species' distribution where conditions are always marginal, may always have been a sink, in which case efforts to manage for healthy populations will be ineffective. One may pick one of these scenarios as most likely, and manage accordingly. The alternative is to conduct the studies of survivorship and return rates necessary to determine which is accurate.

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Table 1. Numbers and distribution of breeding pairs of piping plovers on CAHA and CALO, 1992-1995.

Location	Number of pairs *			
	1992	1993	1994	1995
CAHA				
Bodie Island	0	0	0	~
Cape Point	4	5	5	~
South Beach	0	1	1	~
Hatteras Spit	4	3	3	~
Ocracoke	4	3	2	~
CAHA TOTAL	12	12	11	~
CALO				
Ocracoke Inlet	2	0	2	2
Portsmouth Flat	8	9	7	8
Kathryn-Jane Flat	11	9	12	11
Old Drum	2	1	1	2
New Drum Inlet (NCB)	5	9	10	6
New Drum Inlet (SCB)	3	4	5	4
Power Squadron Spit	2	3	2	2
CALO TOTAL	33	35	39	35
TOTAL	45	47	50	~

* Includes pairs that did not nest but held territories

Table 3. Causes of piping plover nest loss on Cape Hatteras National Seashore and North Core Banks, 1992-1995.

Year/Location	Total # of nests	Total # of losses	Predator		Flooding/Sand		Human		Abandoned		Unknown	
			N	%	N	%	N	%	N	%	N	%
1992 CAHA	14	6	3	50	0	0	0	0	0	0	3	50
NCB	39	30	6	20	11	37	0	0	0	0	13	43
TOTAL	53	36	9	17	11	21	0	0	0	0	16	30
1993 CAHA	21	12	5	42	0	0	0	0	0	0	6	50
NCB	48	30	10	30	5	15	0	0	4	13	11	37
TOTAL	69	42	15	36	5	12	0	0	4	10	17	41
1994 CAHA	18	8	7	88	1	12	0	0	0	0	0	0
NCB	56	46	14	30	19	41	0	0	4	9	9	20
TOTAL	74	54	21	39	20	37	0	0	4	7	9	17
1995 NCB	38	14	5	36	5	36	0	0	2	14	2	14
92-95 TOTAL	234	146	50	34	41	28	0	0	10	7	44	30

Table 4. Numbers, distribution and hatching success of piping plover nests on CAHA and CALO, 1992-1995.

Location	Number of nests and hatching success							
	1992	Hatch %	1993	Hatch %	1994	Hatch %	1995	Hatch %
CAHA								
Bodie Island	0	~	0	~	0	~	~	~
Cape Point	5	80	6	83	6	83	~	~
South Beach	0	~	2	50	1	100	~	~
Hatteras Spit	5	40	4	50	6	50	~	~
Ocracoke	4	50	6	11	5	20	~	~
CAHA TOTAL	14	57	21	42	18	56	~	~
CALO								
Ocracoke Inlet	2	0	0	~	1	0	3	33
Portsmouth Flat	12	33	14	36	8	38	8	63
Kathryn-Jane Flat	14	29	17	41	25	12	16	69
Old Drum	2	0	2	50	2	0	2	100
New Drum Inlet (NCB)	9	11	15	33	20	20	9	56
New Drum Inlet (SCB)	N/A	~	3	66	9	11	~	~
Power Squadron Spit	N/A	~	5	80	1	100	~	~
CALO TOTAL	39	23	56	43	66	20	38	63
TOTAL	53	32	77	43	84	27		

Table 5. De[illegible] summary of type of intruder and response of piping plovers during [illegible]on episodes.

Type of intruder	None	Slight alert	Alert	Call	Lead chicks	Crouch Run	Head Bob	False Incub	Broken Wing	Run to	Hunch Run	Agressn	Fly Chase	Fight	Avoid	Run	Fly	Unkn	Total
Least tern	29	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	32
> 10 LT	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
2-10 LT	17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Common tern	67	1	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	76
2-10 Com. terns	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
30-44 Com terns	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Black Skimmer	8	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
2-10 Black Skim	9	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
24 Black Skim	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1-3 Gull-billed terns	25	1	0	3	0	0	0	1	0	0	0	0	6	1	0	0	0	0	41
Laughing Gull	32	1	2	1	0	0	0	0	0	0	0	0	10	1	0	0	0	1	49
2-5 Laugh gull	6	1	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	11
Herring gull	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8
Great blackb. gull	3	1	2	1	0	0	0	0	0	0	1	0	4	0	0	0	0	0	12
Unspec. gull	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4
2-5 Gulls	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Willet	23	1	1	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	29
2-4 Willets	4	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	7
Black bellied plover	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1-4 Sanderlings	3	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	7
1-3 Piping plovers	1	0	0	1	0	0	0	0	0	0	6	5	7	3	0	0	0	0	23
1-2 Wilson's plovers	7	0	1	0	1	0	0	0	0	0	0	3	4	1	0	0	0	0	17
Amer. Oysterc.	26	0	4	2	0	0	0	1	0	0	0	0	3	0	0	1	0	0	37
2-10 Amer Oyst	11	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	13
Turnstone	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Osprey	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ghost crab	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	4
2-4 Rabbits	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Crow	8	1	5	19	0	1	0	0	0	0	1	0	7	0	0	1	0	0	51
2-4 Crows	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
1-3 Grackles	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Red-winged Blkbd	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Meadowlark	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
2 Swallows	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cormarant(s)	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Egret	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Glossy Ibis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Human(s)	6	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Plane(s)	38	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43
Vehicle(s)	24	3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	30
Other	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2
Observer	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Unspec. gull	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Unspec. tern(s)	26	0	0	1	0	0	0	0	0	0	1	0	15	1	1	1	0	0	47
Unknown	2	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	10
Unknown shorebd	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
None	322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	322
Total	773	16	30	41	3	1	2	4	1	2	13	10	66	11	1	8	1	1	1009

0076732

Figure 1.Frequency distribution of number of intrusions in ten minute periods

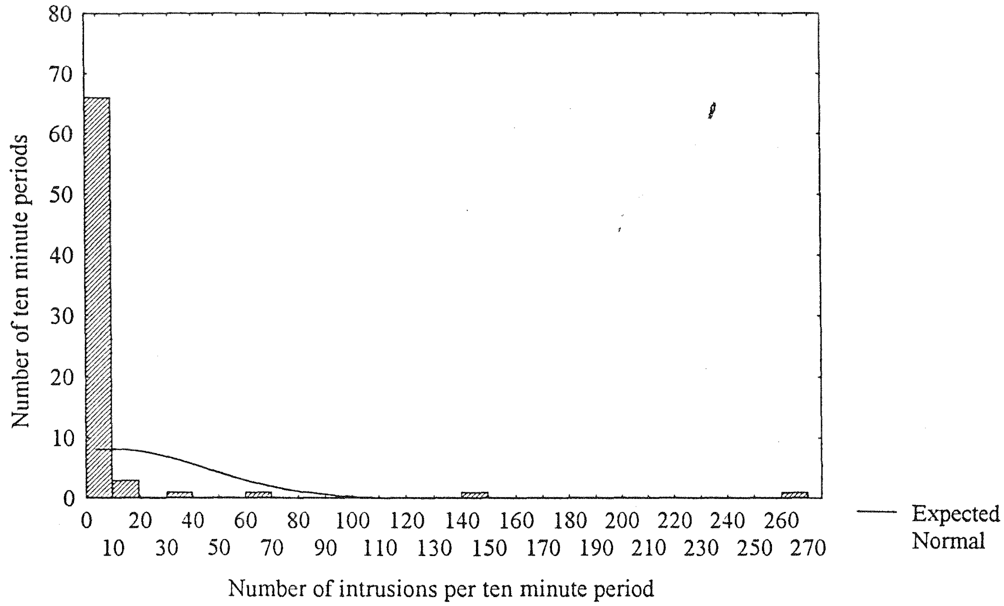
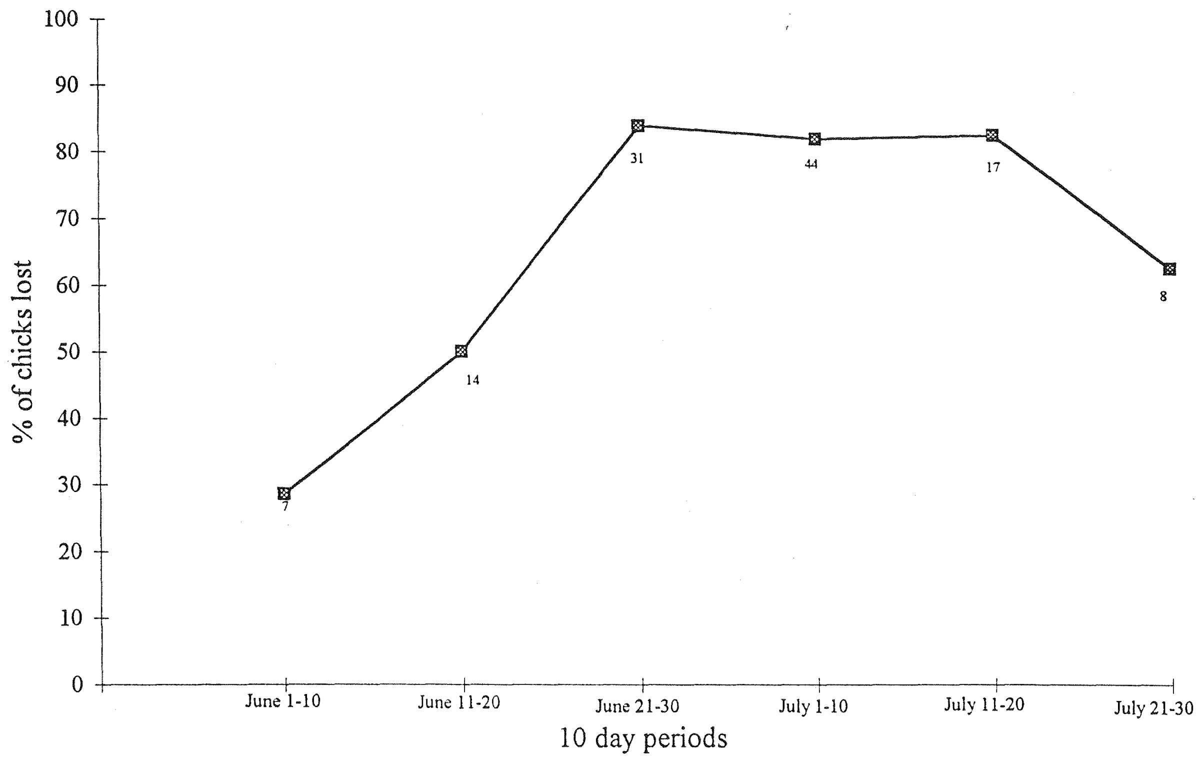


Figure 2. Mortality rate of piping plover chicks hatched in different 10 day periods on NCB, 1992-1994. Numbers indicate sample size.



Species composition and seasonal numbers of shorebirds, gulls, terns and wading birds on the Outer Banks of North Carolina with especial emphasis on selected locations at Lookout National Seashores.

Chapter VI

by

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Dinsmore and Collazo (Chapter 1, This Report) documented seasonal and distribution patterns of the eight most abundant species of shorebirds counted on the Outer Banks of North Carolina. These especies were the focus of attention because numbers allowed rigorous analysis, and because they included species of special concern (e.g., declines; Howe et al. 1989). Another 14 species of shorebirds, 9 species of gulls and 11 species of terns were recorded during beach censuses. Censuses were also conducted at Portsmouth Flats and at three locations along the Core Sound side of Lookout National Seashores. Here we summarize those data. It is hoped that these data, coupled with cumulative information (e.g., Tove 1989), will aid in establishing the status of the species represented by the avian groups reported herein.

Study Area

The Outer Banks are located along the east-central coast of North Carolina (34°34'-35°50' N lat., 75°27'-76°39' W long., Figure 1). The area consists of a series of narrow barrier islands of approximately 228 km in length, stretching from just north of Oregon Inlet in Dare County to Beaufort Inlet in Carteret County. Much of the area is included in Cape Hatteras and Cape Lookout National Seashores. Portsmouth Flats, located on the northern portion of North Core Banks. Three locations, namely, Old Drum Inlet, Mile Post 9 and High Hills, were also monitored in North Core Banks.

Censuses

From March 1992 to December 1993, five outer beach sites ranging from 9-34 km in length were surveyed. Bodie Island (9 km) extended from the south edge of Nags Head south to Oregon Inlet. North Beach (28 km) extended from the Rodanthe pier south to a point 1 km north of the Buxton town limit. South Beach (24 km) extended from just south of the Cape Hatteras lighthouse south to Cape Hatteras point, then west to Hatteras Inlet. Ocracoke Island (28 km) included the entire island from Hatteras Inlet south to Ocracoke Inlet. North Core Banks (34 km) included the entire island from Ocracoke Inlet south to New Drum Inlet. The total amount of outer beach surveyed monthly for shorebirds was 123 km.

Surveys were conducted twice per month by vehicle. All surveys were begun 1.5 h before low tide, except for two counts on North Core Banks in July and August 1992 that were begun 1.5 h before high tide. Numbers of all shorebirds present on the outer beach were recorded. Outer beach is defined as the area from the base of the dune line to the ocean edge, including that portion of the intertidal zone exposed at low tide. Outer beach did not include soundside tidal flats at inlets or other tidal flat habitats. Flying birds were not recorded, unless they were clearly disturbed by the person(s) conducting the census. Since large shorebird concentrations (>500 birds) were rare, data here represent actual counts and not estimates.

Censuses were conducted on Portsmouth Flats nearly monthly from May 1992 to December 1993. The only months missed were December 1992 and October and November 1993. In most months, two censuses were conducted. Most censusing was done at low tide, though single counts in June, July, and September 1992 were done at high tide. While the flats themselves are not influenced by lunar tides, birds using adjacent outer beach habitats would be expected to be more numerous at the time of hight tide as they are driven off beaches during this time. Because of the extent of the flats, only the area north of the trail to Portsmouth Village and the first inlet south of that trail were censused. Coupled with these censuses at Portsmouth, censuses were also conducted along the "Sound" side of North Core Banks. These consisted of visiting each of three locations (i.e., Old Drum Inlet, Mile 9, High Hills) and counting all birds.

Abundance was expressed as the mean of the two monthly censuses. This minimized variance problems associated with repeated measures within month. For a few sites, there was only one count in a given month and this was treated as the estimate for that month. Annual and seasonal numbers were obtained by summing monthly counts. Abundance data were expressed in two ways. First, annual patterns of abundance are described for shorebirds, herons, gulls, and terns. Second, a model was developed to test for seasonal patterns in abundance for selected groups or species. In this model, seasons were defined as spring (April-June) and fall (July-November). These seasons span the major migration periods for the species examined. The effects of site and year on the variability of monthly counts were tested. Month, a repeated measure within season, was nested under the appropriate factor in the nested factorial ANOVA model. To reduce count variance, data were log or square root transformed. The most appropriate transformation was determined by examining plots of residuals.

Group and Species Accounts

Shorebirds

A total of 22 species of shorebirds were detected on beach censuses. Of these, the eight most common species were examined in Chapter 1 (Dinsmore and Collazo 1995, This Report). The seasonal abundances of another 11 species are depicted graphically here. The remaining 4 species were recorded on beach censuses fewer than 5 times; data were not graphed but date and location of sighting is provided.

The Semipalmated Sandpiper (Calidris pusilla), Western Sandpiper (Calidris mauri), Short-billed Dowitcher (Limnodromus grisseus) and Semipalmated Plover (Charadrius semipalmatus) exhibited seasonal trends typical of species using the Outer Banks as migratory stopover areas (Figures 2, 3). These species were most abundant during fall migration (Aug-Nov.) and the short spring migration period (late April - June). Wilson Plovers (Charadrius wilsonia), in contrast, are a resident species which seems to absent in the area for most of the late fall and early winter (Figure 2). Numbers were highest from April through August. Dunlins (Calidris alpina) appear to use the Outer Banks as both migratory and wintering grounds (Figure 3). Numbers were highest in November, but the species was detected through winter, remaining on the area through early spring. Finally, Short-billed Dowitchers were most abundant during July, but was detected through most of the fall in each of the two years of surverys (Figure 3).

Five other species were recorded but there numbers are substantially lower than for the species accounted above. Great Yellowlegs (Tringa melanoleuca), Lesser Yellowlegs (Tringa flavipes), Spotted Sandpiper (Actitis macularia), and Least Sandpiper (Calidris minutilla) were also recorded during the migratory periods, that is, spring and fall each year. Their mean numbers, however, ranged from 0.5 to 10 individuals per month (Figures 4, 5). Marbled Godwitts (Limosa fedoa) also was recorded during censuses in low numbers, but mostly during late fall (Figure 5).

The following are records of species that were recorded 5 or fewer times on beach censuses.

American Avocet (Recurvirostra americana): One was recorded on 23 August 1992 on South Beach.

Killdeer (Charadrius vociferus): From 1-3 were recorded at Bodie I. on 23 February 1993, South Beach on 9 March 1993, North Core Banks on 19 March 1992, North Beach on 13 October 1992, and North Core Banks on 15 November 1992.

White-rumped Sandpiper (Calidris fuscicollis): From 1-2 were recorded at South Beach on 2 June 1993, Ocracoke on 8 September 1992, and South Beach on 14 September 1992.

Pectoral Sandpiper (Calidris melanotos): From 2-4 were recorded at South Beach on 3 August 1993, South Beach on 4 August 1993, and Bodie Island on 24 September 1993.

Gulls

A total of 9 species of gulls was recorded on beach censuses. The seasonal abundances of the 7 most common species were graphed here. The "basic" five species of gulls, namely, Herring (Larus argentatus), Great Black-backed (L. marinus), Ring-billed (L. delawarensis), Laughing (L. atricilla), and Bonaparte's (L. philadelphia) were, as expected, the most common species recorded during censuses (see Tove 1989). These species were recorded in the throusands of individuals on any given census day (Figures 6, 7). Ring-bills, Herrings, and Great Black-backs were significantly ($P < 0.05$) more abundant during spring censuses (Table 1). Consistent with Tove (1989), Lesser Black-backed Gulls (L. fuscus) were recorded from September on through April (Figure 6). Counts were highest in February, averaging 13 individuals. Laughing Gulls, not surprisingly, were abundant from spring through fall (Figure 7). No seasonal differences were detected for this species. Bonaparte's Gulls were detected only during winter (Figure 7). Two species were recorded 5 times. Location and date of sighting is provided below.

Iceland Gull (L. glaucoides): One was recorded on 16 February 1993 on North Beach.

Glaucous Gull (L. Hyperboreus): One was recorded on 3 March 1992 on North Beach.

Terns

A total of 11 species of terns were recorded on beach censuses. The seasonal abundances of the 9 most common species were graphed here. Least Terns (Sterna albifrons), Black Skimmers (Rynchops niger), Gull-billed Terns (Gelochelidon nilotica), Sandwich Terns (Sterna sandvicensis), Common Terns (Sterna hirundo), and Royal Terns (Sterna maxima) were most abundant from late spring through early fall (Figures 8, 9, 10). Common and Least Terns were significantly ($P < 0.05$) more abundant during fall (Table 1). Black Skimmers and Sandwich Terns had a significant site by season interaction. Skimmers were more abundant at North and South Beach and Ocracoke during fall, and at Bodie

Island and North Core Banks during spring (Table 2). Sandwich Terns also followed a similar pattern of abundance by site and season. The obvious exception was the Royal Tern, which was detected throughout the year with high mean counts during April, August and September.

Forster's Tern (Sterna forsteri) were more abundant during fall, with highest mean counts averaging about 700 individuals in October (Figure 9). Caspian Terns (Hydroprogne caspia) also exhibited strong seasonal patterns with highest numbers recorded during the fall (e.g., September, October) (Figure 10). Two 2 species were recorded fewer than 5 times. Location and date of sighting is provided below.

Roseate Tern (Sterna dougallii): One was recorded on 30 July 1992 on North Core Banks.

Sooty Tern (Sterna fuscata): Two were recorded on 1 July 1993 on South Beach.

Portsmouth Flats

A total of 27 species of shorebirds, 5 species of gulls, and 9 species of terns were detected on censuses. Additional species observed were Brown Pelican (Pelecanus occidentalis), Double-crested Cormorant (Phalacrocorax auritus), Great Blue Heron (Ardea herodias), Snowy Egret (Egretta thula), Little Blue Heron (Hydranassa caerulea), Tricolored Heron (Hydranassa tricolor), White Ibis (Eudocimus albus), Canada Goose (Branta canadensis), American Black Duck (Anas rubripes), and Clapper Rail (Rallus longirostris).

Shorebirds were most numerous on the flats from November to May (Figure 11). This was because large numbers of Western Sandpipers and Dunlin wintered in the area. The high May counts include large numbers of Semipalmated Sandpipers. Several shorebird species found on the flats in moderate to large numbers (i.e. Greater Yellowlegs (Tringa melanoleuca), Marbled Godwit, Semipalmated Sandpiper, Western Sandpiper, Short-billed Dowitcher) were scarce on the beaches, probably because these species preferred tidal flats over sandy beaches.

Gulls were most numerous on the flats from July to November, though numbers were low compared to beach counts (Figure 11). Laughing Gulls were the most numerous species, with good numbers of Herring Gulls as well. Gull species composition was similar to that of outer beaches, except that Bonaparte's Gulls did not occur on the flats. Most gulls seen on the flats were probably using the area as a roosting spot.

Terns were most numerous on the flats from May to October (Figure 11). Most were Forster's and Least terns and Black Skimmers. As with the gulls, they were probably using the flats as a roosting place.

North Core counts - Sound side

Overall, High Hills was the location where the highest numbers of any aquatic group was recorded (Figures 12, 13, 14, 15). Shorebirds were most during spring, probably because it included species not found commonly on beach habitats (e.g., Semipalmated and Western Sandpipers) (Figure 12). Peak counts were recorded in 20 of April and May. Gulls did not exhibit strong seasonal patterns, with counts ranging from 50 to 100 individuals (Figure 13). Counts were, by and large, evenly distributed among the three count locations. The clear exception was on 11 Septembers when over 600 individuals were counted. Terns, in contrast, exhibited strong seasonal trends. Highest counts were recorded in spring and fall (Figure 14). With this group, however, we recorded substantially high numbers in Old Drum Inlet. Herons also presented strong seasonal patterns of high counts during spring and fall (Figure 15). For this group of species, Mile 9 emerged as one where counts were as high or higher than High Hills or Old Drum Inlet. Two of the four highest counts (>30 individuals) were recorded in Mile 9.

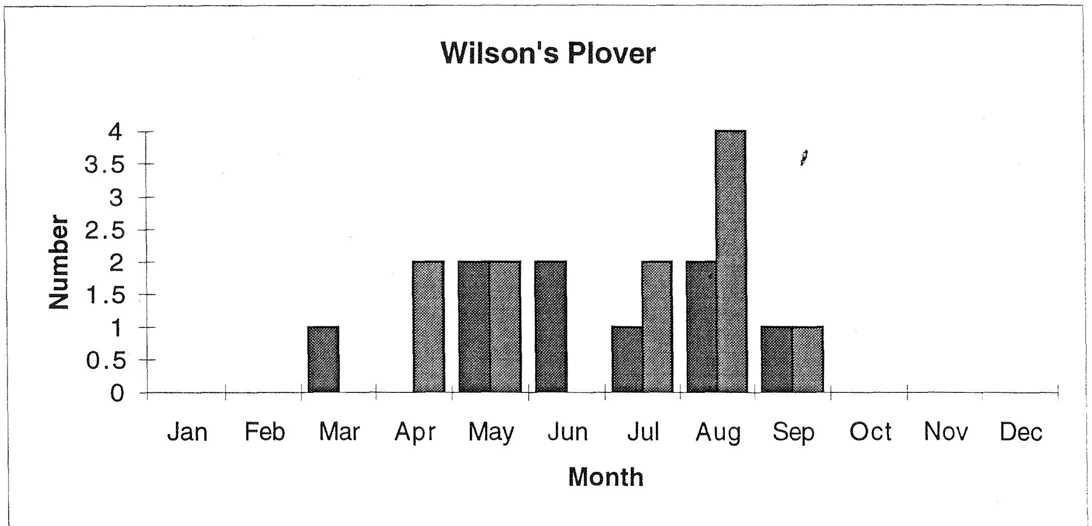
Literature Cited

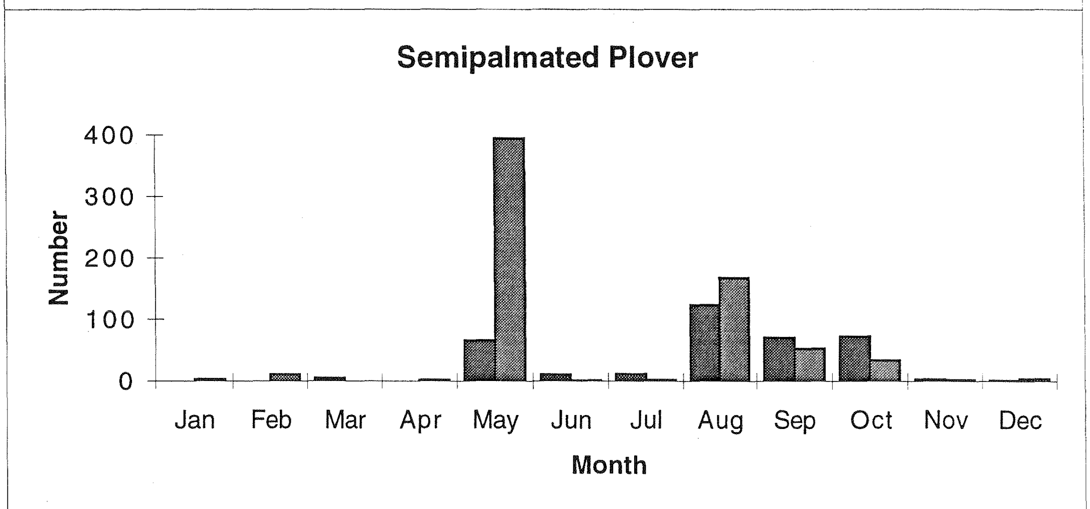
Dinsmore, S. J. and J. A. Collazo. 1995. Seasonal distribution and numbers of shorebirds on North Carolina's Outer Banks. Chapter 1, Final Report, National Park Service.

Tove, M. Reappraisal of the status of gulls in the Carolinas. The Chat 53:53-63.

Figure 2. Seasonal numbers of Wilson's Plovers, Semipalmated Plovers and Semipalmated Sandpipers counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076746


Wilson's Plover
Number
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Semipalmated Plover
Number
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

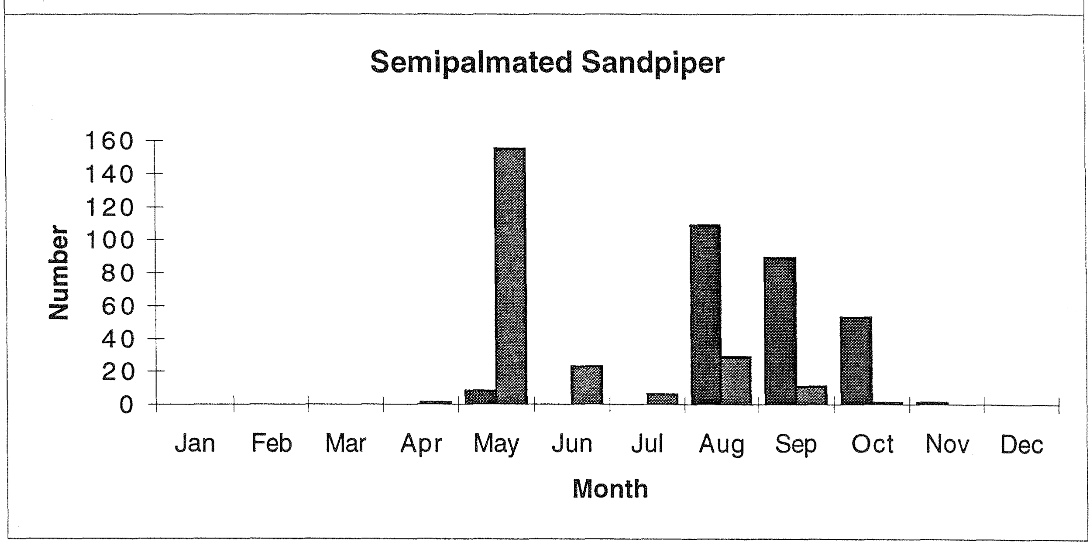
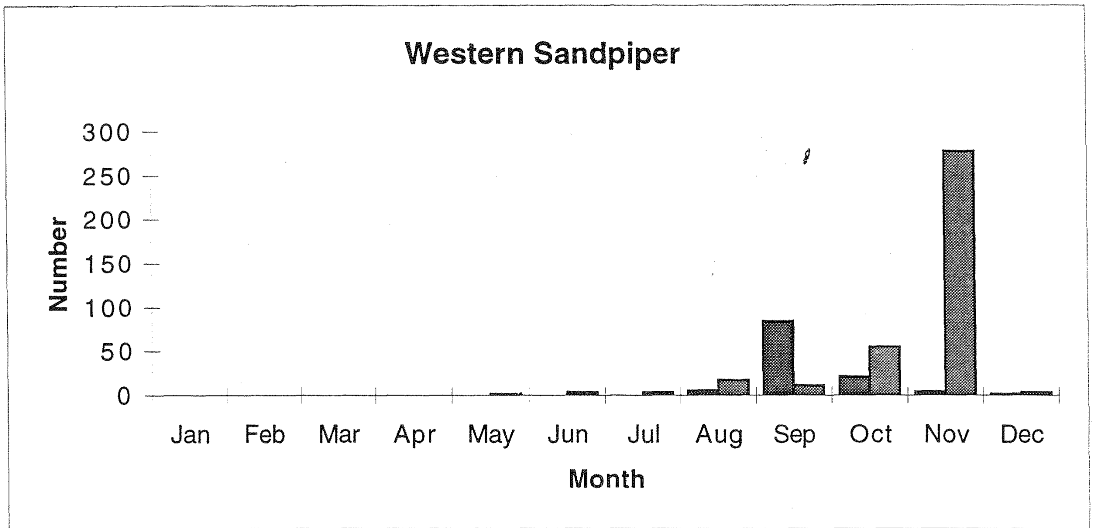
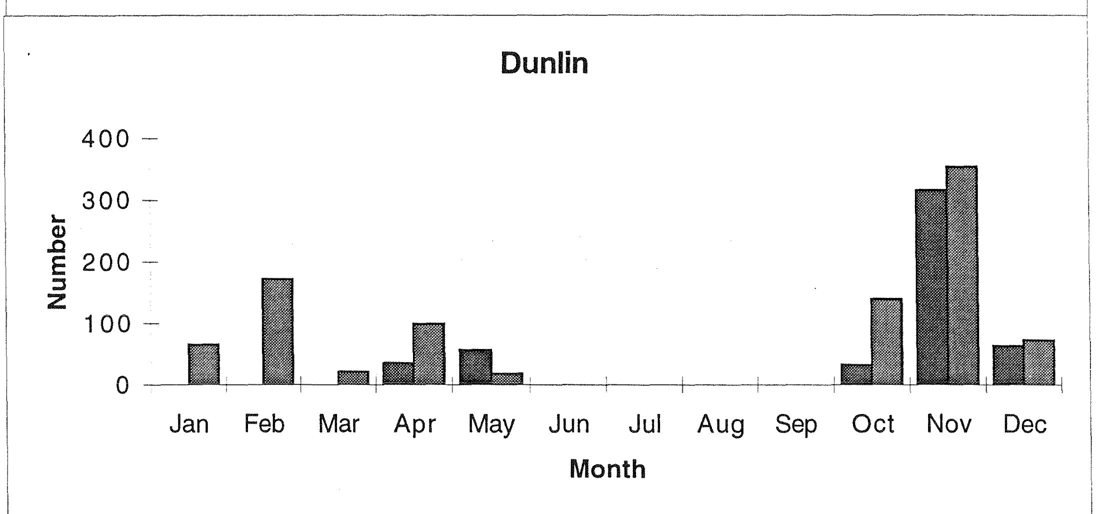

Semipalmated Sandpiper
Number
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 3. Seasonal numbers of Western Sandpipers, Dunlins and Short-billed Dowitcher counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076748


Western Sandpiper
Number
300
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Dunlin
Number
400
300
200
100
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

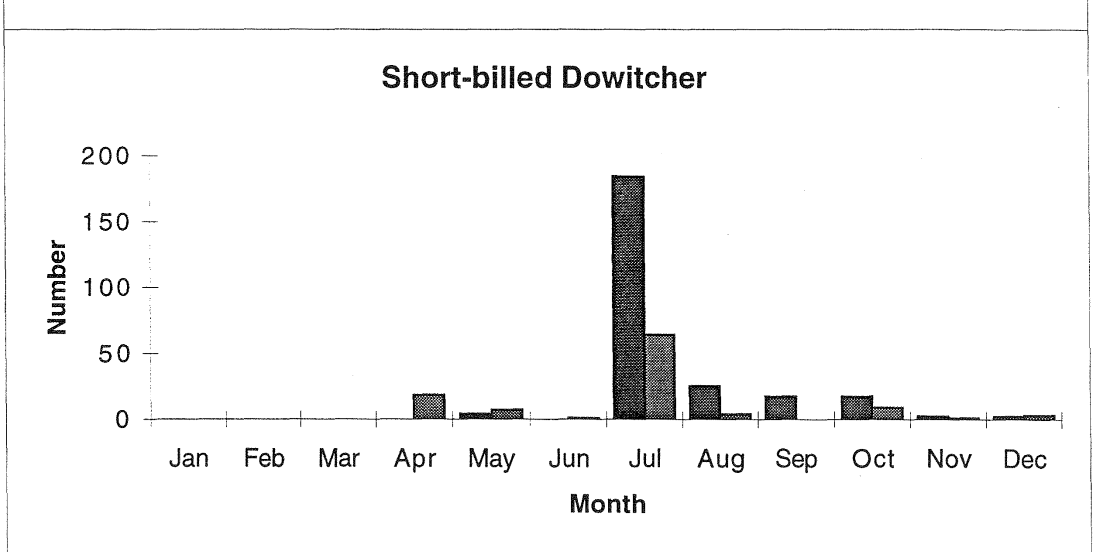
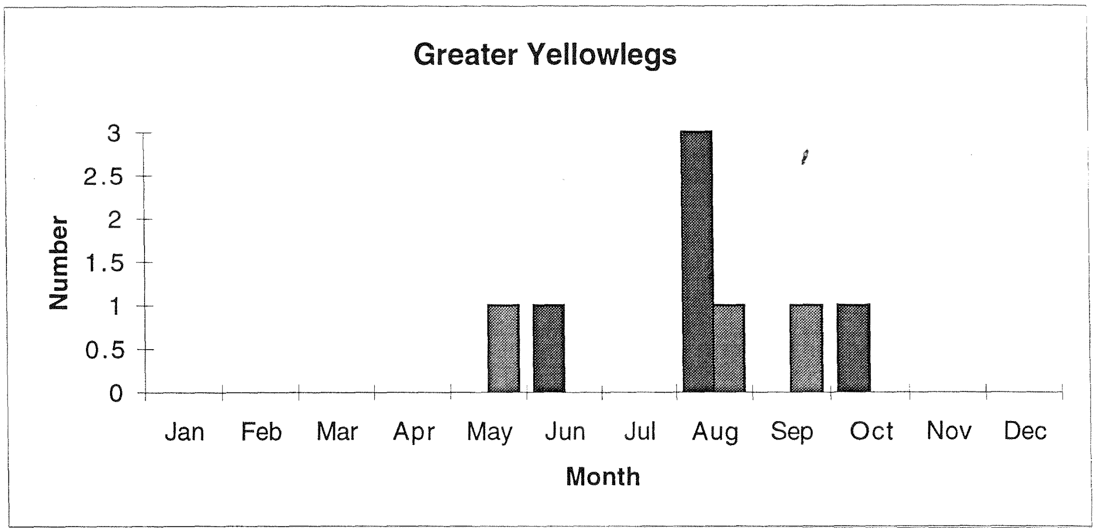
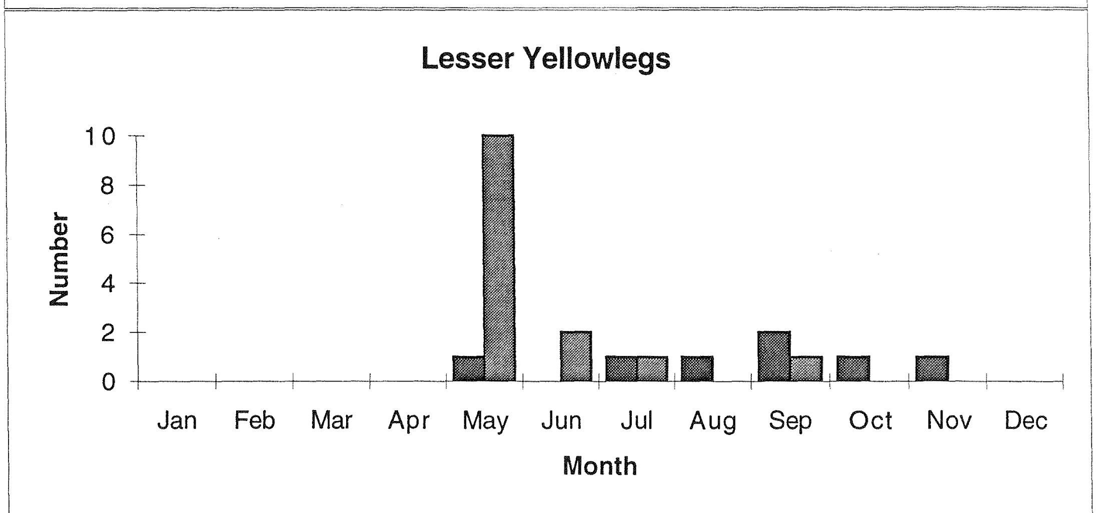

Short-billed Dowitcher
Number
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

Figure 4. Seasonal numbers of Greater Yellowlegs, Lesser Yellowlegs and Spotted Sandpipers counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076750


Greater Yellowlegs
Number
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Lesser Yellowlegs
Number
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

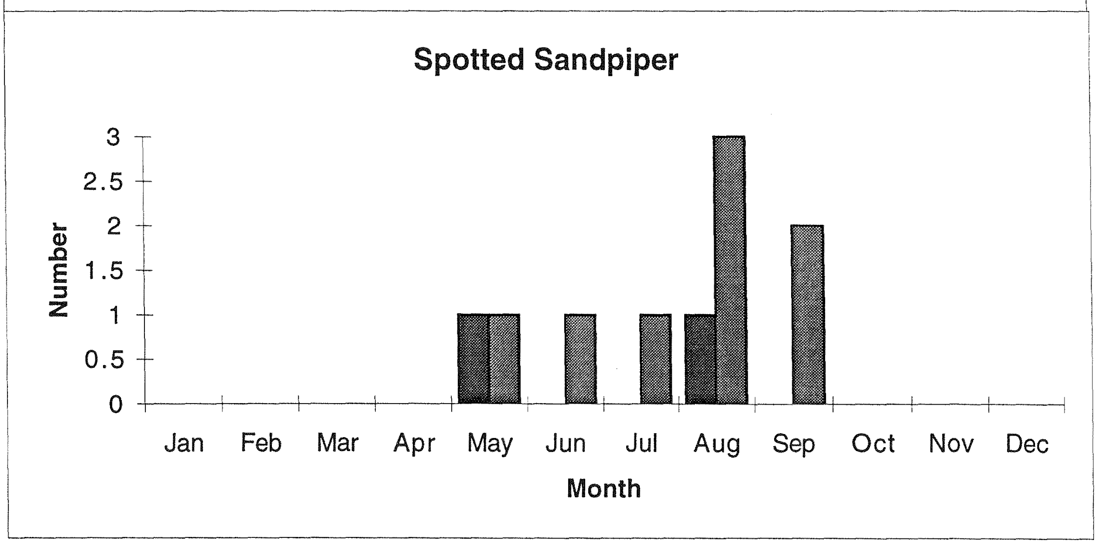
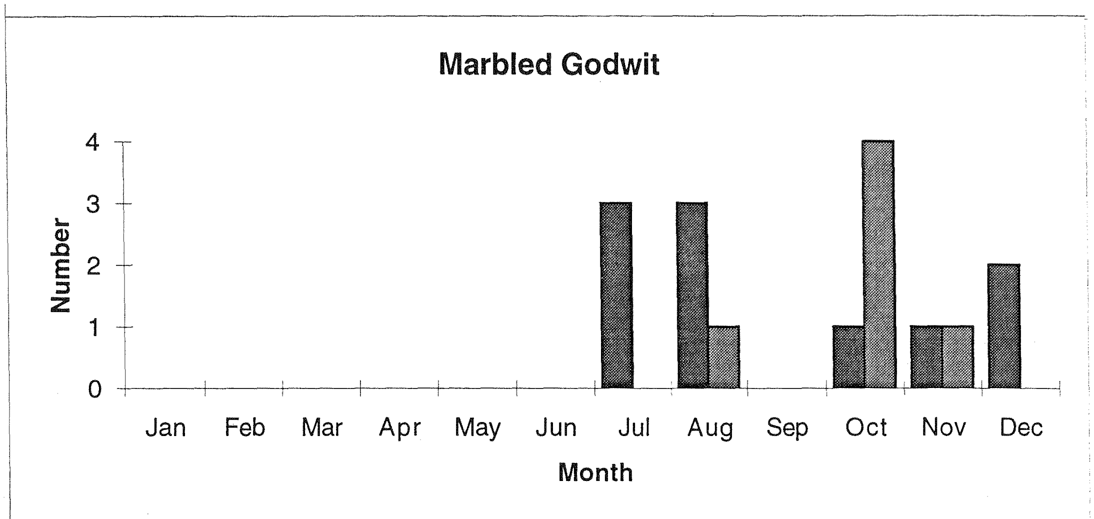

Spotted Sandpiper
Number
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 5. Seasonal numbers of Marbled Godwits, Least Sandpipers counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076752


Marbled Godwit
Number
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

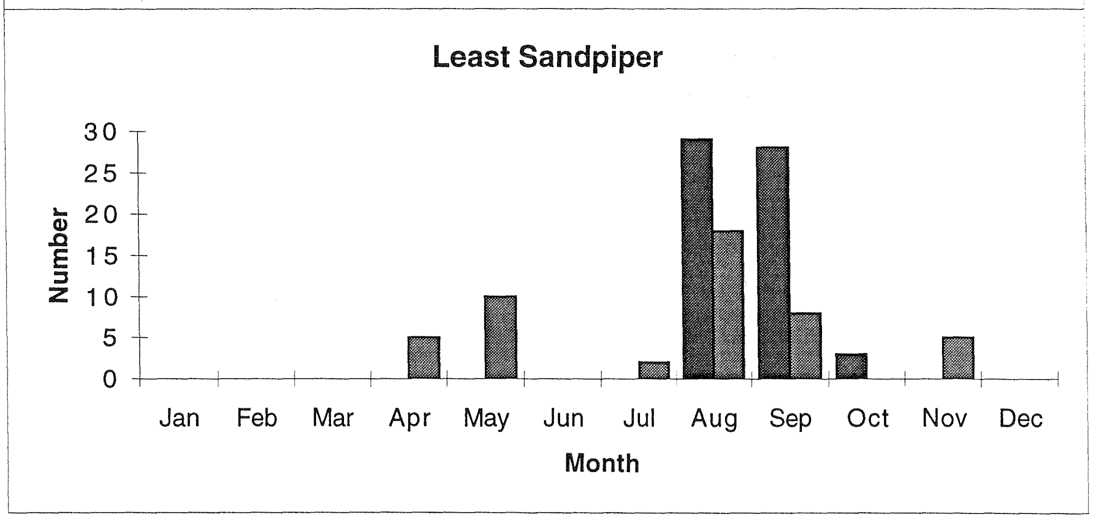
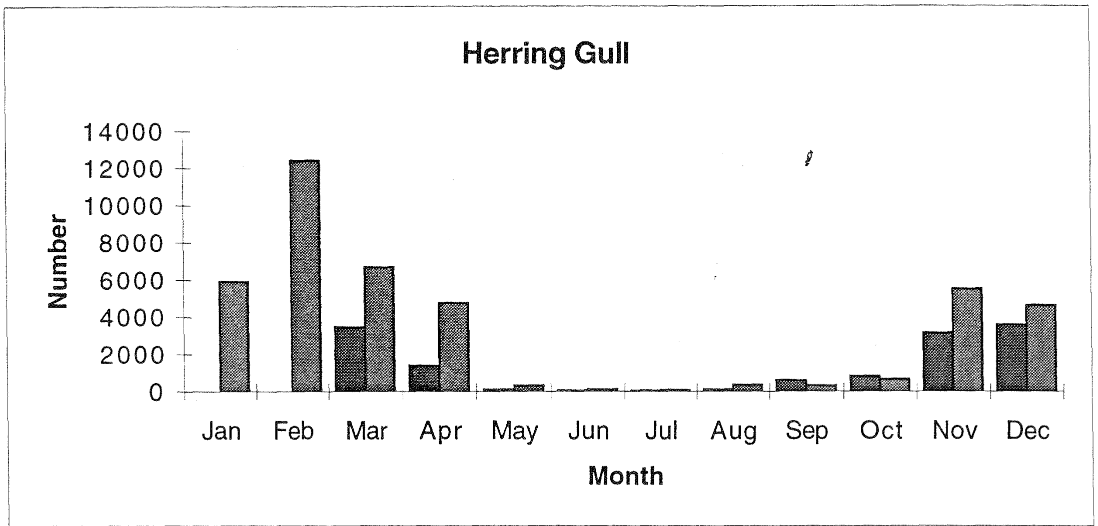
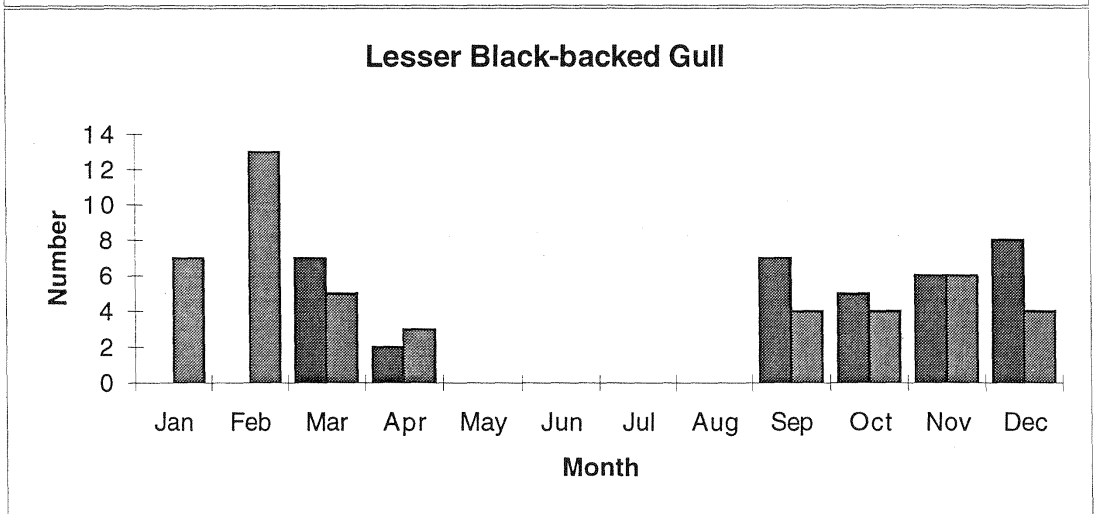

Least Sandpiper
Number
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 6. Seasonal numbers of Herring Gulls, Lesser Black-backed Gulls and Greater Black-backed counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Çarolina.

0076754


Herring Gull
Number
14000
12000
10000
8000
6000
4000
2000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Lesser Black-backed Gull
Number
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
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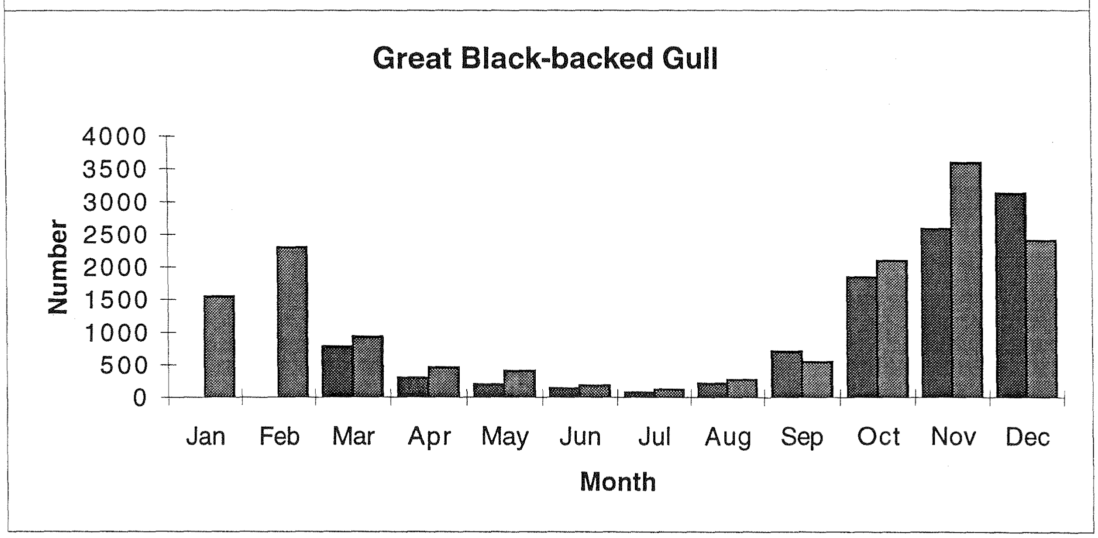
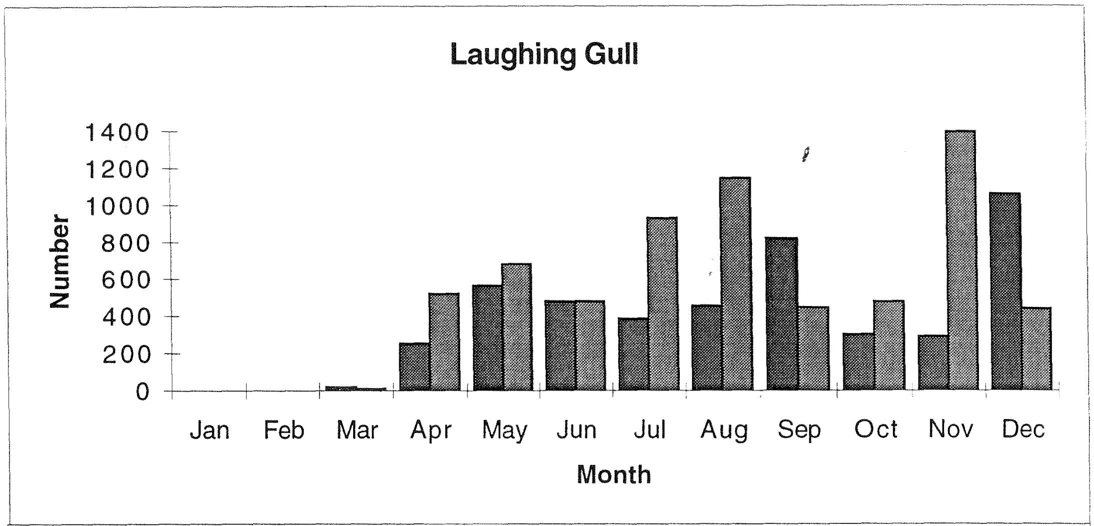
Sep
Oct
Nov
Dec
Month

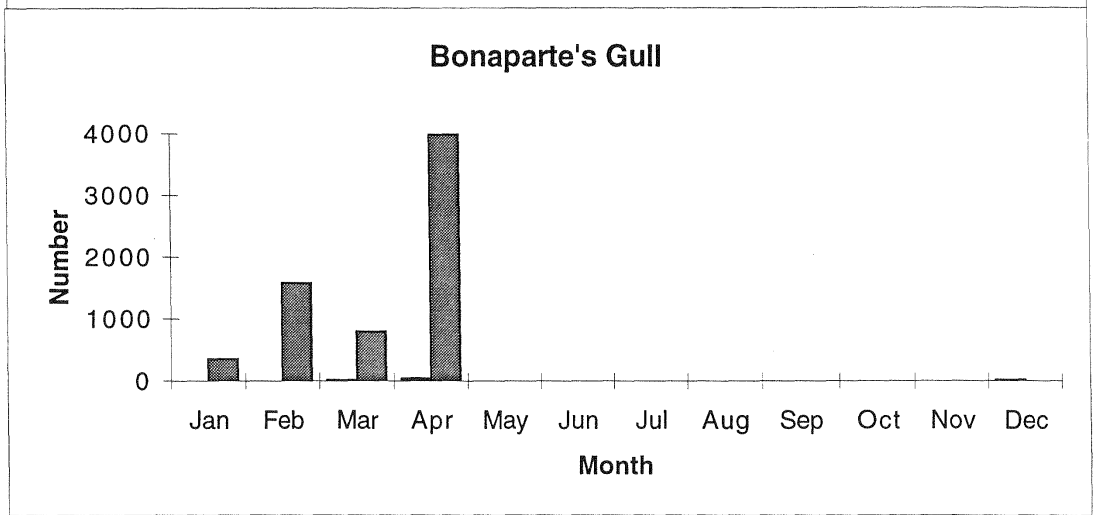

Great Black-backed Gull
Number
4000
3500
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

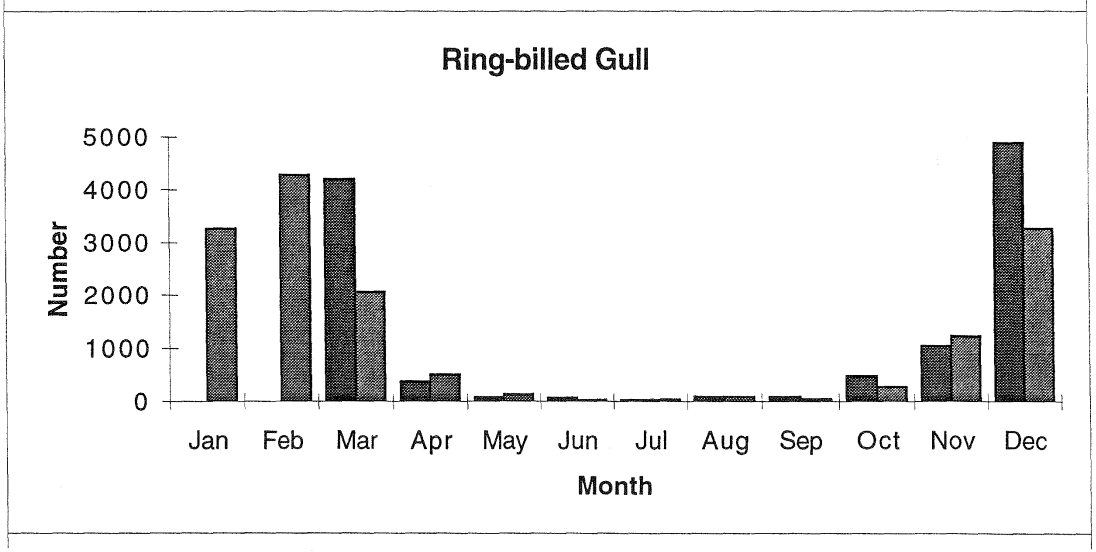
0076755

Figure 7. Seasonal numbers of Laughing Gulls, Bonaparte's Gulls and Ring-billed Gulls counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076756


Laughing Gull
1400
1200
1000
800
600
400
200
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

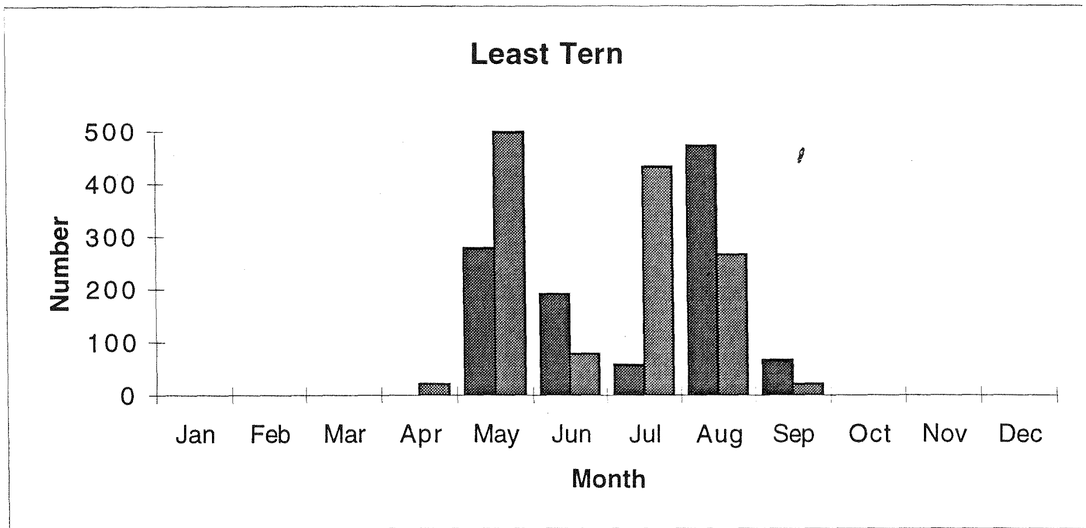

Bonaparte's Gull
4000
3000
2000
1000
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Ring-billed Gull
5000
4000
3000
2000
1000
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

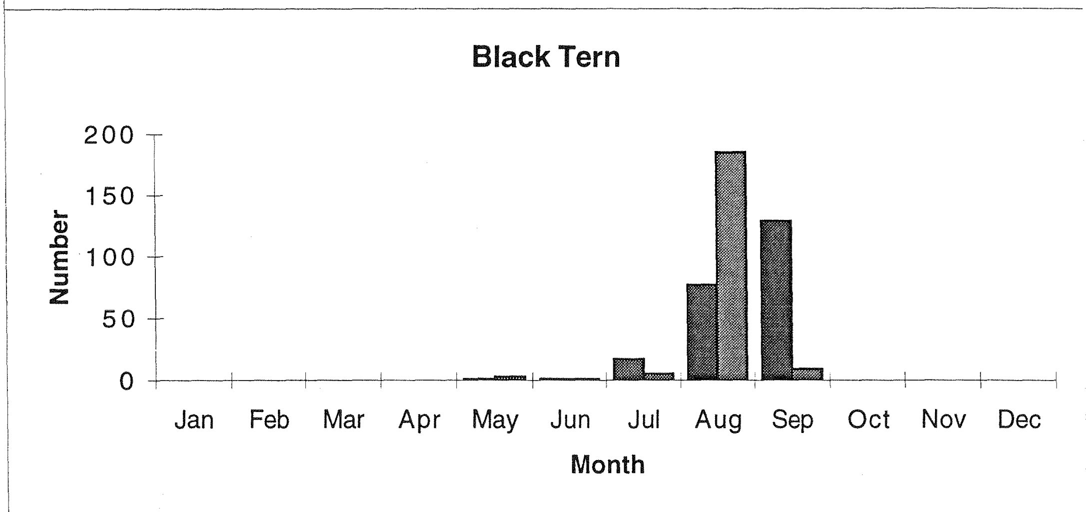
0076757

Figure 8. Seasonal numbers of Least Terns, Black Terns and Black Skimmers counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

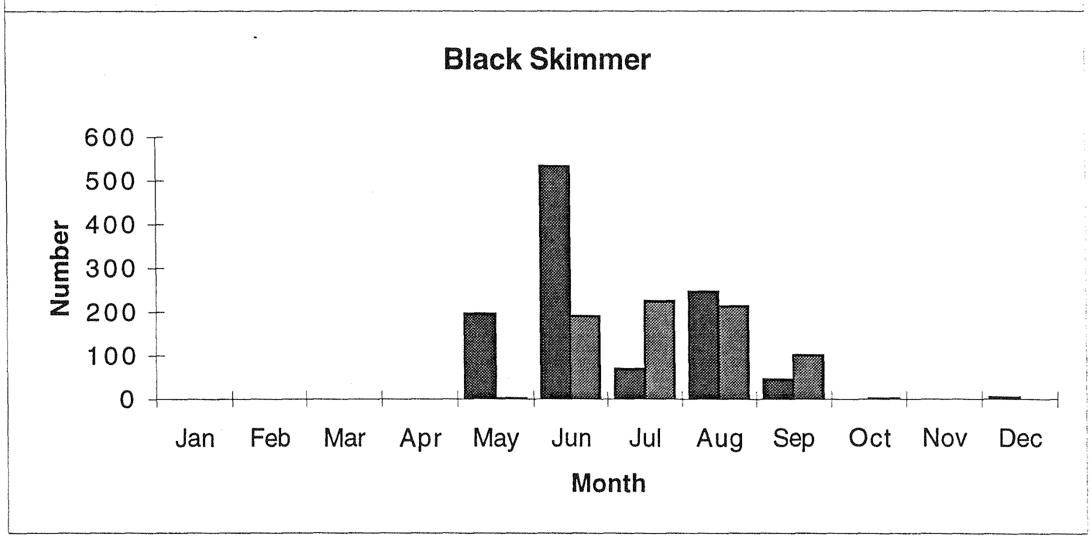
0076758



Least Tern
Number
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



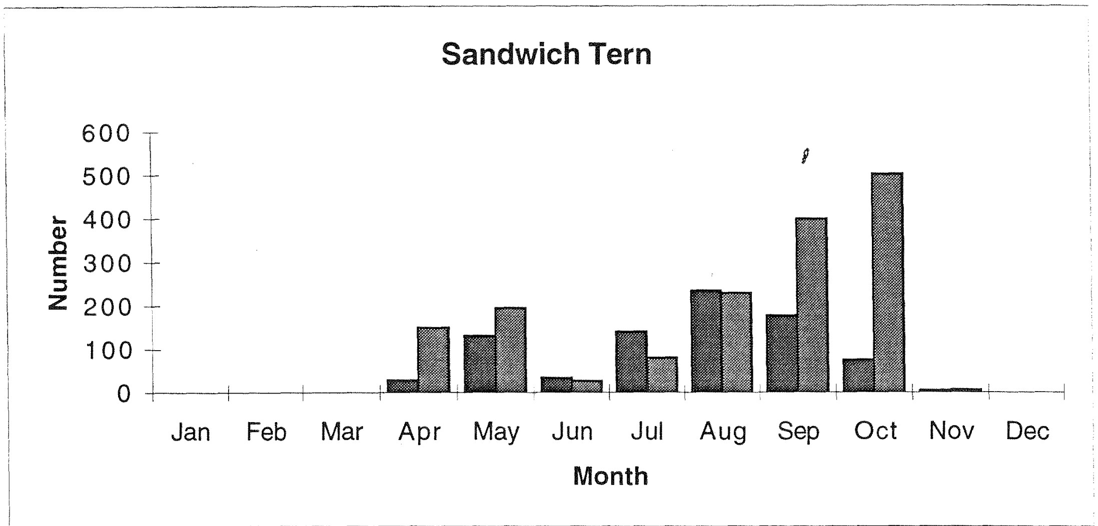
Black Tern
Number
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

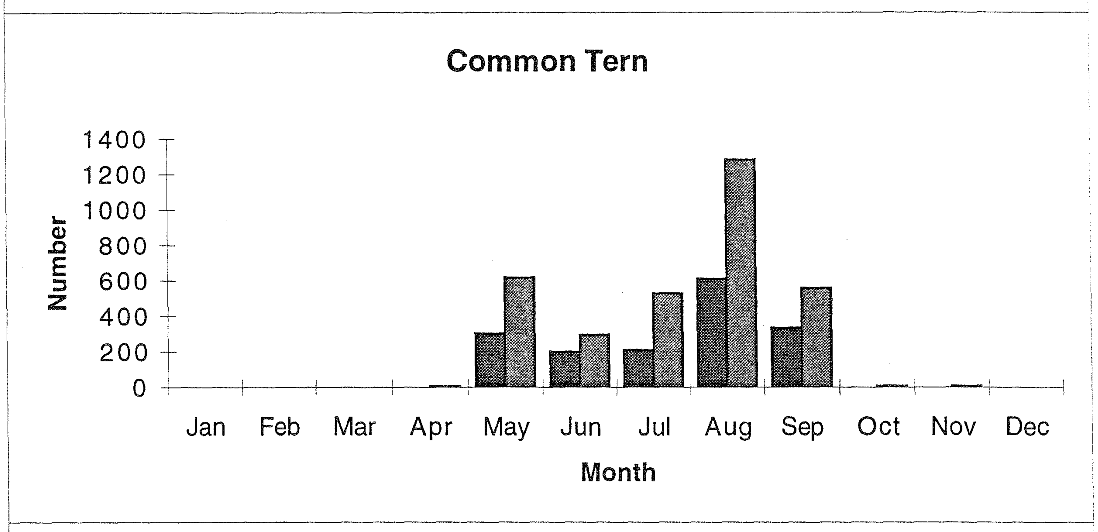


Black Skimmer
Number
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 9. Seasonal numbers of Sandwich Terns, Common Terns and Forster's Terns counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.

0076760


Sandwich Tern
600
500
400
300
200
100
0
Number
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Common Tern
1400
1200
1000
800
600
400
200
0
Number
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

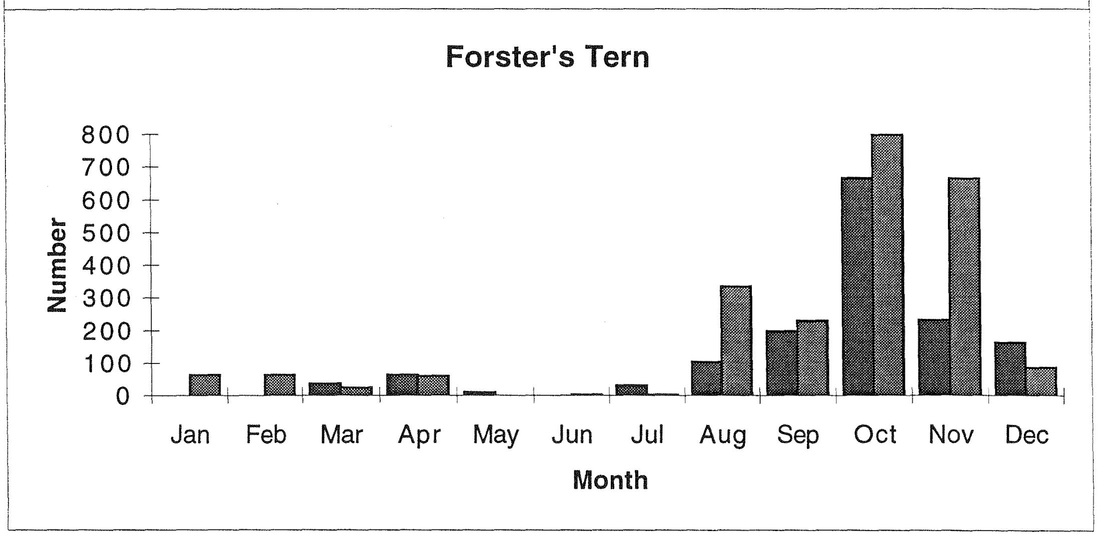
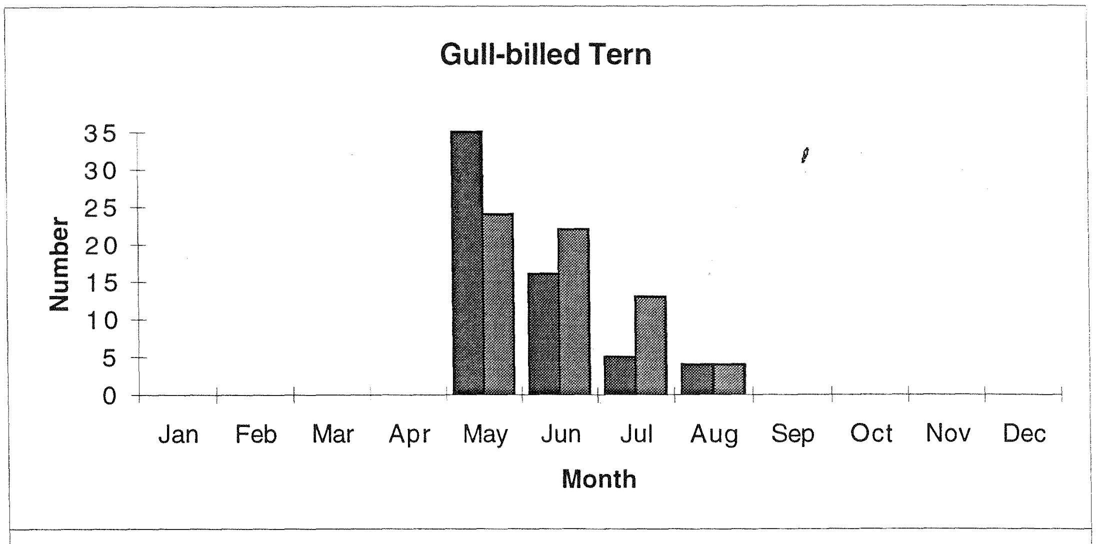
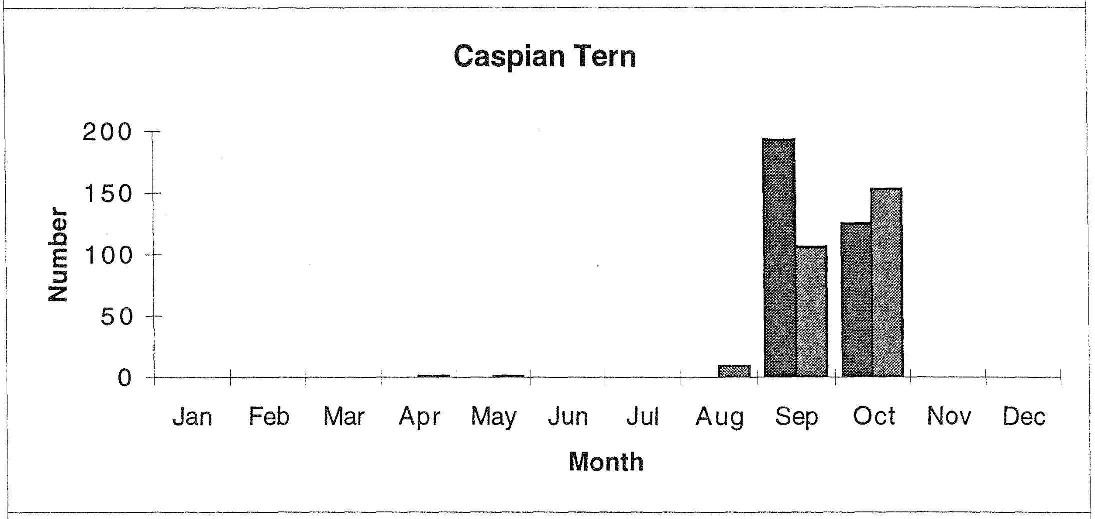
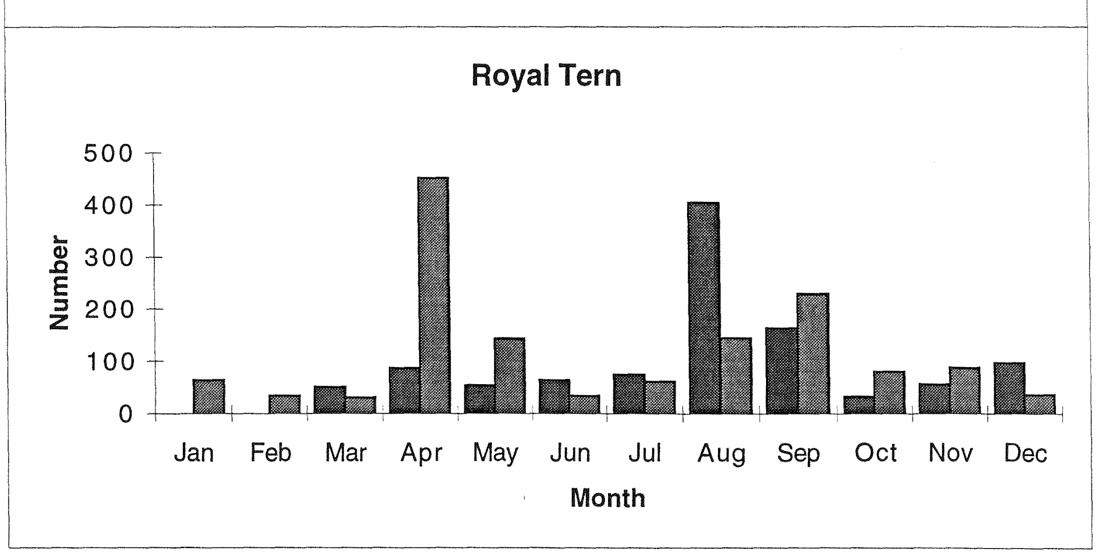

Forster's Tern
800
700
600
500
400
300
200
100
0
Number
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

Figure 10. Seasonal numbers of Gull-billed Terns, Caspian Terns and Royal Terns counted during beach censuses in 1992 (dark bar or left of pair) and 1993 (right of pair) at the Outer Banks of North Carolina.


Gull-billed Tern
Number
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

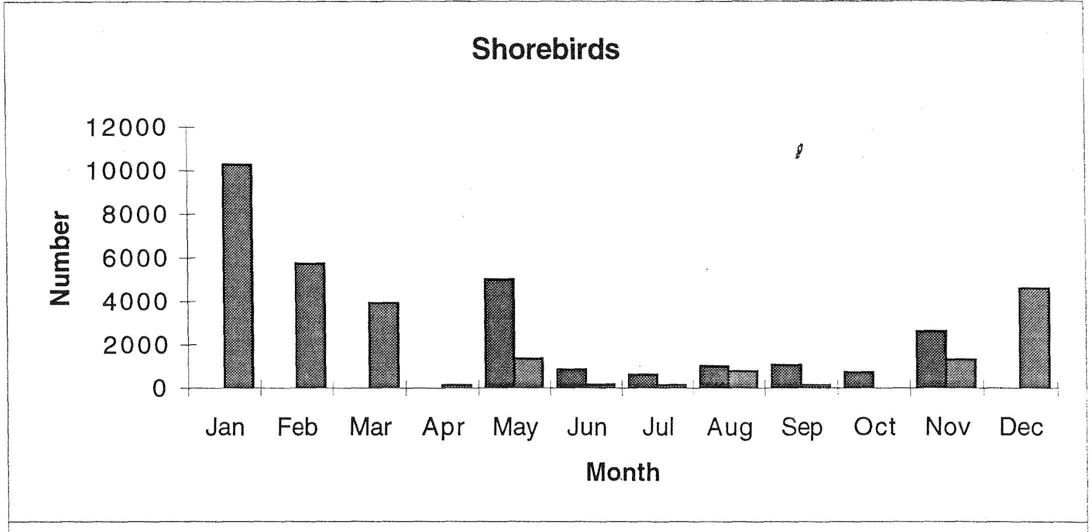

Caspian Tern
Number
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Royal Tern
Number
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

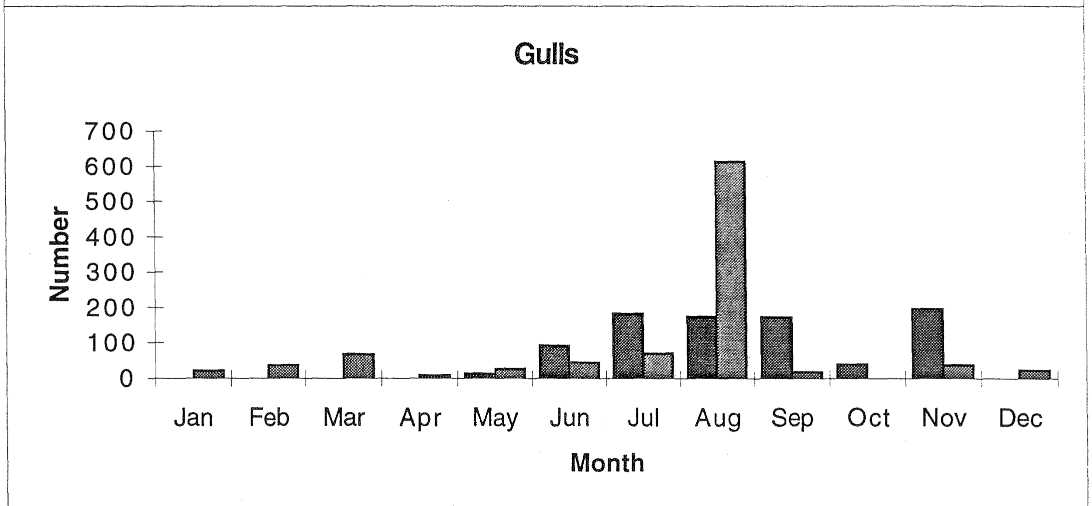
0076763

Figure 11. Seasonal numbers of shorebirds, gulls and counted during censuses from May 1992 to November 1993 at Portsmouth Flats, North Core Banks, North Carolina.

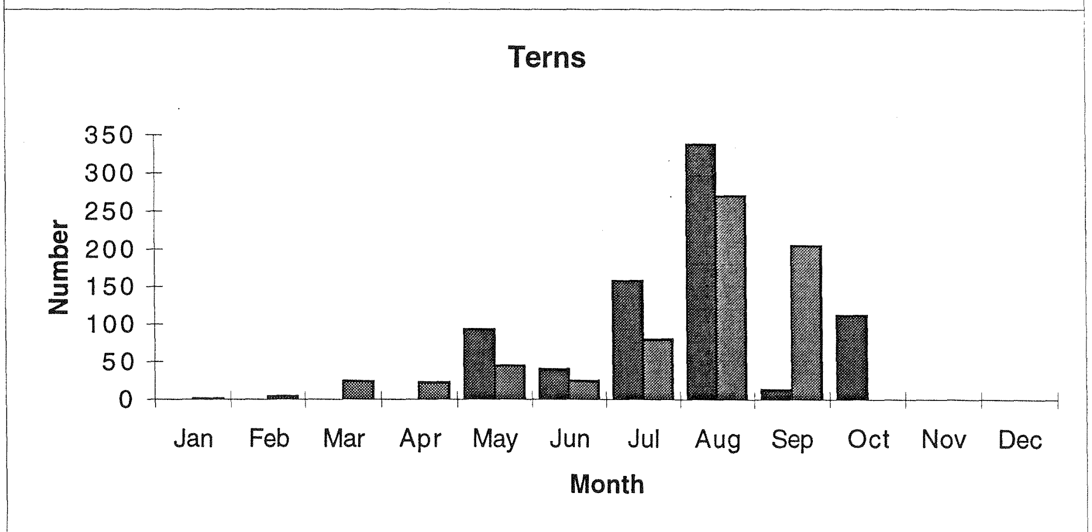
0076764



Shorebirds
12000
10000
8000
6000
4000
2000
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



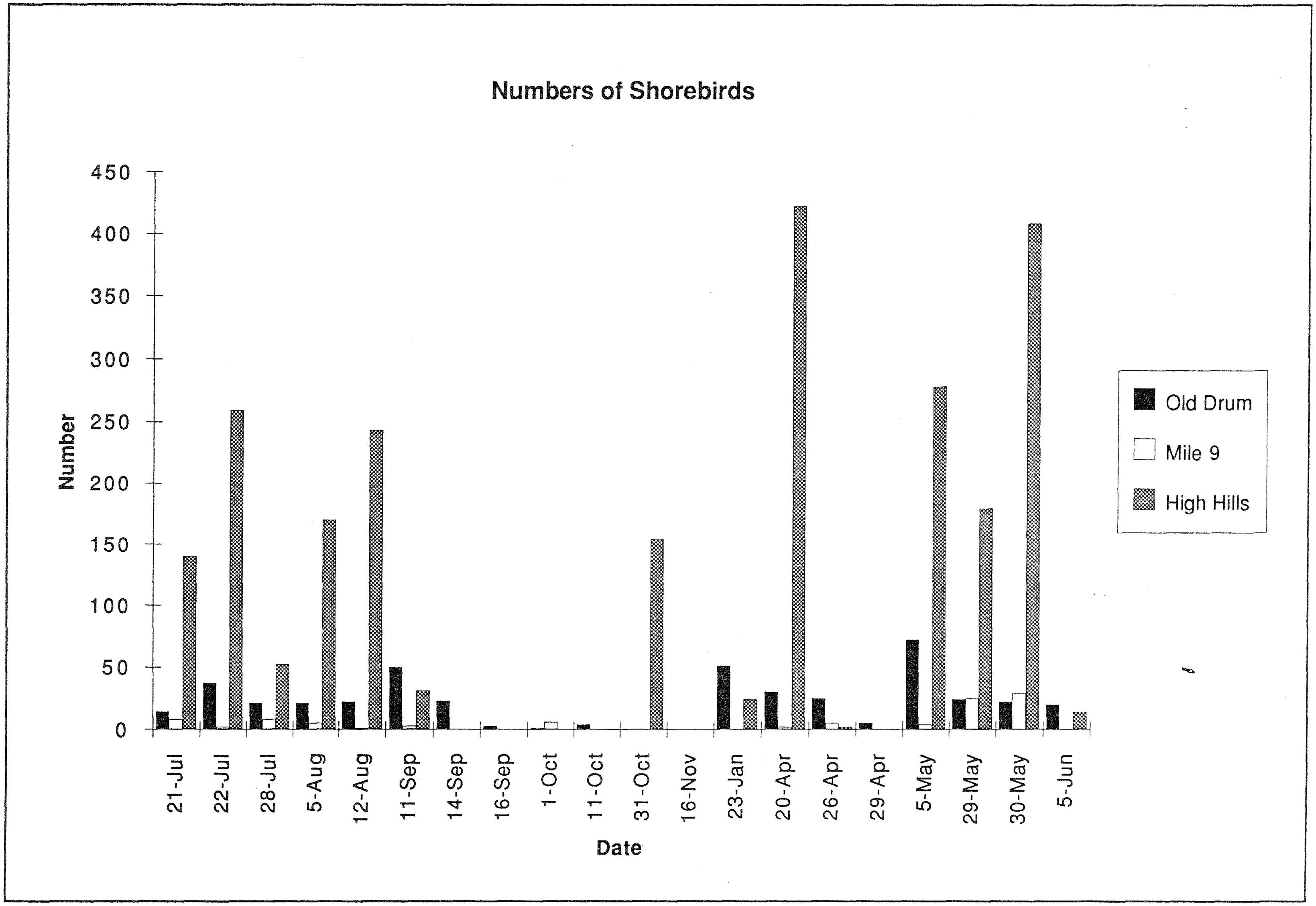
Gulls
700
600
500
400
300
200
100
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



Terns
350
300
250
200
150
100
50
0
Number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 12. Seasonal numbers of shorebirds counted during censuses from May 1992 to November 1993 at Old Drum Inlet, Mile 9 marker and High Hills along the Core Sound side of North Core Banks, North Carolina.

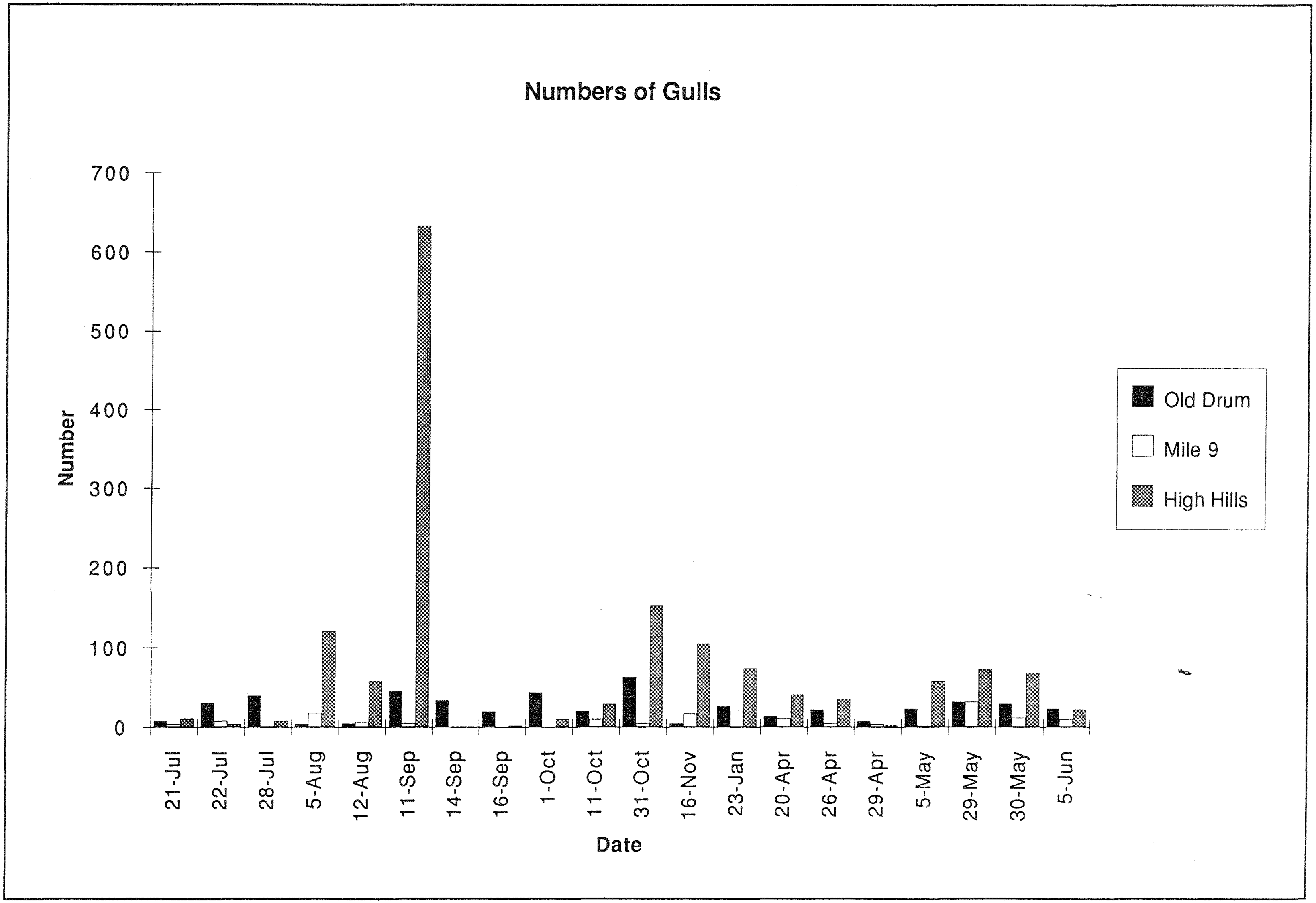
0076766



Numbers of Shorebirds
Number
450
400
350
300
250
200
150
100
50
0
21-Jul
22-Jul
28-Jul
5-Aug
12-Aug
11-Sep
14-Sep
16-Sep
1-Oct
11-Oct
31-Oct
16-Nov
23-Jan
20-Apr
26-Apr
29-Apr
5-May
29-May
30-May
5-Jun
Date
Old Drum
Mile 9
High Hills

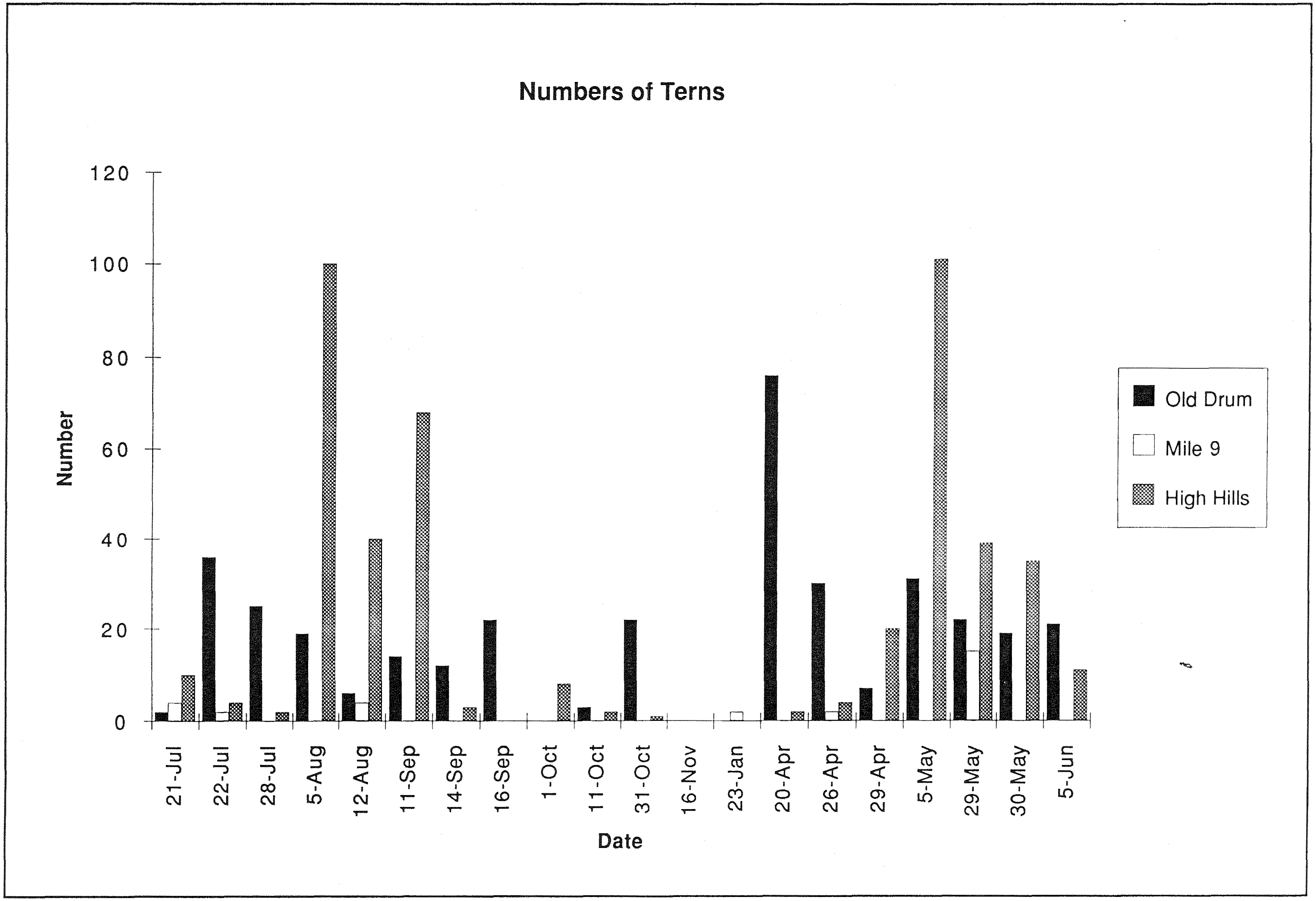
Figure 13. Seasonal numbers of gulls counted during censuses from May 1992 to November 1993 at Old Drum Inlet, Mile 9 marker and High Hills along the Core Sound side of North Core Banks, North Carolina.

0076768



Numbers of Gulls
Number
700
600
500
400
300
200
100
0
21-Jul
22-Jul
28-Jul
5-Aug
12-Aug
11-Sep
14-Sep
16-Sep
1-Oct
11-Oct
31-Oct
16-Nov
23-Jan
20-Apr
26-Apr
29-Apr
5-May
29-May
30-May
5-Jun
Date
Old Drum
Mile 9
High Hills

Figure 14. Seasonal numbers of terns counted during censuses from May 1992 to November 1993 at Old Drum Inlet, Mile 9 marker and High Hills along the Core Sound side of North Core Banks, North Carolina.



Numbers of Terns
Number
120
100
80
60
40
20
0
21-Jul
22-Jul
28-Jul
5-Aug
12-Aug
11-Sep
14-Sep
16-Sep
1-Oct
11-Oct
31-Oct
16-Nov
23-Jan
20-Apr
26-Apr
29-Apr
5-May
29-May
30-May
5-Jun
Date
Old Drum
Mile 9
High Hills

0076770

0076771

Figure 15. Seasonal numbers of herons counted during censuses from May 1992 to November 1993 at Old Drum Inlet, Mile 9 marker and High Hills along the Core Sound side of North Core Banks, North Carolina.

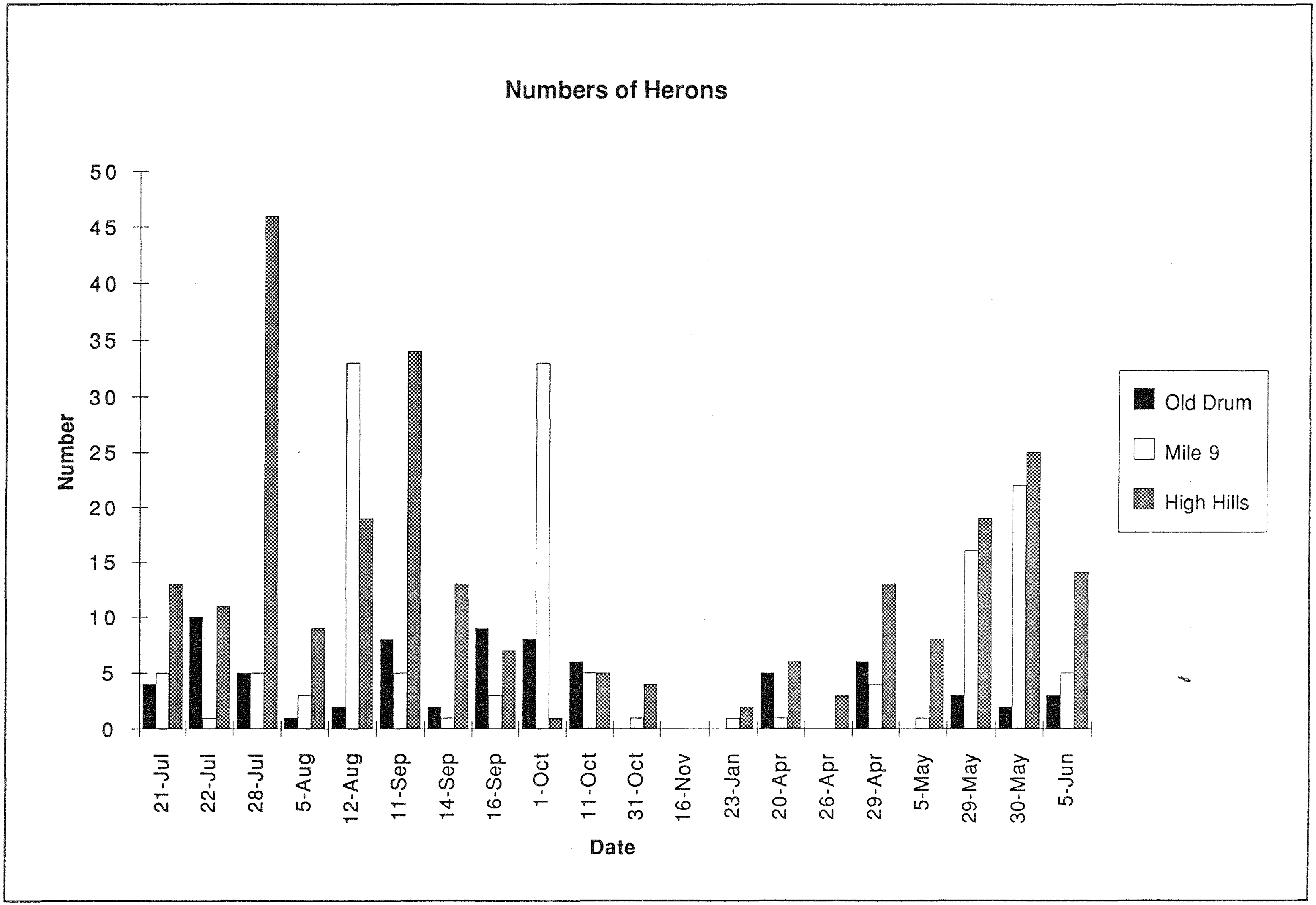

Numbers of Herons
Number
0
5
10
15
20
25
30
35
40
45
50
21-Jul
22-Jul
28-Jul
5-Aug
12-Aug
11-Sep
14-Sep
16-Sep
1-Oct
11-Oct
31-Oct
16-Nov
23-Jan
20-Apr
26-Apr
29-Apr
5-May
29-May
30-May
5-Jun
Date
Old Drum
Mile 9
High Hills

Table 1. Seasonal numbers (mean ± SE) of selected species of gulls and terns during 1992 and 1993 beach censuses in the Outer Banks of North Carolina. Seasons are spring (April-June) and fall (July-November).

Species	Spring	Fall
Ring-billed Gull	69.43 ± 15.22*	40.70 ± 10.34
Herring Gull	1,905.00 ± 11.69*	34.67 ± 1.54
Great Black-backed Gull	45.70 ± 1.43*	13.06 ± 1.36
Common Tern	0.82 ± 1.82	21.37 ± 1.69*
Least Tern	1.22 ± 1.79	9.60 ± 1.64*

* = significantly higher ($P < 0.05$)

Table 2. Numbers (mean ± SE) of Black Skimmers and Sandwich Terns counted during 1992 and 1993 beach censuses in the Outer Banks of North Carolina. Seasons are spring (April-June) and fall (July-November).

Species	Location	Season	Numbers
Black Skimmer	Bodie Island	Spring	11.09 ± 2.88
	North Core Banks	Spring	10.42 ± 4.14
	North Beach	Fall	12.19 ± 2.49
	South Beach	Fall	2. 00 ± 2.49
	Ocracoke	Fall	0.40 ± 2.88
Sandwich Tern	Bodie Island	Spring	15.03 ± 3.04
	North Core Banks	Spring	25.70 ± 4.26
	North Beach	Fall	5.36 ± 2.56
	South Beach	Fall	6.31 ± 2.56
	Ocracoke	Fall	8.26 ± 2.56

Birds of Cape Lookout National Seashore: a checklist.

Chapter VII

by

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0076776

Species	Sp	Su	F	W
Red-throated Loon	C		F	C
Common Loon	C	R	F	C
Pied-billed Grebe	U		U	U
Horned Grebe	F	R	U	F
Red-necked Grebe	R			R
Cory's Shearwater	R	U	U	
Greater Shearwater		R		
Sooty Shearwater	U	R		
Audubon's Shearwater	R	U	U	
Wilson's Storm-Petrel	U	U	U	
Northern Gannet	C	R	C	C
Brown Pelican*	C	C	C	C
Great Cormorant	U	R	U	U
Double-crested Cormorant	C	U	C	C
Magnificent Frigatebird	R	R	R	
American Bittern			U	R
Least Bittern			R	
Great Blue Heron	F	U	F	F
Great Egret*	C	C	C	U
Snowy Egret*	C	C	C	R
Little Blue Heron*	C	C	C	R
Tricolored Heron*	C	C	C	U
Reddish Egret	R	R	R	
Cattle Egret*	C	C	C	
Green Heron*	U	U	U	
Black-crowned Night-Heron*	F	U	F	U
Yellow-crowned Night-Heron	U	U	U	
White Ibis	U	U	U	R
Glossy Ibis	U	U	U	
Tundra Swan	R		R	U
Brant	U	R	U	U
Canada Goose	U	R	U	U
Green-winged Teal	U		U	F
American Black Duck*	C	U	C	C
Mallard	U	R	U	U
Northern Pintail	U		U	F
Blue-winged Teal	U		U	R
Northern Shoveler	U		U	U
Gadwall	U		F	C
American Wigeon	C		C	C
Canvasback	R		U	R
Redhead	U		U	F
Ring-necked Duck			R	R
Greater Scaup	R		U	U
Lesser Scaup	U		U	F
Common Eider	R	R	R	R
Oldsquaw	U		U	U
Black Scoter	U	R	U	F
Surf Scoter	U	R	U	U
White-winged Scoter	R		U	U
Common Goldeneye	U		U	U

Species	Sp	Su	F	W
Bufflehead	F		U	C
Hooded Merganser	U		U	F
Red-breasted Merganser	F	R	U	C
Ruddy Duck	R		R	U
Black Vulture			R	
Turkey Vulture	R	R	R	
Osprey*	F	F	F	
Am. Swallow-tailed Kite	R	R		
Bald Eagle	R	R	R	
Northern Harrier*	C	R	C	C
Sharp-shinned Hawk	U		C	U
Cooper's Hawk	R		U	R
Red-shouldered Hawk	R		R	R
Broad-winged Hawk	R			
Red-tailed Hawk	R	R	R	R
American Kestrel	F		C	F
Merlin	U		F	U
Peregrine Falcon	U		F	U
Ring-necked Pheasant*	U	U	U	U
Northern Bobwhite*	U	U	U	U
Black Rail*	U	U	U	
Clapper Rail*	C	C	C	C
King Rail		R		
Virginia Rail*	F	U	F	F
Sora	U		F	U
Common Moorhen			R	R
American Coot	R		R	R
Black-bellied Plover	C	F	C	F
American Golden-Plover	R	R	U	
Wilson's Plover*	F	F	F	R
Semipalmated Plover	C	F	C	U
Piping Plover*	F	F	F	U
Killdeer	R	R	U	U
American Oystercatcher*	C	C	C	U
Black-necked Stilt	R	R		
American Avocet	R	R		
Greater Yellowlegs	F	U	F	F
Lesser Yellowlegs	U	R	U	
Solitary Sandpiper	U	U	U	
Willet*	C	C	C	F
Spotted Sandpiper	U	F	F	
Upland Sandpiper	R	R		
Whimbrel	F	F	F	R
Long-billed Curlew	R	R	R	R
Hudsonian Godwit			R	
Marbled Godwit	U	U	F	U
Ruddy Turnstone	C	F	F	U
Red Knot	C	U	F	U
Sanderling	C	F	C	C
Semipalmated Sandpiper	C	F	U	
Western Sandpiper	F	C	C	F

Species	Sp	Su	F	W
Least Sandpiper	F	F	F	U
White-rumped Sandpiper	U	U	U	
Baird's Sandpiper			R	
Pectoral Sandpiper	U	U	F	
Dunlin	C	R	C	C
Curlew Sandpiper	R	R	R	R
Stilt Sandpiper	R	U	U	
Buff-breasted Sandpiper		R	R	
Ruff			R	
Short-billed Dowitcher	C	F	C	U
Long-billed Dowitcher	R		R	
Common Snipe	U		U	U
American Woodcock	U	R	U	U
Wilson's Phalarope	R	U	U	
Red-necked Phalarope	R	R		
Red Phalarope	R		R	
Pomarine Jaeger	U	U	U	U
Parasitic Jaeger	U	U	U	
Long-tailed Jaeger	R			
Laughing Gull*	C	C	C	U
Little Gull	R			R
Bonaparte's Gull	F		U	C
Ring-billed Gull	C	U	C	C
Herring Gull*	C	C	C	C
Iceland Gull			R	R
Lesser Black-backed Gull	U	R	U	U
Glaucous Gull				R
Great Black-backed Gull*	C	F	C	C
Black-legged Kittiwake	R		R	U
Gull-billed Tern*	F	F	F	
Caspian Tern	U	U	F	
Royal Tern*	C	C	C	F
Sandwich Tern*	C	C	C	
Roseate Tern	U	R	R	
Common Tern*	C	C	C	
Forster's Tern*	F	F	C	F
Least Tern*	C	C	C	
Sooty Tern*	R	R	R	
Black Tern	U	F	F	
Black Skimmer*	F	C	C	R
Dovekie			R	R
Razorbill			R	R
Rock Dove	R	R	R	
Mourning Dove*	C	C	C	C
Yellow-billed Cuckoo*	U	U	C	
Common Barn-Owl*	U	R	U	U
Short-eared Owl			U	U
Common Nighthawk*	F	F	U	
Chuck-wills-widow*	U	U	U	
Chimney Swift	U	U	U	
Ruby-throated Hummingbird		R	R	

Species	Sp	Su	F	W
Belted Kingfisher*	U	U	U	U
Red-headed Woodpecker	R		R	
Red-bellied Woodpecker			R	
Yellow-bellied Sapsucker			U	R
Downy Woodpecker			R	
Northern Flicker	C	R	C	F
Eastern Wood-Pewee	U		F	
empidonax sp.			U	
Eastern Phoebe			C	R
Great-crested Flycatcher*	F	F	F	
Western Kingbird			U	
Eastern Kingbird*	F	U	C	
Purple Martin	U	U	R	
Tree Swallow	U		C	U
Northern Rough-winged Swallow	R	R		
Bank Swallow	R	U		
Cliff Swallow		R		
Barn Swallow*	C	C	C	
Blue Jay	R		R	
Fish Crow*	C	C	C	U
Carolina Chickadee		R		
Red-breasted Nuthatch			F	U
Brown Creeper			U	
Carolina Wren*	F	F	F	F
House Wren	U		F	U
Winter Wren			U	R
Sedge Wren	U		U	U
Marsh Wren*	U	U	F	F
Golden-crowned Kinglet			C	U
Ruby-crowned Kinglet			F	U
Blue-gray Gnatcatcher	U	R	U	
Eastern Bluebird	R		R	
Veery	R			
Gray-cheeked Thrush	R		U	
Swainson's Thrush			U	
Hermit Thrush			U	R
Wood Thrush			U	
American Robin	U		C	U
Gray Catbird*	U	U	F	U
Northern Mockingbird*	U	U	U	U
Brown Thrasher*	U	U	U	U
American Pipit			U	
Cedar Waxwing	U	R	U	U
European Starling*	U	U	U	U
White-eyed Vireo	U	U	U	
Solitary Vireo			U	R
Philadelphia Vireo			R	
Red-eyed Vireo	R	R	F	
Blue-winged Warbler			R	
Tennessee Warbler			U	
Orange-crowned Warbler	U		U	U

Species	Sp	Su	F	W
Nashville Warbler			R	
Northern Parula	U	R	U	
Yellow Warbler	U	U	F	
Chestnut-sided Warbler			R	
Magnolia Warbler			F	
Cape May Warbler	R		C	
Black-throated Blue Warbler	R		C	
Yellow-rumped Warbler	C		C	C
Black-throated Green Warbler	R		U	
Blackburnian Warbler	R		R	
Yellow-throated Warbler	R	R		
Pine Warbler			U	R
Prairie Warbler*	F	F	C	R
Palm Warbler	U		C	U
Bay-breasted Warbler			R	
Blackpoll Warbler	U		F	
Black-and-white Warbler	R	U	F	
American Redstart	R	U	C	
Prothonotary Warbler	R	U		
Ovenbird			F	
Northern Waterthrush	R	U	U	
Connecticut Warbler			R	
Common Yellowthroat*	F	F	C	U
Hooded Warbler	R		R	
Wilson's Warbler			R	
Canada Warbler	R			
Yellow-breasted Chat*	U	U	U	
Summer Tanager	R			
Scarlet Tanager	R		U	
Northern Cardinal*	F	F	F	F
Rose-breasted Grosbeak	R		F	
Blue Grosbeak	U	U	F	
Indigo Bunting	U		F	
Painted Bunting	R	R		
Rufous-sided Towhee*	F	F	F	F
Chipping Sparrow		R	U	
Clay-colored Sparrow			R	
Field Sparrow			U	
Lark Sparrow		R	R	
Savannah Sparrow	C		C	C
Grasshopper Sparrow			R	
Sharp-tailed Sparrow	F		F	F
Seaside Sparrow*	F	F	F	F
Fox Sparrow			U	U
Song Sparrow*	F	F	C	C
Lincoln's Sparrow			R	
Swamp Sparrow	F		F	F
White-throated Sparrow	U		F	U
White-crowned Sparrow	R		F	R
Dark-eyed Junco	U		F	U
Lapland Longspur			R	

Species	Sp	Su	F	W
Snow Bunting			R	R
Bobolink	U	U	F	
Red-winged Blackbird*	C	C	C	C
Eastern Meadowlark*	C	C	C	C
Boat-tailed Grackle*	C	C	C	F
Common Grackle	U	U	U	
Brown-headed Cowbird*	U	U	U	R
Orchard Oriole*	U	U		
Northern Oriole	U	U	F	
Purple Finch	R		R	U
House Finch	R	R	U	U
Pine Siskin			R	
American Goldfinch	R	R	U	U
Evening Grosbeak	R			R

Legend

C=Common
F=Fairly Common
U=Uncommon
R=Rare
*=Nesting documented or suspected

Seasons

Sp=Spring (March-May)
Su=Summer (June-August)
F=Fall (September-November)
W=Winter (December-February)

Shorebird Habitat Mapping on the Outer Banks of North Carolina: an attempt to evaluate changing habitats with aerial photography.

Chapter VIII

by

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Raleigh, NC 27695

Objective

At the request of Dr. Jaime Collazo and Dr. Ted Simons, a pilot project was undertaken to develop a geographical information system (GIS) containing historic shorebird habitat gain or loss on the outer banks of North Carolina.

Procedure

STEP 1: Determine what existing digital information was readily available from various state and federal agencies. Existing digital data was not available that met the study objective because of the spatial resolution of Landsat Thematic Mapper imagery ,28.5 meters, and the currentness of existing digital vector data ,12/12/82. Existing aerial photographs were available and chosen for the project.

STEP 2: Delineate land use and land cover types on black and white aerial photographs taken on January 24, 1945. The classification was based on the vegetation scheme outlined in "'Vegetation Mapping and GIS for the Cape Hatteras National Seashore.' Barrier Island Ecology of the Mid-Atlantic Coast: A Symposium. Technical Report NPS/SERCAHA/NRTR-93/04. December 1992."

STEP 3: Georeference the delineated photographs and transfer the information via a zoom transfer scope onto a digital basemap.

Results

Existing digital geospatial data were available from the North Carolina Center for Geographic Information and Analysis (NCCGIA). The Landsat Thematic Mapper imagery available covers the entire study area. However, the spatial resolution, 28.5 meters, and the date of the imagery, December 5, 1988, did not meet the specifications of the study objective. First, because of the spatial resolution, it is not possible to delineated specific land cover types in the classified imagery. Second, it was determined that the currentness of the data set, December 1988, was to recent to create a historic shorebird habitat gain or loss database.

A second alternative data set was available from the North Carolina State University, Computer Graphics Center (CGC). These data were based on aerial photographs taken December 12, 1982. Again, the date of the aerial photographs did not comply with the study objective, the data was determined to be too recent to provide a historical study. As a result, black and white aerial photographs taken January 24, 1945 were used to begin the development a GIS.

The photographs were obtained by Dr. Jaime Collazo. A portion centered around Ocracoke, NC was used as a test site. The photographs were delineated based on the chosen classification scheme. When the delineation was complete, 1:24000 topographic maps were obtained to georeference the delineated photographs via a zoom transfer scope. It was determined that there was insufficient data to georeference the photographs to the basemaps. This is because there were not enough static features present on the photographs and basemaps to ensure the entire study area was georeferenced. For example, the transfer was possible in areas around Ocracoke because of existing roads on the photographs and basemaps. However, in the areas away from Ocracoke, no roads were present on the photographs or the basemaps. For this reason, it was not possible to remove the distortion inherent in the aerial photographs. The procedure and results were verified by Dr. Hugh Devine and Dr. H.M. Cheshire of CGC. It was concluded that it was not possible to quantify the degree of historic change of selected shoreline habitats based on the 1945 aerial photographs and other available resources.

Recommendations

Because of the nature of aerial photographs, it is recommended that a database of shorebird habitat be developed based on existing digital geospatial data collected by the North Carolina State University Computer Graphic Center. This database should be used as a base to determine shorebird habitat gain or loss over time. Also, recent photography should be used because, usually, the quality is better than earlier photography, 1945 for example. It is also recommended that global positioning systems (GPS) be used to develop shorelines. This information could be used to develop basemaps if the area is GPSed at the same time the area is flown to take aerial photographs. The GPSed shore line could be used to georeference the photographs if static features, such as roads are not present.

Another possibility to assist in georeferencing aerial photographs of areas without static features is with the use of monuments. Monuments could be placed in areas void of static features and GPSed. It would be imperative that the monuments be visible on the aerial photographs. This would allow the distortion in the photographs to be removed and allow the photographs to be georeferenced. It is important to remember that the GPS data would need to be differentially corrected to reduce the inherent error inserted into the GPS signal by the Department of Defense.

ERDC TN-DOER-E25
October 2008

Coastal Inlets as Strategic Habitat for Shorebirds in the Southeastern United States

by Brian R. Harrington

PURPOSE: The purpose of this technical note is to bring together information from the International Shorebird Surveys (ISS) to demonstrate shorebirds' keystone-use of inlet habitats on marine coasts as compared to other coastal habitats in the southeastern United States including North Carolina, South Carolina, Georgia and Florida. Many inlets in the U.S. are affected by activities regulated by the U.S. Army Corps of Engineers (Corps). The goal of this Technical Note is to raise awareness of the importance of inlet habitats to coastal wildlife, including several species of shorebirds in the highest categories of conservation concern. This summary is largely based on an evaluation and presentations made at a workshop coordinated by American Bird Conservancy (ABC) working with the Corps of Engineers (Corps), held February 1-4, 2005 at Jekyll Island, Georgia (Guilfoyle et al. 2006; http://el.erdc.usace.army.mil/dots/coastalbirds.html). The ERDC and ABC hosted a series of three workshops dealing with coastal Corps activities and bird conservation. The Jekyll Island workshop covered the South Atlantic Coast, essentially from the Virginia-North Carolina border to south Florida. Subsequent workshops covered the North Atlantic and the Gulf Coasts. Workshop objectives were to expand capabilities of the Corps to contribute to various bird conservation plans, to make the bird conservation community aware of opportunities that exist through working with the Corps, to address and hopefully reduce some areas of conflict, and to improve interagency and organization cooperation for bird conservation in these coastal regions. This report, which provides guidance on how to create and manage dredged-material islands as early-successional bird habitat, supports the objectives and was funded from a research work unit under the Corps of Engineers Dredging Operations and Environmental Research (DOER) program titled, "Reducing conflicts between coastal engineering projects and bird habitat needs." (http://el.erdc.usace.army.mil/dots/coastalbirds.html).

Figure 1. Red Knots (*Calidris canutus*) and other birds at a coastal inlet in Georgia.

BACKGROUND: The Corps is responsible for managing and maintaining navigable coastal and inland waterways of the United States. Activities associated with the maintenance of waterways and shorelines in the coastal region include dredging, dredged material disposal operations, and beach nourishment. Coastal engineering projects can potentially create, enhance, degrade, or destroy foraging and nesting habitat at important coastal bird breeding, stopover, or wintering sites. Operations near sites important to birds should be carefully designed so as to reduce negative impacts as well as to protect and conserve existing foraging habitats or beach and upland nesting areas.

This technical note is part of a peer-reviewed series of focused publications that address two different areas where the Corps could better contribute to bird conservation: 1) enhancing the practice of dredged material disposal for the creation and maintenance of bird nesting islands, shorebird and waterbird foraging habitat, and wetland restoration projects that provide high quality bird habitat; and 2) designing and implementing coastal engineering projects that provide better nesting, foraging, and roosting habitats for shoreline-dependent birds. The Corps is working closely with American Bird Conservancy to improve communication with the bird conservation community to assist in the conservation of birds while simultaneously carrying out its various missions (Guilfoyle et al. 2006, 2007).

Sand spits, jetties, islets, tidal flats, shoals and sandbars often are associated with inlets, and are important habitats to a variety of coastal birdlife, including pelicans, cormorants, gulls, terns, and “shorebirds.” Shorebirds in the United States are roughly 50 species of sandpipers, plovers, and their allies. Some shorebirds breed on southeastern U.S. coasts and may spend migration or winter periods there as well, whereas others visit southeast coasts principally during nonbreeding seasons (migration and/or winter). Breeding areas for most species are in Arctic regions of Canada and Alaska. However, four species breed in coastal habitats of the Southeast, including Piping plover (*Charadrius melodius*), Snowy plover (*C. alexandrinus*), Wilson’s plover (*C. wilsonius*), and American Oystercatchers (*Haematopus palliatus*) (Hayman et al. 1986). Most of the shorebird species that occur in the southeastern United States visit during nonbreeding seasons, and coastal habitats along the Atlantic and Gulf Coasts of the Southeast are important wintering and migratory habitat for a majority of the shorebirds that breed in the United States (Withers 2002). This note focuses on the nonbreeding seasons, illustrating the importance of inlet habitats to many species of migratory shorebirds.

Inlet habitats in the southeastern United States frequently are affected by waterway and beach nourishment projects that are regulated and/or operated by the Corps. Associated Corps activities include channel dredging for maintenance and improvement of navigable waterways for boat traffic, and/or removing sand from intertidal or supratidal sandbars for use in beach nourishment projects. There is a potential for conflict between these important Corps activities and wildlife habitat needs. The main purpose of this publication is to illustrate the importance of inlet locations to shorebirds, and to describe those species that potentially would be most affected by Corps actions around inlets. The goal is to show that disproportionately high numbers of seven species of shorebirds use inlet habitats, and that six out of seven species are of high conservation priority, according to wildlife experts (Brown et al. 2001). Further research should be done to identify whether or not there are important conflicts through loss of key habitats, and if so, how to ameliorate for them.

METHODS: Ideally, numbers of shorebirds using inlet habitats would be determined in an unbiased survey of inlets and all other coastal habitats on a substantial portion of the U.S. coast. With the exception of one species, the American Oystercatcher (Brown et al. 2005), no such evaluation exists. However, a large database of shorebird counts – The International Shorebird Surveys (ISS) – is available. In the ISS, shorebirds have been counted following a standardized protocol at hundreds of U.S. coastal locations. The ISS is focused on migration seasons (Spring = 1 April through 10 June, and Fall = 10 July-31 October), asking volunteer cooperators to count all shorebirds at a specific site selected by the cooperator once every 10 days. For more information about the ISS, visit links through www.manomet.org or see Harrington et al. (1989).

Species names used in this note are those approved by the American Ornithologists' Union. For binomial names see http://www.aou.org/checklist/index.php3#char .

For this publication, all coastal ISS sites in the southeastern United States were evaluated (NC, SC, GA, and FL, N = 361 sites), characterizing each as being either 'inlet habitat' (N = 98) or 'not inlet' habitat (N = 234). Inlets were defined as locations where water bodies such as rivers, lagoons, or narrow mouths of bays were connected to ocean waters along a barrier beach shoreline; all other coastal sites were 'not inlet.'

For each location, the highest count for each of 22 shorebird species (listed in Table 1) that are common on southeast U.S. coasts were identified. Maxima were used for simplicity, keeping in mind that there are close correlative relationships between maximum, mean, and median counts in the ISS database.[1]

Variance among ISS counts is high both within and among sites. This is because (a) some sites have thousands of shorebirds, others have only dozens; (b) migration periods differ among species (e.g., in fall some species migrate in July, others not until September or October; (c) some sites are counted only in one season (spring or fall), others in both; (d) some sites are visited during only one year, others for multiple years; and (e) migration itself is characterized by brief spells of high counts and long spells of (generally) lower or zero counts. Due to the large and non-homogeneous variance of bird numbers counted at ISS sites, a non-parametric Wilcoxon Scores test was used (NPAR1WAY (SAS Institute, Inc. 2004)) to compare the occurrence of each of the 22 species at inlet versus non-inlet coastal habitats. Relative abundance of species at the 98 inlet sites was compared to the 234 non-inlet sites. Statistically significant differences were based on normal approximation values (two-tail) where the probability was less than 0.05.

RESULTS: Seven of the 22 shorebird species were found more often than expected ($P < 0.05$) at inlet locations versus non-inlet locations (Table 1). Six of these seven "inlet species" are either of High Conservation Concern or Imperiled according to the United States Conservation Plan (Table 1). Only one of the 22 shorebird species, the Sanderling (*Calidris alba*), was found significantly more often at non-inlet than inlet locations (Table 1).

[1] Unpublished data, Brian Harrington, Senior Scientist, Shorebird Research and Conservation Program, Manomet Center for Conservation Sciences, Manomet, MA.

Table 1. Relative occurrence of 22 shorebird species at 'inlet' and 'non-inlet' coastal locations in the southeastern United States. Species shown in bold were present in significantly higher numbers at inlets than at other coastal sites with the exception of one (italicized) whose numbers were higher at non-inlet locations.

Species	% of inlet sites[1] with species present	% non-inlet sites[1] with spp. present	Inlets					Not inlets					P^3	Conservation Priority[4]
			Max[2]	Med[2]	Mean	Min[2]	IQR[2]	Max	Med	Mean	Min	IQR[2]		
American Avocet	9	6	84	0.0	1.0	0	0	1050	0.0	7.2	0	0	0.3480	3
Am. Oystercatcher	38	31	250	0.0	13.2	0	2	350	0.0	6.3	0	4	0.1127	4
Black-bellied Plover	**87**	**79**	**500**	**10.0**	**46.6**	**0**	**40**	**3000**	**5.5**	**45.0**	**0**	**26**	**0.0030**	**3**
Dunlin	65	60	4700	10.5	248.5	0	150	5500	7.0	156.2	0	100	0.2000	3
Greater Yellowlegs	31	29	35	0.0	1.5	0	1	250	0.0	4.4	0	1	0.9214	3
Long-billed Dowitcher	10	9	20	0.0	0.7	0	0	325	0.0	4.7	0	0	0.8919	2
Least Sandpiper	39	34	1050	0.0	25.5	0	10	4580	0.0	43.7	0	4	0.3934	3
Lesser Yellowlegs	19	24	150	0.0	2.9	0	0	1200	0.0	16.8	0	0	0.2820	3
Marbled Godwit	27	23	120	0.0	6.2	0	1	363	0.0	9.6	0	0	0.5562	4
Piping Plover	**44**	**24**	**110**	**0.0**	**6.5**	**0**	**5**	**235**	**0.0**	**4.0**	**0**	**0**	**0.0004**	**5**
Red Knot	**42**	**32**	**10000**	**0.0**	**373.8**	**0**	**118**	**6500**	**0.0**	**126.2**	**0**	**7**	**0.0364**	**5**
Ruddy Turnstone	**79**	**65**	**3736**	**10.5**	**64.9**	**0**	**28**	**800**	**4.0**	**26.8**	**0**	**25**	**0.0091**	**4**
Sanderling	***92***	***71***	***1500***	***40.0***	***137.9***	***0***	***132***	***6150***	***12.0***	***181.3***	***0***	***68***	***<.0001***	***4***
Short-billed Dowitcher	55	47	6000	7.0	186.0	0	69	1370	0.0	66.9	0	50	0.1241	4
Semipalmated Plover	60	58	1653	6.0	68.3	0	59	1000	3.0	45.7	0	25	0.1961	2
Semipalmated Sandpiper	30	22	660	0.0	28.8	0	5	1500	0.0	29.5	0	0	0.1469	3
Snowy Plover	**26**	**15**	**105**	**0.0**	**2.7**	**0**	**1**	**70**	**0.0**	**2.0**	**0**	**0**	**0.0383**	**5**
Spotted Sandpiper	26	28	30	0.0	1.3	0	1	120	0.0	2.3	0	1	0.7921	2
Western Sandpiper	**62**	**45**	**9430**	**5.0**	**211.8**	**0**	**63**	**3000**	**0.0**	**104.3**	**0**	**17**	**0.0041**	**4**
Whimbrel	26	22	125	0.0	5.2	0	1	150	0.0	3.9	0	0	0.4827	4
Willet	87	76	1003	7.5	56.5	0	44	2550	6.0	70.9	0	49	0.5204	3
Wilson's Plover	**44**	**26**	**185**	**0.0**	**13.7**	**0**	**10**	**200**	**0.0**	**6.6**	**0**	**1**	**0.0004**	**4**

1 Based on maximum counts made at 98 inlets and 234 'non-inlets.
2 Max = maximum count, Med = median count, Min = minimum count, IQR = interquartile range.
3 Normal approximation values based on two-tail Wilcoxon Scores, NPAR1WAY, SAS Institute, 1989.
4 5 = Highly Imperiled, 4 = Species of High Concern, 3 = Moderate Concern, 2 = Low Concern (U.S. Shorebird Conservation Plan).

DISCUSSION: Shorebird activities in coastal habitats are substantially influenced by tide levels; during lower tides shorebirds tend to be foraging, while at higher tides they tend to be resting (Ruiz et al. 1989). For many kinds of shorebirds the supra-tidal sandy habitats of inlets provide important areas for resting (Ruiz et al. 1989), especially at higher tides when intertidal habitats are inundated. At lower tides, some of these inlet-loving species prefer foraging on invertebrates characteristic of sandy, intertidal habitats such as sandbars or barrier beaches, which often are present at inlets. Other species may travel short distances from inlet resting sites to intertidal habitats landward of the inlets where intertidal habitats typically are muddier.[1] In this publication, shorebird numbers were simply assessed at inlets and other coastal habitats without regard to whether the birds were foraging or resting.

Implications: The results reported here suggest that the Corps should minimize any potential impacts to inlet habitats during inlet-related projects in southeastern U.S. coastal locations because of the potential negative impacts on inlet-dependent birdlife. This study suggests that the occurrence and numbers of shorebirds using coastal habitats of the Southeast is skewed towards use of inlet habitats versus other coastal habitats, and that this is especially true in the case of seven species that rank high in national conservation priorities (Table 1). One of these seven species, the Piping Plover, is endangered in its Great Lakes population (*C. melodus circumcinctus*) (Goossen et al. 2002), the bulk of which spend the winter nonbreeding season on the U.S. southeastern coast (Goossen et al. 2002, Noel 2006). Another of the seven species, the Red Knot (*Calidris canutus*), was listed as a Candidate Species under the U.S. Endangered Species Act in 2006. Although alteration of bird habitats by the Corps during inlet-related projects was not a focus of this investigation, the potential effects (e.g., as illustrated in Figures 2 and 3) should be better understood. It should also be noted that 14 of the 22 species in this analysis showed no difference between inlet and non-inlet areas, suggesting that inlets are used equally by these species and therefore, may be very important habitats for them as well.

Sampling: Sites included in the ISS are selected for coverage by the volunteer cooperators doing the counting, and conceivably there could be a bias towards coverage of sites having higher versus lower numbers of shorebirds. However, it is difficult to imagine any bias that would cause inlets having higher numbers and/or occurrence of shorebirds to be selected relatively more often than non-inlet locations having higher numbers and/or occurrence of shorebirds. In short, the evidence indicates that inlet habitats are unusually important to at least seven species of coastal shorebirds in the Southeast. Based on personal observations by the author 'inlet-o-philia' is assuredly prevalent in other types of southeastern U.S. coastal birds, including various species of gulls, terns, cormorants, and Brown Pelicans.

ACKNOWLEDGEMENTS: Data evaluated for this report were all collected between 1974 and 2001 by hundreds of volunteers working with the International Shorebird Surveys (ISS) and the author extends thanks to all of these volunteers. Through the years, partial financial support of the ISS has been provided by the U.S. Fish and Wildlife Service, the U.S. Geological Survey, The Nancy Hardon Hand Fund, the Manomet Center for Conservation Sciences and others. Report reviews were provided by Mr. Casey Lott (American Bird Conservancy); Dr. Jim Fraser (Virginia Polytechnic Institute); and Drs. Richard A. Fischer and Michael P. Guilfoyle of the Environmental Laboratory, ERDC. The author also thanks Stephen Brown at Manomet for statistical and other advice.

Figure 2. An inlet showing intertidal ebb and flow sandbars, extensive development of sandspits, sandflats attached to barrier islands, and muddier tidal flats on the sheltered (inland) side of the barrier beach. Photo by Walker Golder, National Audubon Society.

Figure 3. Stabilized inlet, where jetties impede sand flow parallel to the barrier beach, reducing potential for formation of ebb and flow sandbars and sandspits. Photo by Walker Golder, National Audubon Society.

POINTS OF CONTACT: For additional information, contact Brian Harrington (508-224-6521, bharr@manomet.org), Manomet Center for Conservation Sciences, Manomet, MA 02345 U.S.A., or the manager of the Dredging Operations and Engineering Research (DOER) Program, Dr. Todd Bridges (601-634-3624, Todd.S.Bridges@usace.army.mil). This technical note should be cited as follows:

> Harrington, B. R. 2008. *Coastal inlets as strategic habitat for shorebirds in the southeastern United States*. DOER Technical Notes Collection. ERDC TN-DOER-E25. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/dots/doer/.

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Useful web sites

http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05feb-dots
PowerPoint presentations from the joint Corps/American Bird Conservancy February 2005 meeting on Jekyll Island entitled, "The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast - and - A Symposium on the Wintering Ecology and Conservation of Piping Plovers"

http://www.abcbirds.org
The American Bird Conservancy

http://www.manomet.org/
Manomet Center for Conservation Sciences (home of the International Shorebird Surveys).

SUBCOMMITTEE DOCUMENT

DRAFT

NEGOTIATED RULEMAKING COMMITTEE
12th Regulatory Negotiation Meeting
February 3, 2009

NOTES – ROUTES AND AREAS AERIAL PHOTOGRAPHY MAPS

The attached maps should be read while referring to (1) the document entitled Key Issues and Options Identified For Routes And Areas By Joint Subcommittees (February 2, 2009) distributed at the Committee meeting, and (2) documents distributed by the respective groups listed below.

The following Committee members and organizations assisted with the development of the lines on the maps as identified below:

LINE #1:

American Sports Fishing Association (Bob Eakes)
Avon Property Owners Association (Frank Folb)
Cape Hatteras Anglers Club (Larry Hardham)
Commercial Fishing (Michael Peele)
Dare County (Warren Judge)
Hyde County (David Scott Esham)
North Carolina Beach Buggy Association (Jim Keene)
OBPA (John Alley)
Outer Banks Chamber of Commerce (Scott Leggat)
Recreational Fishing Alliance (Patrick Paquette)
Rodanthe-Waves-Salvo Civic Association (C.A. Duke)
United Four Wheel Drive Association (Carla Boucher)
Water Sports Industry (Trip Foreman)

LINE #2

Cape Hatteras Recreational Alliance (Jim Lyons)

LINE #3

Audubon, North Carolina State Office (Walker Golder)
Defenders of Wildlife (Jason Rylander)
NRDC (Destry Jarvis)
Southern Environmental Law Center (Derb Carter)
The Wilderness Society (Destry Jarvis)

The designation VC-A and VC-B illustrate two proposals discussed at the January 6-7, 2009 Committee meeting for when the areas in front of the villages would be open to ORVs. The Committee did not reach consensus on the approach to the Villages.

0076797

SUBCOMMITTEE DOCUMENT

PEA ISLAND
MARCH 2007
PAGE 2

PEA ISLAND
MARCH 2007

PAGE 3

RODANTHE, WAVES, SALVO
MARCH 2007

SUBCOMMITTEE DOCUMENT

0076801

SOUTH OF SALVO
MARCH 2007

SUBCOMMITTEE DOCUMENT

CAPE POINT
MARCH 2007

BUXTON AND FRISCO
MARCH 2007

HATTERAS
MARCH 2007

SUBCOMMITTEE DOCUMENT

SUBCOMMITTEE DOCUMENT

0076807

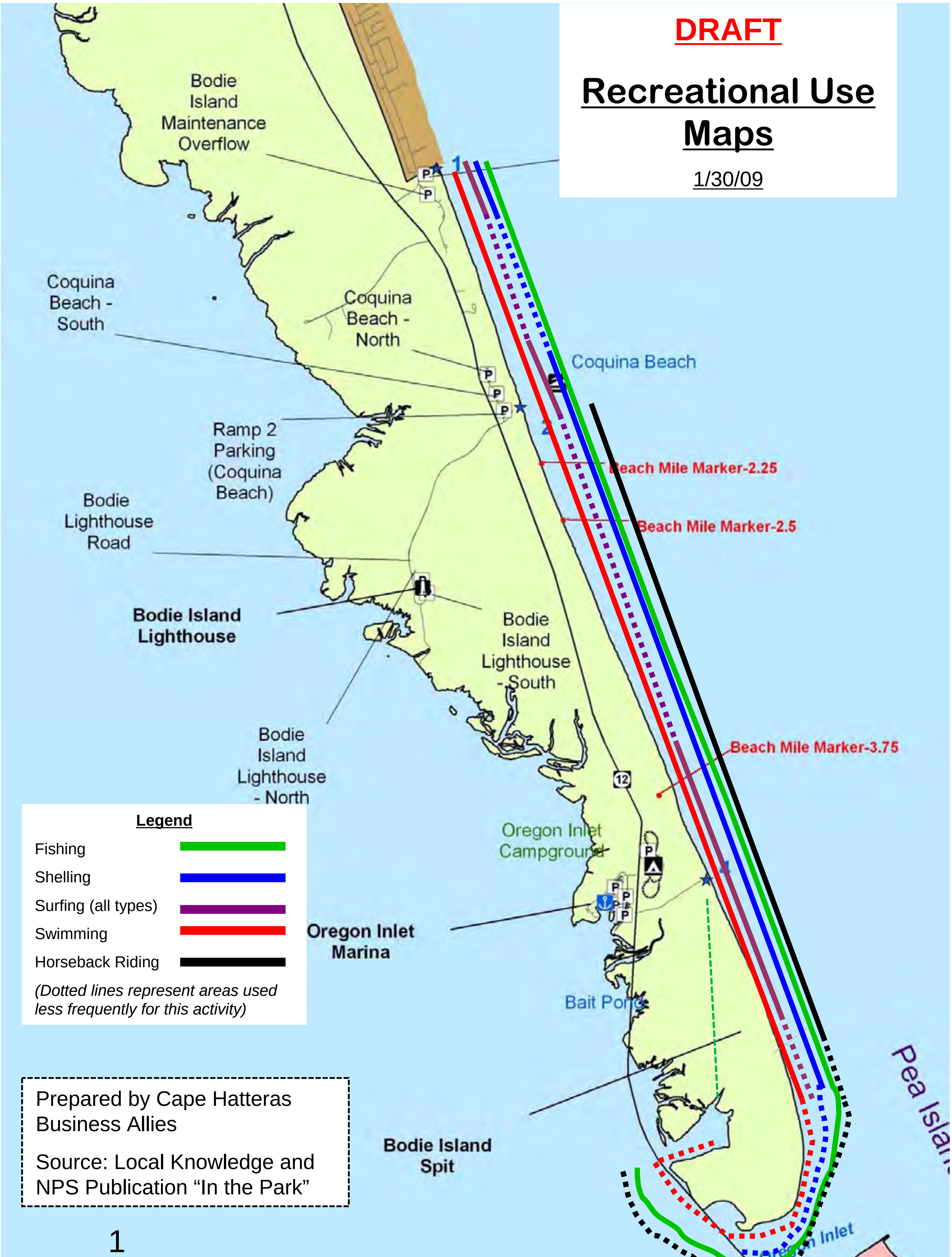
SOUTH OCRACOKE

0076809

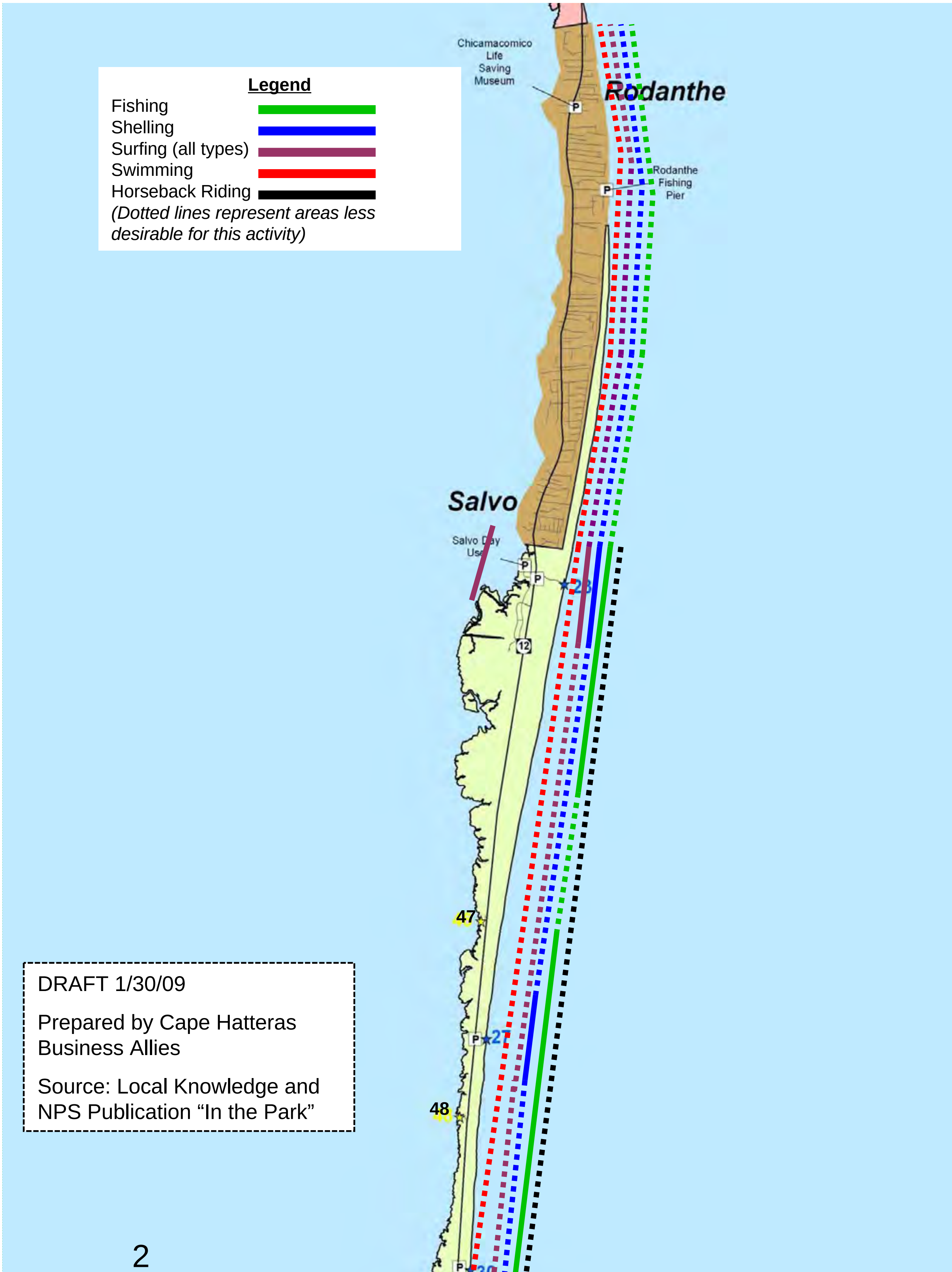
DRAFT

Recreational Use Maps

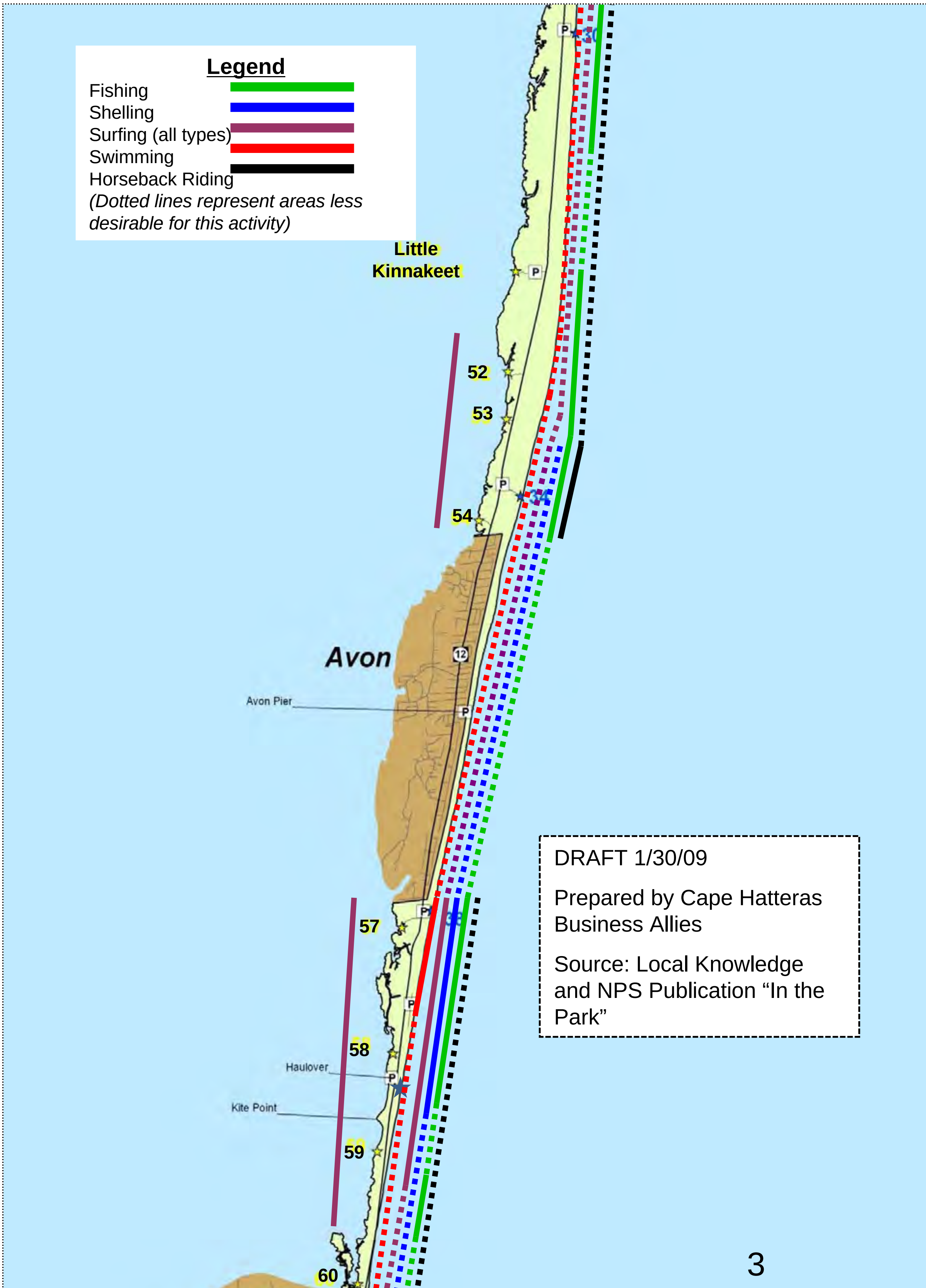
1/30/09



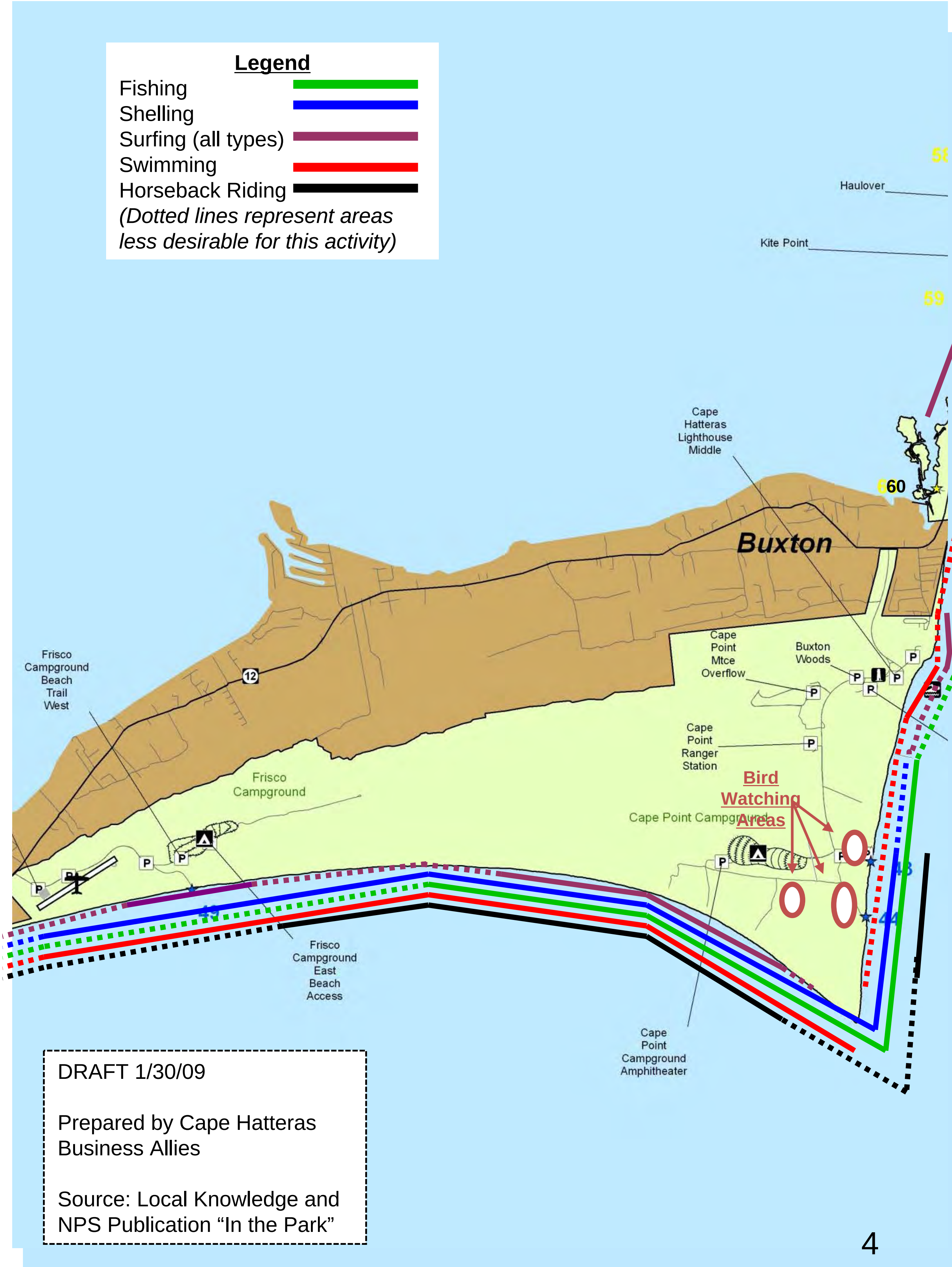
0076810


Legend
Fishing
Shelling
Surfing (all types)
Swimming
Horseback Riding
(Dotted lines represent areas less desirable for this activity)
Chicamacomico Life Saving Museum
Rodanthe
Rodanthe Fishing Pier
Salvo
12
23
47
27
48
30
DRAFT 1/30/09
Prepared by Cape Hatteras Business Allies
Source: Local Knowledge and NPS Publication "In the Park"

0076811



Legend
Fishing
Shelling
Surfing (all types)
Swimming
Horseback Riding
(Dotted lines represent areas less desirable for this activity)
Little Kinnakeet
52
53
54
Avon
12
Avon Pier
57
58
Haulover
Kite Point
59
60
DRAFT 1/30/09
Prepared by Cape Hatteras Business Allies
Source: Local Knowledge and NPS Publication "In the Park"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Cape Hatteras Lighthouse Middle
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Buxton
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Frisco Campground Beach Trail West
Cape Point Mtce Overflow
Buxton Woods
Cape Point Ranger Station
Bird Watching Areas
Frisco Campground
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49
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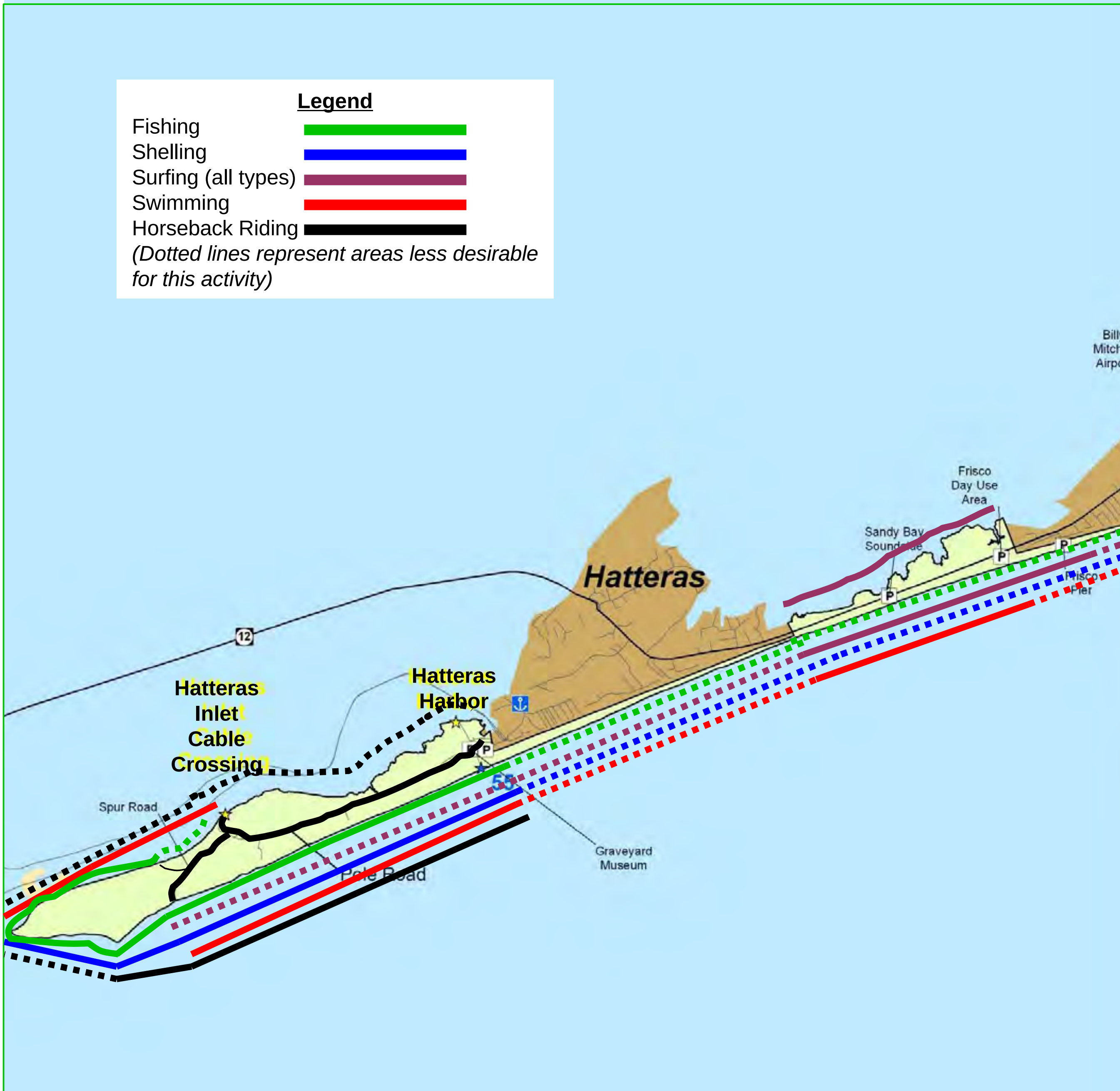

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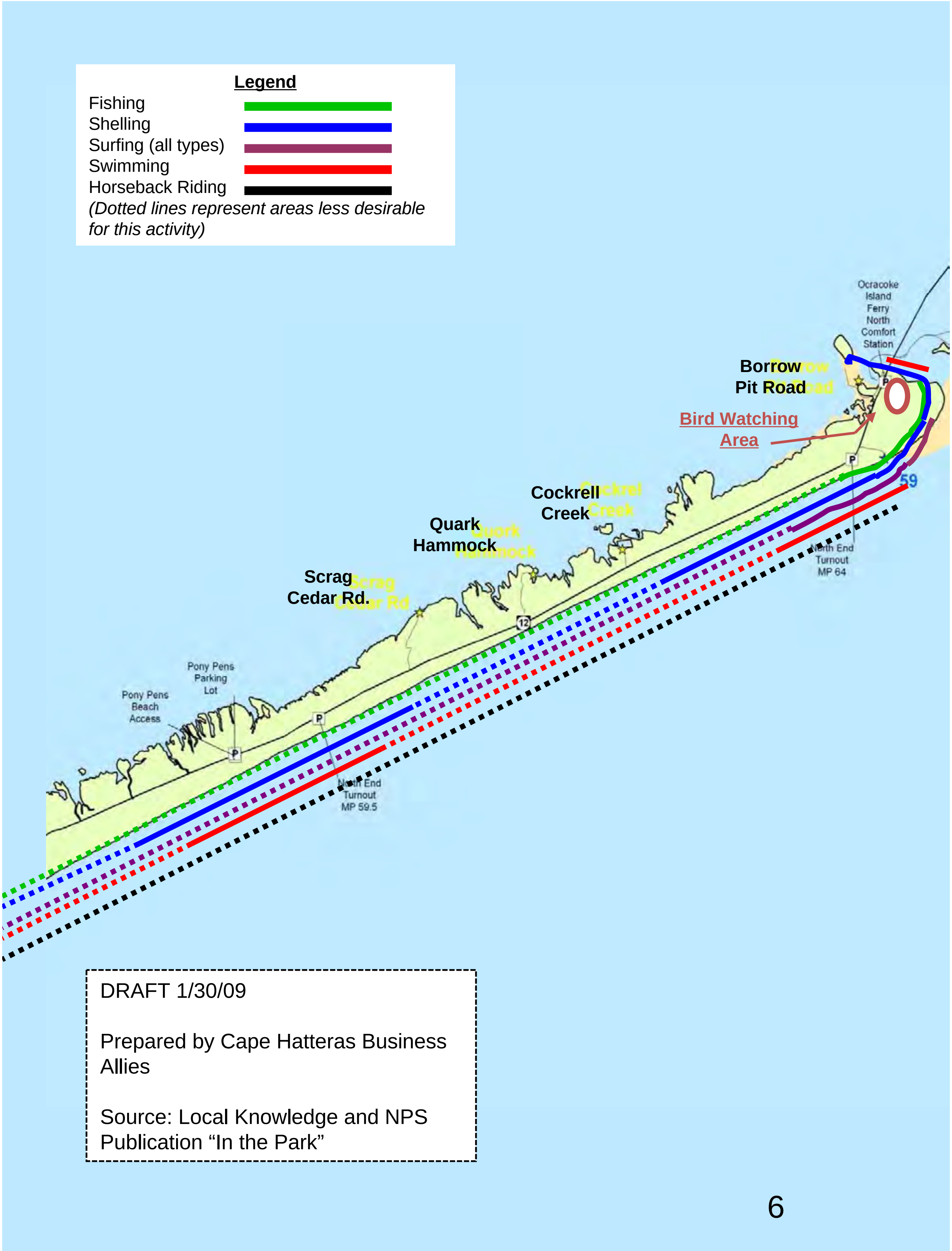

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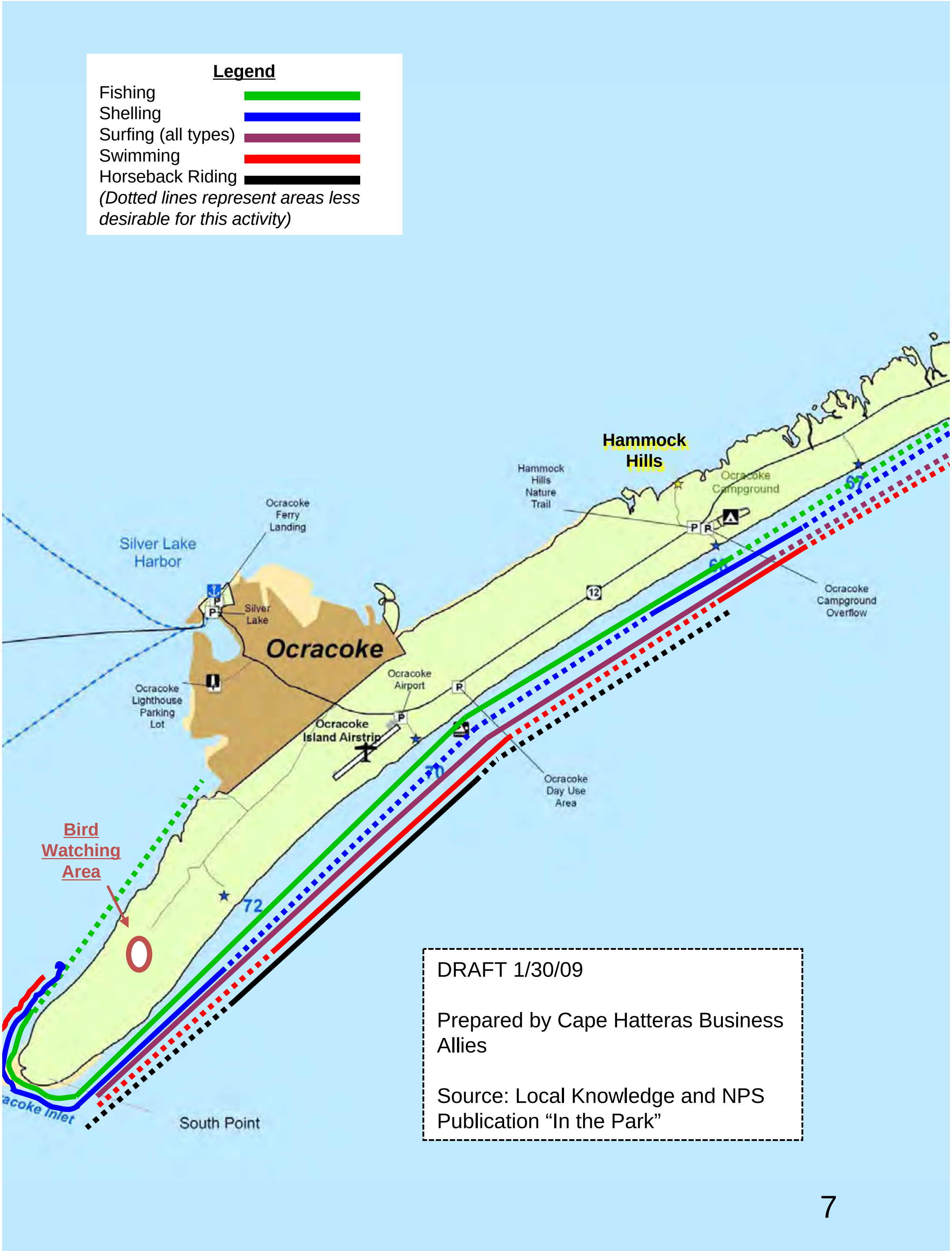
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(Dotted lines represent areas less desirable for this activity)
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Ocracoke Ferry Landing
Silver Lake Harbor
Silver Lake
Ocracoke
Ocracoke Campground Overflow
Ocracoke Airport
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ABSTRACT

TARR, NATHAN MOLONEY. Fall Migration and Vehicle Disturbance of Shorebirds at South Core Banks, North Carolina. (Under the direction of committee chair Theodore R. Simons).

Anthropogenic disturbance has been implicated as a factor related to declines in shorebird populations because shorebirds depend upon coastal stopover sites where human recreation is concentrated for resting and refueling between long, energetically-expensive migration flights. We examined the use of South Core Banks, a barrier island on North Carolina's Outer Banks, by migrating shorebirds and recreationists during fall and measured the effects of vehicle disturbance on shorebird behavior and habitat use. To describe spatial, temporal, and tidal patterns in shorebird and vehicle abundance, we performed weekly surveys of birds and vehicles from all-terrain vehicles, recording the species, numbers, and microhabitat locations (i.e. surf, swash zone, dry sand, and wet sand) of all individuals within half-mile ocean beach segments. We summarized survey data by week, tide, beach section, and daylight hour in order to identify patterns in abundance. Shorebird densities on South Core Banks were similar to those reported for other sites on the Outer Banks, and their numbers decreased slightly throughout the season, but peaked several times. Gull and vehicle numbers increased throughout the fall while tern numbers decreased. As a group, shorebirds were more or less evenly distributed along the southeast facing beach, but individual shorebird species showed unique spatial patterns in abundance. Several species, including Sanderlings (*Calidris alba*), Black-bellied Plovers (*Pluvialis squatarola*), Semipalmated Plovers (*Charadrius semipalmatus*), Red Knots (*Calidris canutus*), and Ruddy Turnstones (*Arenaria interpres*), were more abundant on the ocean beach during high tide than during low tide. They used a sand spit and a portion of the ocean beach on the southern half of the island as roosting sites at high tide. Shorebirds were abundant in areas where vehicle abundance was also relatively

high, but their distribution among microhabitats was opposite that of vehicles; vehicles were primarily located on dry sand while shorebirds were typically found in the swash zone and wet sand microhabitats.

Many environmental, habitat, and biological factors influence the distributions of nonbreeding shorebird, and they are often confounded. To examine whether or not vehicle disturbance is one of these factors, we employed a before-after-control-impact (BACI) experimental study design that isolated disturbance effects from spatial or temporal differences among sites. We manipulated disturbance levels within beach closures using paired control and impact plots and measured bird abundance and Sanderling behavior during before and after periods on both control and impact plots. Control plots were closed to vehicles during both the before and after periods. Treatment plots were closed to vehicles during the before period but subjected to a fixed level of vehicle disturbance during the after period. Differences in shorebird abundance and behavior between paired control and treatment plots provided an estimate of vehicle disturbance effects. We found that disturbance has a negative effect on site use by shorebirds, all birds, and Black-bellied Plovers. The two most abundant species of shorebird at our study sites, Sanderlings and Willets (*Catoptrophorus semipalmatus*), did not show a significant decrease in abundance in response to disturbance, but disturbance influenced Sanderling activity by decreasing the proportion of time that they spent roosting and increasing the proportion of time that they spent active. Microhabitat use shifted towards the swash zone when disturbance was introduced. We conclude that vehicle disturbance influences shorebirds' use of ocean beach habitat for roosting during the nonbreeding season and that experimental BACI study designs provide a practical tool for measuring the effects of disturbance on wildlife without the confounding that affects purely observational approaches.

Fall Migration and Vehicle Disturbance of Shorebirds at South Core Banks, North Carolina.

by
Nathan Moloney Tarr

A thesis submitted to the Graduate Faculty of
North Carolina State University
In partial fulfillment of the
Requirements for the degree of
Master of Science

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APPROVED BY:

Kenneth H. Pollock

Jaime A. Collazo

Theodore R. Simons
Committee Chair

DEDICATION

To Krystal Black for her love, support, and patience, and to my great grandparents, T.J. and Betty Beck. Though I never met them, their appreciation for wildlife has permeated generations and provided me happiness.

BIOGRAPHY

I was raised in Charlotte, NC, where I enjoyed spending time outside and developed a fondness for animals. While an undergraduate at Guilford College, I became increasingly interested in environmental issues and North Carolina's flora and fauna. Soon after graduating, I decided to pursue a career that combined my appreciation for birds and my desire to promote wildlife conservation. I alternated between working in natural foods stores and on research projects through North Carolina State University until I was accepted as a graduate student in the USGS North Carolina Cooperative Fish and Wildlife Research Unit.

ACKNOWLEDGMENTS

Many people have helped me get to this point. Without their generosity and support, I wouldn't be doing something that I enjoy so much. My wife, Krystal Black, has been supportive during hard times, picked up my slack, and paid the bills. My mother and father, Brian and Kathleen, have given me encouragement and positive thoughts. My grandparents, Stan, Elsa, and Norman, have been endlessly enthusiastic about my endeavors.

I would like to thank my advisor, Ted Simons, for giving me the opportunity to work on this project. He has been encouraging and patient and provided excellent guidance. I appreciate the freedom and independence he gave me. My graduate committee members have also been very helpful. Ken Pollock provided statistical wisdom and general enthusiasm for my project, and Jaime Collazo provided invaluable shorebird expertise and advice.

I am indebted to Jeff Cordes for helping me get my shorebird identification skills up to par, establishing almost any beach closures that I requested, and being all-around dependable. Michael Rikard and Jon Altman offered support and cooperation and, in general, looked out for the well being of me and my field assistants. I thank Rebecca Ryan Hamilton, Adam Efird, Morgan Gilmour, Nikki Flood, and Scott Stollery for their hard work, long hours, tolerance of harsh conditions, and for the hundreds of miles of ATV driving and bird surveying they did. The law enforcement division and other staff at Cape Lookout were very cooperative and willing to enforce beach closures. Funding for this research was provided by the NPS and the USGS through an NRPP grant.

I thank my fellow graduate students and the coop unit's post docs; Jerome Brewster, Shiloh Schulte, Krishna Pacifica, Matt Alldredge, Ed Laurent, Arielle Waldstein, Becky Keller, Kelsey Obenernuefemann, Jason Riddle, Ashton Drew, Corey Shake, and Mike Holliman. They provided a supportive and helpful community, much needed explanations of basic biological and statistical matters, and tolerated my complaining. I especially thank Jerome for showing me the ropes early on and Ed for helping me get my data in a manageable format. I also thank Wendy Moore, Meredith Henry, and Susan Marschalk for giving the kind of administrative support that made everything as easy as possible.

Many people provided me with opportunities that opened the doors to graduate school. Lynn Moseley sparked my interest in birds while I was an undergraduate at Guilford College. She arranged my first research-related jobs, and without her support and encouragement over the years, I wouldn’t have made it to graduate school. I am extremely thankful that I crossed her path and that she took me under her wing. Moni Bates, Jamie Mason, Salina Kovac Kohut, Chris Moorman, George Hess, Jerome Brewster, Bob Mulvihill, and Bob Leberman gave me valuable opportunities to work in the field, and Sarah Mabey was very helpful during the final steps to getting into graduate school.

Finally, I would like to acknowledge all the birds that we disturbed in this study.

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CHAPTER 1

Shorebirds and Anthropogenic Disturbance

Anthropogenic disturbance is a category of human activities, either intentional or unintentional, that elicit responses by wildlife (Morton 1996, Walker et al. 2005). It can also be thought of as the combination of a stimulus and response, where stimuli include a variety of activities such as nature watching, photography, hiking, and off-road vehicle (ORV) driving (Knight and Cole 1991). Wildlife responses can include changes in behavior, physiology, distribution, or reproduction, and they are influenced by the type, timing, location, frequency, and predictability of human activities (Knight and Cole 1991). Human disturbance of wildlife is a topic that has received considerable attention during the last half century as human recreation levels have increased in parks and refuges, and wildlife managers and conservationists have sought to understand its effects (Cole and Knight 1991, Hill et al. 1997).

Wildlife managers seek to understand disturbance so that they can balance the costs of human disturbance to wildlife with the benefits that recreation provides in educating the public, generating support for conservation, and increasing awareness of conservation issues (Cole and Knight 1991, Gill 2007, Sutherland 2007). By identifying the causes and effects of disturbance, managers can focus their efforts and resources on activities that are the most detrimental and maintain activities that contribute to both human recreation and conservation (Gutzwiller 1991). In this chapter, we provide an overview of sources and effects of disturbance, wildlife responses, and the methods used to study shorebird disturbance.

The severity, type, and frequency of disturbance can directly influence a species' response (Knight and Cole 1991, McGowan and Simons 2006, Taylor et al. 2007), but other factors, such as species-specific tolerances, temporal differences, flocking, pre-disturbance behavior, landscape, and intraspecific differences, such as age, can act indirectly (Knight and Cole 1991, Morton 1996).

Responses to disturbance are often classified as behavioral, distributional, physiological, or reproductive. Behavioral responses include specific behaviors, such as fleeing, or changes in the frequency of a specific behavior and they can be viewed as reflecting a tradeoff between perceived risk and the opportunity cost of responding (Stillman and Goss-Custard 2002, Pomeroy 2006). Short-term behavioral responses could turn into long-term effects on individuals. These effects include; decreased productivity, reductions in physical condition and survival, changes in habitat use, and subsequent changes in feeding ecology (Knight and Cole 1991). The cost of a behavioral response is influenced by the timing, frequency, and type of stimuli (Cole and Knight 1991, Burger 1995), but it is also influenced by the individual's nutritional condition, the availability of resources, and other factors (Gill et al. 2001a, Stillman and Goss-Custard 2002, Beale and Monaghan 2004, Stillman et al. 2007). This complexity makes behavioral responses difficult to interpret (Gill et al. 2001b).

Disturbance can cause birds to alter their use of habitats (distributional responses). Distributional responses can be spatial (Pfister et al. 1992) or temporal (Burger and Gochfeld 1991b). Either way, they result in changes in a habitat's functional availability, quality, or carrying capacity for a species (Morton 1996, Hill et al. 1997). As with behavioral responses, it is often difficult to interpret the costs of distributional responses on populations (Gill et al. 2001b).

Physiological responses can occur even when behavioral responses are not apparent (Morton 1996, Bouton et al. 2005, Walker et al. 2005). They include changes in metabolism and heart rate, thermal relationships, nutrition, endocrine and immune system responses. Physiological responses are presumably more directly tied to the survival and fecundity of individuals than behavioral responses, and they are, therefore, likely to serve as better measures of disturbance consequences. Physiological responses are difficult to measure in the field because it is difficult to obtain the baseline information required for comparisons and to understand the mechanisms by which responses are connected to demographic rates (Chabot 1991, Wikelski and Cooke 2006).

Reproductive responses include nest abandonment, reduced egg laying, reduced hatching success, lower energy acquisition in young, and chick mortality (Tremblay and Ellison 1979, Piatt et al. 1990, Knight and Cole 1991, Lafferty et al. 2006). These responses are sometimes the direct result of behavioral responses by parents or young (Lafferty et al. 2006, McGowan and Simons 2006). They are directly connected to population size.

The ultimate goal of disturbance research is often to identify population level effects to improve the management of human-wildlife interactions. A variety of research approaches have been used to understand disturbance effects (Hill et al. 1997, Gill 2007). Morton (1996) identified seven approaches to studying disturbance: flush response, behavioral and energetic changes measured in the field with time budgets, distribution and displacement studies using observations or telemetry, physiological responses (i.e. heart rate) measured in the field and laboratory, simulation models that investigate population level effects, inferences from studies involving unintentional disturbance (i.e. researcher visits to nests), and inferences from studies with intentional disturbance treatments. Gill (2007) identified three approaches used in studies of disturbance effects on patterns of resource use: site-based, demographic, and population level perspectives. These three approaches focus on changes in site use, changes in fecundity or survival, and density-dependent processes that occur due to shifts in habitat use.

Most disturbance research is based on observational field studies that identify correlations between disturbance and one of the responses discussed above. Experimental studies provide more useful information because they can identify cause and effect relationships and because in observational studies disturbance is often confounded with other factors (Gutzwiller 1991). Gutzwiller (1991) identified several important biological issues that make disturbance studies difficult. First, the effect of disturbance may not be evident immediately. If the response occurs later in a species life cycle, then longer studies are needed to accurately assess an impact (Gutzwiller 1991, Walker et al. 2005). Second, it is important to identify the levels of disturbance that exceed an animal's tolerance (Morton 1996). Tolerance is the level of activity that an individual is willing to withstand without responding (Walker et al. 2005). Third, habituation may occur at different levels (location, timing, spatial scale, frequency, periodicity, and duration) of disturbance. Experiments should, therefore, include treatments of various levels (Gutzwiller 1991, Knight and Cole 1991). Predictable, benign activities may eventually fail to elicit a behavioral response even if they occur at high levels (Gutzwiller 1991, Knight and Cole 1991). Fourth, it is important to consider the spatial scale of disturbance. Disturbance could have negative effects on a species when it encompasses entire home ranges, territories, or other areas exclusively used for a behavior or resource. Therefore, the size of experimental units would, ideally, match the size of areas used for response activities (Gutzwiller 1991). Fifth, subtle characteristics of disturbance may have the capacity to influence the disturbance response, thus increasing the variability of the response and decreasing the statistical power of the experiment. Adhering to a strict, consistent protocol and randomizing observers and other aspects of the study that may increase variability can help avoid bias due to subtle stimuli (Gutzwiller 1991). Sixth, predators could be influenced by disturbance resulting in lower predation rates in disturbed areas. More research is needed to understand the interaction between predation and disturbance (Sutherland 2007), but predation can influence habitat use and foraging behavior in shorebirds (Pomeroy 2006). Seventh, attempting to simultaneously study both the process and pattern of disturbance may compromise the interpretability of study results (Gutzwiller 1991). For example, capturing and banding birds to find out how their use of a site is affected by disturbance would preclude the ability to simultaneously and accurately measure disturbance effects on the overall abundance of the species at that site. Eighth, past events and local and regional processes may influence current experiments (Gutzwiller 1991). It is possible for disturbance effects to carryover into study sites from nearby or recent disturbances, and responses to disturbance at experimental units are partly shaped by processes, such as predation or density dependence, that can manifest at a larger scale.

Gutzwiller (1991) also identified some important statistical challenges to disturbance studies. One challenge is that experimental units in field studies often vary due to different habitat characteristics and environmental factors can cause variability in the response. For example, McGowan et al. (2002) found that the response of wintering Red Knots to disturbance increased with wind speed and temperature. The use of covariates is one approach to isolating treatment effects, and randomization can sometimes decrease the need for using covariates (Gutzwiller 1991).

Despite the biological and statistical challenges involved in disturbance research, several studies have found evidence of disturbance effects on birds. Thomas et al. (2003) found that increased human presence caused migrating Sanderlings to spend less time foraging. Burger (1991) obtained similar results for wintering Sanderlings, noting an inverse relationship between daytime disturbance and time spent foraging at night (Burger and Gochfeld 1991a).

Disturbance can influence distributional patterns in bird abundance and habitat use. Morton (1996) analyzed biweekly counts of bird and human activities on the ocean beach at Assateague Island National Seashore during the winter and found that disturbance was negatively correlated with Sanderling abundance. Sanderlings were less abundant on weekends on the south end of the island where vehicles were allowed. Pfister et al. (1992) found that human disturbance on front beaches caused migrating Sanderlings and Black-bellied Plovers to shift their activity to back-beach habitats. Wintering Snowy Plovers (*Charadrius alexandrinus*) at Devereux Slough in Santa Barbara, California avoided trail heads where humans and dogs were abundant (Lafferty 2001). Klein et al. (1995) found that some migrant waders were more likely to avoid roads as traffic increased. Wintering Black-tailed Godwits (*Limosa limosa*) changed the timing of their use of feeding sites in response to disturbance, but the ability of the habitat to support godwits was not affected by disturbance (Gill et al. 2001a). When a pedestrian trail that introduced disturbance to Finney et al.'s (2005) study area was redesigned to constrain human activity, Golden Plovers (*Pluvialis apricaria*) spent their time closer to the trail.

Disturbance can have physiological effects such as elevated energy expenditure, elevated hormone levels, and other responses. Fleeing responses in wildlife are known to increase heart rate, cardiac output, and blood sugar (Gabrielsen and Smith 1995). Breeding Chinstrap penguins (*Pygoscelis antarcticus*) in Antarctica that were captured and handled for 30 seconds showed an increase in stomach temperature of 2°C that lasted for two to three hours and was accompanied by an increase in energy expenditure (Gabrielsen and Smith 1995). Magellanic penguin (*Spheniscus magellicanicus)* nestlings in Argentina that were exposed to ecotourism had elevated corticosterone levels while the adults did not. Elevated corticosterone levels early in life can have significant negative effects on an individual when it is older (Walker et al. 2005).

Disturbance can negatively influence breeding productivity in several ways. It can deter birds from establishing or maintaining nests. Tremblay and Ellison (1979) compared reproductive success in nesting colonies of Black-crowned Night Herons (*Nycticorax nycticorax*) subjected to various frequencies of researcher visits and found that colonies with elevated visitation levels had lower reproductive success due to less egg laying and increased nest abandonment. Lafferty et al. (2006) documented that once a section of beach was closed to pedestrians, Snowy Plovers began to use it as a nesting site. Least Auklets (*Aethia pusilla*) in lower disturbance sites had a higher hatching success, and Crested Auklets (*Aethia cristatella*) in high disturbance areas abandoned nests (Piatt et al. 1990). Pierce and Simons (1986) compared reproductive success in Tufted Puffin (*Fratercula cirrhata*) breeding colonies with low, moderate, and heavy investigator disturbance rates, and found higher rates of nest abandonment, longer incubation periods, and decreased chick growth and survival in heavily disturbed areas. Chicks from disturbed nests were lighter and had shorter wings at fledging than chicks from undisturbed nests. Bouton et al. (2005) found that Wood Storks (*Mycteria Americana*) nesting in an area with boat disturbance fledged fewer young than storks in an area without disturbance due to lower hatching success and chick survival. Ruhlen et al. (2003) found that Snowy Plover chick loss was three times greater on weekends and holidays than on weekdays. Although their study design didn't address the cause of chick death, they suggested that disturbance may cause a shift in parental behavior that leads to less care of chicks and subsequent mortality. McGowan and Simons (2006) tested the hypothesis that disturbance increased American Oystercatcher (*Haematopus palliatus*) parental activity during incubation and found that disturbance was correlated with a high rates of adult movement to and from nest during incubation. Nests with a higher number of parental trips had a lower probability of daily nest survival.

Despite the extensive body of research aimed at understanding the consequences of anthropogenic disturbance, there are still many unanswered questions. Gaps in knowledge involve difficulties in identifying and measuring the correct responses to disturbance in order to assess population level consequences, and measuring the effects of disturbance on individual fitness (Chabot 1991, Knight and Cole 1991, Sutherland 2007). Answering these questions will require a greater understanding of connections between behavior, physiology, reproduction, and disturbance and developing study designs that can isolate responses to disturbance from responses to environmental, biological, and habitat factors.

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Chapter 2

Spatial and Temporal Patterns in the Distributions of Birds and Recreationists at South Core Banks, North Carolina During the Fall

ABSTRACT

We describe the autumnal shorebird community, as well as human recreation, on the ocean beach of South Core Banks, North Carolina, an Atlantic Coast barrier island within Cape Lookout National Seashore. We conducted weekly surveys of birds and vehicles from ATVs, recording the species, numbers, and microhabitat locations (i.e. surf, swash zone, dry sand, wet sand) of all birds within half-mile segments of ocean beach. We summarized survey data by week, tide, segment, and daylight hour in order to describe the spatial, temporal, and tidal patterns in bird and human abundance. Shorebird densities on South Core Banks were similar to those reported for other sites on North Carolina's Outer Banks. Total shorebird numbers were fairly consistent across hours and most segments of the island, while individual shorebird species showed unique spatial and temporal patterns in abundance. Shorebird numbers on South Core Banks decreased slightly throughout the season, but peaked several times. We found that shorebirds' use of the ocean beach and its microhabitats is related to tide levels, and we identified two shorebird roosting sites. Bird distributions overlapped considerably with those of recreationists, but segregation may have occurred at the microhabitat scale.

INTRODUCTION

Many shorebird species make long, biannual migrations between breeding and wintering grounds, and these migrations are often punctuated by stops for resting and refueling (Gill and Handel 1990, Skagen 2006). Several species, including Ruddy Turnstones (*Arenaria interpres*), Sanderlings (*Calidris alba*), Black-bellied Plovers (*Pluvialis squatarola*), and Red Knots (*Calidris canutus*), have shown evidence of population declines in recent years (Bart et al. 2007), prompting attempts to identify the habitats on which they depend and challenges they face during migrations. Anthropogenic disturbance is one potentially harmful factor present at many stopover sites that may have negative impacts on shorebirds (Gill 2007).

Dinsmore et al. (1998) identified the Outer Banks of North Carolina as an important stopover habitat for shorebirds using the Atlantic flyway. Compared to other areas on the Atlantic and Gulf Coasts where extensive shorebird surveys have been conducted, the Outer Banks were relatively important to Sanderlings, Whimbrels (*Numenius phaeopus*), and Piping Plovers (*Charadrius melodus*), with Sanderlings more common on the Outer Banks than at other sites on the Atlantic Coast (Dinsmore et al. 1998). Shorebird abundance peaks twice per year on the Atlantic Coast, once in spring and once in fall (Morton 1996). Shorebird numbers during fall migration are larger than during spring (Dinsmore et al. 1998). Populations of at least one species, the Sanderling, returns to sites used during previous migrations and remains within relatively small areas (<10 km segments of beach) during stopovers (Dinsmore et al. 1998).

South Core Banks lies just south of the southernmost sites on the Outer Banks that Dinsmore et al. (1998) examined, and it was not included in their surveys. We conducted weekly counts of birds and vehicles on South Core Banks to describe patterns in bird and human abundance on its ocean beaches. Our objectives were to identify spatial and temporal patterns in the use of ocean beach habitats by shorebirds and to compare shorebird abundance on South Core Banks to the sites examined by Dinsmore et al. (1998). We also wanted to compare patterns in the abundance of humans and shorebirds and look for evidence of tide and time of day effects on their use of ocean beach habitats. Through this study, we hope to provide a context for the management of nonbreeding shorebirds on South Core Banks as well as for studies of their habitat use during fall migration and research on their relationships with human activity.

METHODS

Cape Lookout National Seashore (CALO) is located on North Carolina's Outer Banks between Ocracoke Island and Bogue Banks. South Core Banks is a barrier island with 41 km of ocean beach between miles 23 and 47.5 of Cape Lookout National Seashore (Fig. 2.1). The ocean beach stretching from mile marker 23 to 44 faces southeast and is relatively straight, has relatively consistent structure, and a low profile. The ocean beach between miles 44 and 47.5 faces west and has two distinctive features. Cape Lookout Point (the point) is a sand peninsula that fluctuated from 0.2 to 0.5 mi in length due to tide levels and the movement of sand during storms. The Power Squadron Spit is a northeast-pointing, sand peninsula with a very low profile that changes shape and area within and between years and tide levels. A camp with rental cabins is located near mile marker 30, and an historic lighthouse is located near mile marker 41.

South Core Banks is a popular destination for anglers who drive on ocean beaches between miles 23 and 46, on a back road that runs behind the primary dunes from mile 24 to 44, and on several paths (ramps) that connect the two. The Power Squadron Spit, a portion of Cape Lookout Point (point closure), the area between miles 41 and 42.5 remain closed to public vehicles for bird protection.

Other sections of beach are temporarily closed to public vehicles for sea turtle and bird nest management each spring, summer, and early fall. National Park Service staff regularly drives all-terrain vehicles through all closures. Beach closures are established with rope fences at the closures' edges that stretch from the high tide line to the dunes. Signs advertise that the closures protect bird or turtle nests.

We counted birds, vehicles, and pedestrians on South Core Banks' ocean beaches from ATVs during fall 2005, 2006, and 2007. We conducted surveys approximately twice per week between 26 September and 15 November 2005, 10 September and 5 November 2006, and 23 August and 22 October 2007. We defined weeks as the seven day periods beginning on 23 August, 30 August, 6 September, 13 September, 20 September, 27 September, 4 October, 11 October, 18 October, 25 October, 1 November, and 8 November. We attempted to survey the entire island once per week at both high and low tides during fall 2005 and high and rising tides during fall 2006 and 2007. We defined high tide as the 4 h period centered at peak high tide, low tide as the 4 h period centered at peak low tide, and rising tide as the 4 h period beginning at peak low tide. We were often unable to cover the entire island during surveys due to adverse weather or logistical constraints, so we often surveyed the island in sections over several days.

We divided the ocean beach into 51 half-mile segments, which we treated as sampling units. These segments were placed so that their northernmost edge corresponded with half-mile increments of the mile marker system used by CALO, and they were named after the increment that their northern border corresponded with. Their eastern border was the surf, and their western border was the primary dune line. While the lengths of segments (their northern to southern edge) were constant, their width (the distance from the dune to the surf) varied with tide levels and wave height. Three segments had dimensions and structures that were anomalous to the other segments. The point was triangular in shape with ocean beach on two of its three sides, giving it twice as much beach per mile as the other segments. Its length and area varied with weather and tide and its northwestern edge abutted the edges of two beach segments and the point closure. The point closure was a triangular area between segments 43.5, 44, and the point, that included areas of dry sand, several small dunes, and, occasionally, a tidal pool. We did not survey the point closure in 2005. Segment 47 was located at the tip of the Power Squadron Spit. It was usually 0.5 mi long and triangular, but its very low profile meant that its exact shape, area, and dimensions varied greatly with changes in winds, tides, and swells. In general, the area of segment 47 was larger than that of the other segments.

We performed surveys by driving an ATV through segments at a speed of 5-15 mph and recording all birds, vehicles, pedestrians and dogs on the beach, in the surf within 100 m of the shore, and flying above the surf or beach. We identified all individuals to the species level, except when it was not possible, in which case we used the names “shorebird,” “gull,” “tern,” or “songbird.” Table 2.1 lists which species were included in each of these categories. Prior to 27 October 2005, no gulls or terns were identified to the species level. We recorded unidentified shorebirds as “peep” when we could not determine whether they were Semipalmated Sandpipers (*Calidris pusilla*), Least Sandpipers (*Calidris minutilla*), or Western Sandpipers (*Calidris mauri*), and we used “dowitcher” for Short-billed and Long-billed Dowitchers (*Limnodromus spp*). We use the name “off-road vehicle” (ORV) to refer to pickup trucks, jeeps, sport utility vehicles, and modified recreational vehicles and ATV to refer to four-wheelers.

We drove in a straight line through linear segments and usually surveyed adjacent segments consecutively. When surveying the point, we traveled along one swash zone to the tip and along the other swash zone when returning, making sure not to double count birds between the two swash zones. When surveying the point closure, we traveled on the outside edges until all birds within the closure had been counted. When surveying segment 47, we simply made an attempt to cover all areas of the segment and count all birds exactly once. During all surveys, we made a concerted effort not to double count birds that moved ahead of us as we traveled through plots. We alternated the direction of travel through segments each week. Observers took as much time as they needed to count all individuals in each segment.

We recorded the microhabitat locations of individuals at the time of first detection. Microhabitat categories were defined as: surf, which extended from 100 m offshore to the water's edge; swash zone, the area where waves washed onto the beach; wet sand, areas above the water's edge that were still wet from previous tide levels; and dry sand, the area between the upper reaches of the wet sand and the dune line. During the 2005 season, we did not distinguish between the swash zone and wet sand. Birds frequently flushed as we approached, but we recorded their location prior to their movement.

We believe that our counts provided good estimates of true bird abundance in segments because most segments were relatively narrow, we were able to see all portions of the beach, and the movement of birds in response to the ATV aided identification and counting. Inaccuracies in our counts do, however, exist because observers likely missed some birds that were roosting in tire tracks or other depressions in the sand and missed birds that flushed at long distances from the ATV. Some birds were probably double-counted as they moved in response to the ATV, but observers avoided double counting birds by stopping as little as possible, only traveling in a straight line, and only counting birds in front of or beside them. We estimated the size of large flocks by counting by 10's or 100's, likely causing measurement error to increase with flock size. These errors were probably most frequent at segment 47 because it was non-linear in shape, large, and often contained large roosting flocks.

We looked for patterns in bird abundance and human recreation by summarizing counts by species, week, daylight hour, segment, tide, year and microhabitat. We generated a list of species that use the ocean beaches of South Core Banks during fall by listing all species detected during surveys or otherwise observed on the ocean beach. We also calculated the number of surveys with at least one individual detected and the total number of detections from all surveys for each species to identify common and abundant species. Flyover detections were excluded from this summary.

Although our surveys were not designed to provide accurate estimates of population sizes on South Core Banks, we generated rough estimates by summing all detections for day-tide combinations when we surveyed every segment on the island. We refer to these summed counts as complete surveys. Complete surveys were performed at low tide on 9 October 2005, high and rising tide on 20 October 2006, rising tide on 25 October 2006, high and rising tide on 3 November 2006, high tide on 11 September 2007, high tide on 4 October 2007, rising tide on 12 October 2007, and rising tide on 19 October 2007. On two occasions, high tide of 11 October 2006 and high tide of 12 October 2007, we were able to survey all segments except for those in vehicle exclosures. We report the total vehicle counts from these occasions because all segments that were open to public vehicles were surveyed. Flyover detections of birds were included in this summary. Some segments were surveyed twice during these periods, so we randomly selected one for inclusion by flipping a coin. We calculated shorebird densities on the beach to compare with densities reported by Dinsmore et al. (1998) for other sites on the Outer Banks. We calculated densities (birds/km) by dividing the average number of individuals counted during complete surveys by the length of South Core Banks' ocean beaches (41 km).

We examined temporal patterns in abundance over the fall season by plotting an index of island abundance over time for each species. To calculate the index of island abundance, we summed the means from all segments. We removed flyovers from this analysis because we suspected that the detectability of birds in the air was less than that of birds on the ground or in the surf and that the removal of flyover detections would, therefore, decrease the heterogeneity associated with our indices. Detections from all other microhabitats were initially summed to give the total abundance for each survey by species. Surveys from all tides, years, observers, and weeks were included.

We examined abundance relative to time of day by calculating the mean number of individuals per survey for each daylight hour (6:00 to 19:00 EST). We eventually omitted hours 6:00 and 19:00 because their sample sizes were very small compared to those of other hours. We also excluded flyover detections for this summary but included data from all other microhabitats, calculating the total abundance of each species for each survey first. All tides, observers, years, and weeks were included.

To describe spatial patterns in abundance over the island, we calculated the average abundance of each species at each segment. Flyovers were excluded from calculations and counts from all other microhabitats were first summed to give the total abundance for each survey by species. Data from surveys for all years, observers, tides, and weeks were used. We then separated data by tide and year combinations and again calculated means for each segment to look for differences in spatial patterns between years and tides. We performed paired *t*-tests on high and rising tide means to assess any differences in abundance between tide levels. We compared low tide and high tide distributions in 2005, and we compared rising tide and high tide distributions using 2006 and 2007 data. We compared high tide distributions from 2005, 2006, and 2007 because high tide was the only level that we consistently surveyed each year (we sampled low tide in 2005 and rising tide in 2006 and 2007). We did not, however, perform statistical tests on the means from the three years because year effects would have been confounded with week effects, since there was little overlap between the 2005 and 2007 survey seasons.

Lastly, we examined patterns in microhabitat use by comparing the proportions of total detections that were from each microhabitat during high and rising tide. We did not include 2005 data in this analysis because observers did not distinguish between the swash zone and wet sand microhabitats in 2005.

RESULTS

We performed a total of 2,316 segment surveys. These surveys were relatively well distributed among segments, years, and tides, but not among weeks and daylight hours. Each segment was surveyed between 40 and 50 times (mean = 45.41) with the exception of the point closure, which was surveyed 32 times. Segments between 38.5 and 40.5 were surveyed slightly fewer times than other segments (Fig. 2.2). The total number of surveys per year was similar for all segments except for the point closure, which was never surveyed during 2005. Segments were, on average, surveyed fewer times during 2005 than during 2006 and 2007 (2005 mean = 11.65, 2006 mean = 16.51, 2007 mean = 17.25). The number of surveys per tide level was also similar for all segments except that segment 40 was surveyed only 3 times during low tide in 2005 (mean = 5.41 surveys per segment). The number of surveys performed per week was relatively similar among segments but not among weeks (Fig. 2.3). Our 2005, 2006, and 2007 field seasons spanned different time periods, but all included the entire month of October. This is reflected in the relatively large sample size for weeks during October compared with those of late August, early September, and early November. The number of surveys performed per daylight hour was not consistent across segments (Fig. 2.4). A more general comparison of surveys per time of day with morning defined as before 10:59, midday defined as between 11:00 and 15:59, and evening defined as after 16:00 shows better evenness in the number of surveys performed among different times of the day. In general, however, large proportions of the total number of surveys were from between 8:00 and 10:00 and 13:00 and 16:00 and very few surveys were performed after 17:00 (Fig. 2.5). This distribution is in part due to the fact that day length decreased throughout our field seasons.

The average survey length was 5.73 min (SD = 3.22, max = 37 min, n = 2,200), excluding segment 47 (mean = 23.73 min, SD = 17.344, max = 85 min, n = 40), the point (mean = 11.61 min, SD = 6.14, max = 39 min, n = 44) and the point closure (mean = 11.84 min, SD = 6.95, max = 31 min, n = 32).

We observed 54 bird species from 17 families on the ocean beach (Table 2.1), including 21 species of shorebirds, 6 species of gulls, and 9 species of terns. Sanderlings, Willets (*Catoptrophorus semipalmatus*), Great Black-backed Gulls (*Larus marinus*), Herring Gulls (*Larus argentatus*), and Black-bellied Plovers were the species most frequently present during surveys. They were detected during 1,937, 1,104, 959, 925, and 885 surveys respectively. Sanderlings also had the largest number of total detections (40,807), followed by Laughing Gulls *Larus atricilla* (11,237), Great Black-backed Gulls (10,662), Herring Gulls (10,040), and Willets (8,025). Our complete surveys show that total abundance on the ocean beach varied greatly for many species (Table 2.2). Total shorebird numbers ranged between 145 and 1,984 individuals. American Oystercatcher (*Haematopus palliates*) numbers were between 3 and 18 individuals, Black-bellied Plover numbers ranged between 8 and 293, and Ruddy Turnstone numbers were between 5 and 74. Dunlin (*Calidris alpina*) and Sanderling numbers were highest on 3 November 2006 (163 and 1,475 individuals, respectively) and had minimum counts of zero and 59, respectively. Willet numbers were between 28 and 389, and the maximum number of Red Knots counted during a complete survey was 17.

Gull abundance totals from complete surveys ranged between 172 and 4,692 individuals. Great Black-backed Gull numbers were between 35 and 629, Herring Gull numbers were between 46 and 1,395, Laughing Gull numbers were between 76 and 1,125, Lesser Black-backed Gull (*Larus fuscus*) numbers were between 2 and 62, and Ring-billed Gull (*Larus delawarensis*) numbers were between 5 and 2,181.

Tern numbers from complete surveys ranged between 23 and 1,226. The maximum counts of individuals on the island's ocean beaches during any one complete survey were 95 for Caspian Terns (*Sterna caspia*), 416 for Forster's Terns (*Sterna forsteri*), 237 for Royal Terns (*Sterna maxima*), and 500 for Sandwich Terns (*Sterna sandvicensis*). The maximum counts were from high tide surveys.

On two days, we surveyed the entire island during both high and rising tides (20 October and 3 November 2006). On 3 November 2006 the numbers of all shorebirds, gulls, and terns on the ocean beaches were either higher or equal to their numbers at rising tide. A complete count on 20 October 2006 also showed greater numbers at high tide than rising tide for Black-bellied Plovers, Piping Plovers, Red Knots, Ruddy Turnstones, Sanderlings, Semipalmated Plovers (*Charadrius semipalmatus*), Willets, Great Black-backed Gulls, Herring Gulls, Laughing Gulls, Lesser Black-backed Gulls, Caspian Terns, Forster's Terns, Royal Terns, and Sandwich Terns.

The largest number of vehicles (ATVs and ORVs summed) we counted during a complete survey was 149 on 12 October 2007 and the lowest number was 10 on 11 September 2006. ATV numbers ranged between 4 and 30, and ORV numbers ranged between 6 and 119. Boats were occasionally within 100 m of the swash zone, and the most we counted in a complete survey was 49. Pedestrian numbers were highest at 240 people on 12 October 2007.

Total shorebird densities on South Core Banks were similar to those reported by Dinsmore et al. (1998) for Ocracoke Island but they were only 50% of those reported for North Core Banks and 25% of densities at North Beach (the 25km of beach between the Rodanthe, NC pier and 1 km north of Buxton, NC, Table 2.3). Black-bellied Plover, Piping Plover, American Oystercatcher, Whimbrel, and Ruddy Turnstone densities were similar to those of other sites on the Outer Banks. Willet density was smaller than at all other sites, and North Beach had a density three times that of South Core Banks. Red Knot density was similar to that of all other sites except North Core Banks, which had six times the number of Red Knots. Sanderlings density (individuals per km) at South Core Banks was similar to Ocracoke, less than at North Core, and much less than at North Beach (Table 2.3).

Temporal patterns

Our index of shorebird numbers showed a slight decreasing trend throughout the season with peaks during the end of August, middle of September, and second and fourth weeks in October (Fig 2.6). Sanderling numbers peaked at the same times as overall shorebird numbers, but their numbers were largest during the end of October (Fig. 2.7). Willet and Black-bellied Plover numbers were also variable throughout the season, but both showed a decreasing trend over the fall (Fig 2.7). Willets were most abundant during the third week of September and Black-bellied Plovers were most abundant during the first week of September. American Oystercatcher abundance decreased throughout the season and was near zero by the beginning of November (Fig 2.8). The abundance of Red Knots and Piping Plovers was highly variable, and our largest estimate of Red Knot abundance was during the week of 8 November. Wilson's Plover (*Charadrius wilsonia*) numbers were highest in August and decreased to near zero during September (Fig 2.8). Dunlin arrived during the first week of October and peaked during the first week in November (Fig. 2.9). The numbers of Semipalmated Plovers on the South Core's beaches were highly variable, but they seemed to decrease overall throughout the season. No individuals were counted in the second week of November (Fig 2.9). Ruddy Turnstone numbers were greatest at the end of August. They decreased until 27 September, then increased, and remained relatively constant.

Our index of gull abundance on South Core Banks showed that numbers increased throughout the season with a sharp rise during the end of October (Fig. 2.6). Tern abundance was variable throughout the fall but declined abruptly at the end of September (Fig 2.6). All weeks prior to 27 September had larger numbers of terns than did weeks after 27 September. The numbers of pelicaniformes (Brown

Pelicans (*Pelecanus occidentalis*) and Double-crested Cormorants (*Phalacrocorax auritus*) stayed constant until a slight increase during the first week of November (Fig. 2.10). Peregrine Falcon (*Falco peregrinus*) abundance was largest in October and began increasing during the middle of September. We detected Merlins (*Falco columbarius*) between the weeks of 6 September and 1 November.

Pedestrian and vehicle numbers showed similar patterns after the first week in September (Fig. 2.11). Prior to September, vehicle numbers increased while pedestrian numbers decreased. After the week of 6 September, both tended to increase in abundance. There were peaks in both the number of vehicles and pedestrians during the weeks of 27 September and 1 November. The numbers of ATVs and moving vehicles (moving ATVs or ORVs) were very similar, and the two followed the same temporal pattern (Fig. 2.12). Likewise, the numbers and trends of ORVs and stationary vehicles (parked ATVs or ORVs) were similar. A very small proportion of the people we recorded were moving (i.e. running or walking), and their numbers were close to zero by the week of 6 September (Fig. 2.13).

The average numbers of shorebirds and vehicles counted during surveys was consistent across daylight hours (Fig. 2.14). Average gull and tern counts per survey followed similar patterns across daylight hours with a peak at 12:00 (Fig. 2.14). Gull numbers increased during the afternoon, while tern numbers decreased. The means of Sanderlings counted per segment survey during the morning and afternoon hours were larger than those from midday (Fig. 2.15). Willet, Black-bellied Plover, Wilson's Plover, and Ruddy Turnstone counts were all consistent among daylight hours (Figs. 2.16 and 2.17). Semipalmated Plover counts were higher at 12:00 and 13:00 than at other times of the day (Fig. 2.17). The means of American Oystercatcher counts were lower during midday than during morning and afternoon (Fig. 2.16). Piping Plover abundance was highest between 11:00 and 13:00 (Fig. 2.16).

The abundance of moving ATVs and ORVs did not vary among daylight hours, but the numbers of stationary ATVs and ORVs showed peaks at 12:00 and 16:00 (Fig. 2.18).

Spatial patterns

Shorebird abundance was relatively even across segments with the exceptions of low abundance between miles 44 and 46.5 and high abundance at segments 47 (mean = 17.85, SE = 3.80) and 30 (mean = 38.49, SE = 5.34, Fig 2.19). 2006 and 2007 data indicate that high tide abundance was greater than rising tide abundance (difference in means = 13.08, two-tailed t = 3.48, df = 50, P = 0.001), especially for segments between miles 36 and 42 and at segments 46 and 47 (Fig 2.20). 2005 data showed a similar pattern with high tide means being greater than low tide means for segments between miles 36.5 and 40.5, at segment 47, and at the point (Fig. 2.21). The patterns of abundance among segments at high tide were similar across years except for higher means at segments 24, 24.5, 29.5, and 30 in 2006 (Fig. 2.22).

The distribution of Sanderlings was similar to that of total shorebird abundance (Fig. 2.23). On average, there were more than 10 individuals in segments between miles 23 and 44 and fewer than 10 between miles 44 and 47 and at the point closure. Mean Sanderling abundance was largest at cape point (mean = 39.77, SE = 4.67) and segments 30 (mean = 38.49, SE = 5.34) and 39.5 (mean = 25.05, SE = 4.61). Abundance at high tide was greater than at rising tide (difference in means = 6.84, two-tailed t = 5.89, df = 50, P < 0.0001), especially between miles 23 and 30.5, between miles 36 and the point, and at segment 47 (Fig. 2.24). Differences between high and low tide are not apparent from 2005 data (Fig 2.25), and the high tide distribution of Sanderlings appeared similar across years (Fig 2.26).

Willets were common in all segments but were primarily distributed away from the inlets (Fig. 2.27). They were most abundant between miles 27 and 44 with peaks at segments 40.5 (mean = 6.45, SE = 1.71) and 29.5 (mean = 7.04, SE =

1.37). Their numbers did not appear to vary with tide level (difference in rising and high tide means = 0.32, two-tailed t = 1.45, df = 50, P = 0.077, Fig. 2.28). Mean high tide abundance was lowest in 2005 for many segments (Fig. 2.29).

The average number of Black-bellied Plovers was between two and seven at most segments. We identified three distinct areas with relatively high abundance; mile 23, segments between miles 33.5 and 41, and segments at the Power Squadron Spit (Fig. 2.30). Segments 47 and 37.5 had the most Black-bellied Plovers (mean = 6.38, SE = 4.63 and mean = 3.76, SE = 1.87, respectively). Abundance was greater at high tide than at rising tide in each of these three areas (Fig. 2.31), as well as for all segments (difference in means = 2.13, two-tailed t = 4.57, df = 50, P < 0.0001). The area between miles 33.5 and 41 also supported more birds at high tides than during rising tides, but this pattern was not apparent from 2005 data (Figs. 2.32 and 2.33).

Semipalmated Plover distributions were similar to those of Black-bellied Plovers. Their numbers were very low in most segments (less than one), and three distinct areas had relatively high abundance; the areas between miles 23 and 26, between miles 34 and 41, and at segments 46, 46.5, and 47 (Fig. 2.34). Semipalmated Plover numbers were largest in segments 47 and 46.5 (mean = 35.55, SE = 12.14, and mean = 2.74, SE = 1.72, respectively). They used these areas almost exclusively during high tide (Figs. 2.35 and 2.36). We did not find a statistically significant overall difference between high and rising tide means, but this was likely due to large variance (difference between means = 2.38, two-tailed t = 1.48, df = 50, P = 0.15).

Ruddy Turnstones were most abundant south of mile 35 and at the northernmost 3 mi portion of the island (Fig. 2.37). Of these areas, the point (mean = 4.14, SE = 0.90) and segment 41.5 (mean = 1.83, SE = 0.46) had the highest abundance. High tide means were greater than rising tide means for segments between miles 37.5 and 46 (Fig. 2.38), and there was a statistically significant difference in the high and rising tide means of all segments (difference = 0.42, two-tailed t = 3.43, df = 50, P = 0.001). In 2005, there was an area on the southern half of the island for which high tide means were greater than low tide means (between miles 35.5 and 42.5), but there was also an area on the northern half of the island, between miles 23 and 30, with higher abundance at low tide (Fig. 2.39). High tide distributions appeared similar among all three years (Fig. 2.40).

Unlike Ruddy Turnstones, American Oystercatchers were primarily distributed along the northern half of South Core Banks, between miles 25.5 and 28.5 (Fig. 2.41). They were most abundant at segment 27 (mean = 1.17, SE = 0.36) followed by segments 25.5 (mean = 0.69, SE = 0.23), 28 (mean = 0.68, SE = 0.19), and 28.5 (mean = 0.65, SE = 0.21). The patterns of abundance at high and rising tide both resembled the pattern of overall abundance and their means were not different (two tailed t = 0.20, df = 50, P = 0.84, Fig. 2.42).

We observed Red Knots at most segments on the island, but average counts were generally small. Only one segment, segment 23, had a mean greater than one (mean = 1.08, SE = 0.52, Fig. 2.43). High tide abundance was greater than low tide abundance at segments between miles 23 and 25 and between 27.5 and 29 during 2005 (Fig. 2.44). 2006 and 2007 data, however, suggest that abundance at high tide was not greater than at rising tide (difference in means = 0.25, two-tailed t = 0.46, df = 50, P = 0.65, Fig. 2.45).

We primarily encountered Piping Plovers at the northern and southern ends of the island, and they were most abundant at segments 46.5 (mean = 0.67, SE = 0.53), and 47 (mean = 2.36, SE = 0.69), which make up the Power Squadron Spit (Fig. 2.46). Mean abundance for these segments was larger at high tides than at low or rising tides (Figs. 2.47 and 2.48).

We only detected Wilson's Plovers at segments 39.5, 40.5, 46.5, and 47. All encounters with this species, with the exception of one, were at high tide.

Gulls were common throughout the ocean beaches of South Core Banks, but we identified three distinct peaks in their distribution across segments (Fig. 2.49). One, their numbers were relatively high around segment 29.5 (mean = 100.77, SE = 15.78). Two, they were abundant at the point (mean = 70.30, SE = 16.64) and segment 44 (mean = 105.47, SE = 34.49). Three, they were abundant in the segments that make up the Power Squadron Spit (segment 47 mean = 228.85, SE = 93.49, max = 3,631). Their distribution did not appear to vary by tide (difference in high and rising tide means = 2.70, two-tailed $t = 0.69$, df = 50, P = 0.50, Fig. 2.50) but high tide means were lowest during 2007 (Fig. 2.51).

The spatial distribution of terns was similar to that of gulls with peaks at segment 47 (mean = 144.60, SE = 38.87) and around the point closure (closure mean = 46.63, SE = 26.97; point mean = 42.20, SE = 16.23; segment 44 mean = 84.26, SE = 31.57, Fig. 2.52). The area between miles 28 and 31.5 also had relatively large numbers of terns. Tern numbers were only larger at high tide than low or rising tide at segment 47 (difference in high and rising tide means for all segments = 3.01, two-tailed $t = 0.85$, df = 50, P = 0.40, Figs. 2.53 and 2.54). The high tide distribution of terns did not appear to vary over years, except that numbers were low at segment 44 during 2007 compared to numbers from 2006 and 2007 (Fig. 2.55).

We counted pelicaniformes in most segments, and their numbers were highest at segment 47 (mean = 31.58, SE = 6.24, Fig. 2.56). For both high and rising tide, they were more abundant at segment 47 (high tide mean = 33.57, SE = 9.90, rising tide mean = 14.07, SE = 33.57, Fig. 2.57). Their distribution at high tide was consistent across years (Fig. 2.58).

The relative abundance of all vehicles (ORV and ATV numbers combined) among beach segments was representative of that of ORVs and stationary vehicles. Vehicle numbers were largest at the point (mean = 12.98, SE = 1.49) and segments 43.5 (mean = 7.09, SE = 1.06), 23 (mean = 4.16, 0.68), 35.5 (mean = 3.13, SE = 0.61), and 30.5 (mean = 3.04, SE = 0.58, Fig 2.59). The largest numbers of vehicles counted during one segment survey were 43 vehicles at segment 44, 38 vehicles at the point, and 30 vehicles at segment 34.5. The patterns of abundance across segments were similar at all tides and years, with the exception of lower abundance at some segments between miles 34 and 39 during the 2007 season (Figs 2.60, 2.61, and 2.62). The distribution of ATVs was similar to that of all vehicles but with smaller average abundance at each segment (Fig. 2.63)

Average counts of moving vehicles for all but one segment, the point (mean = 1.02, SE = 0.19), were less than one (Fig. 2.64). Moving vehicles were also abundant at segment 44 (mean = 0.72, SE = 0.34) and between miles 30 and 34.5 where means ranged between 0.56 and 0.68. The maximum number of vehicles counted in one survey was 14 at segment 44, followed by 10 vehicles at segment 44.5, and 9 vehicles at segment 30.5. Spatial patterns in abundance appeared similar across tide levels and years (Figs. 2.65, 2.66, and 2.67).

Pedestrians were distributed similar to vehicles except for in the area between miles 41 and 42.5, where pedestrian abundance was relatively high and vehicle abundance was relatively low (Figs. 2.59 and 2.68). The segments with the highest mean pedestrian abundance were the point (mean = 19.68, SE = 2.59), segment 43.5 (mean = 8.56, SE = 1.59), and segment 23 (mean = 5.63, SE = 1.07).

We found differences in microhabitat use between high and rising tides for some species of shorebirds. We counted more shorebirds during high tide surveys than during rising tide surveys, and shorebirds were more frequently encountered in dry sand microhabitats at high tide than during rising tides (Fig. 2.69). For all shorebird species except for Willets and American Oystercatchers, we recorded more individuals at high tides than at rising tides. Black-bellied Plovers, Semipalmated Plovers, and Piping Plovers showed similar differences in microhabitat use between high and rising tide (Figs. 2.70, 2.71, and 2.72). They used the swash zone very little at high tide and shifted from the dry sand to the swash zone during rising tides. Red Knots were in all three microhabitat types during high tides, however we only observed one individual in the dry sand during rising tide surveys (Fig. 2.73). American Oystercatchers were most common in the swash zone during rising tides but their distribution shifted toward dry areas at high tide so that more individuals were in the dry sand at high tide than rising tide (Fig. 2.74). Sanderling, Willet, and Ruddy Turnstone numbers were lower in the dry sand than in the swash zone or wet sand during both tide levels (Figs. 2.75, 2.76, and 2.77). They did, however, increase their use of the dry sand microhabitat and decrease their use of the swash zone during high tide.

We counted similar numbers of gulls during high and rising tides. The proportions of individuals in the surf and swash zone were similar across tide levels, but there were slightly more in the dry sand and fewer in the wet sand during rising tides than high tides (Fig. 2.78). Terns were distributed evenly between the dry and wet sand during high tide but a small proportion of individuals used the swash zone during rising tides (Fig. 2.79). The proportions of Brown Pelicans and Double-crested Cormorants using the dry sand and swash zones were similar between tides but during rising tides, fewer individuals were in the wet sand and more were in the surf (Fig. 2.80).

Moving and stationary vehicles were concentrated in the dry sand portions of beach segments during high and rising tides, but both were more abundant on wet sand during rising tides (Figs. 2.81 and 2.82). Pedestrians were also observed in the dry sand more than in the other locations (Fig. 2.83). They did not appear to shift their distribution on the beach with changes in tide level.

DISCUSSION

The ocean beach of South Core Bank is used by a variety of shorebird, gull, and tern species between the end of August and middle of November. Shorebird numbers are similar to those reported at other sites on the Outer Banks (Table 2.3), and they show distinct patterns in abundance over time and space that overlap with those of human activity in the park.

The patterns in total abundance within the fall differed between the species and groups that we examined, and they were consistent with ones reported by Dinsmore et al. (1998) for other sites on the Outer Banks. We identified six general patterns. The numbers of terns, Black-bellied Plovers, Willets, American Oystercatchers, Wilson's Plovers, and Semipalmated Plovers generally declined throughout the fall (Figs. 2.7-2.9). This group includes species that breed at CALO (American Oystercatcher, Wilson's Plover, Willet, and tern species). Gulls, pelicaniformes, and Dunlins showed increases in abundance as the season progressed (Figs. 2.6 and 2.7). Total shorebird and Sanderling numbers exhibited a variable pattern that suggests pulses in migration (Fig. 2.6 and 2.7). Ruddy Turnstone numbers were fairly constant as the season progressed, but temporarily declined during the end of September (Fig. 2.9). Red Knots and Piping Plovers showed a fifth pattern, which was one of sporadic peaks throughout the season with periods of absence and no clear general increasing or decreasing trend (Fig. 2.8). We speculate that this is a result of small local population sizes and inconsistent detections. When detected, Red Knots were usually in small flocks. Piping Plovers seemed to use the ocean beach inconsistently. Merlin and Peregrine Falcon numbers clearly showed an increase followed by a decrease, whereby their numbers increased from zero, peaked, and decreased back to zero within the season (Fig. 2.10).

Shorebirds, as a whole, were evenly distributed among segments between miles 23 and 44 (Fig. 2.19), but the spatial distributions of individual species were unique. Black-bellied Plovers and Semipalmated Plovers were relatively abundant in the same areas; the spit, the northern end of the island, and a section of beach between miles 33.5 and 41 (Figs. 2.30 and 2.34). They were both more abundant at high tide in these areas (Figs. 2.32 and 2.36). Willets were distributed in an "M" shape with smaller numbers at the northern and southern tips of the island and in the middle

(Fig. 2.27). Sanderlings were more evenly distributed across the island than other shorebirds, but still had relatively low numbers between the point and the Power Squadron Spit (Fig. 2.23). Ruddy Turnstones were concentrated on the southern half of the island, and they were relatively abundant between 33.5 and 41, along with Black-bellied and Semipalmated Plovers (Fig. 2.37). American Oystercatchers were concentrated in the northern half of the island. We observed the largest flocks of oystercatchers at segments between miles 25 and 29 (Fig. 2.41). During 2007, our field season was early enough that some adults and juveniles were still on breeding territories between miles 35 and 41. Piping Plover numbers were largest at the Power Squadron Spit and near Ophelia Inlet (Fig. 2.46). They were rarely or never present at segments between miles 25.5 and 42.5. Red Knots were most abundant at the northern tip of the island and were encountered infrequently at various other segments along the island (Fig. 2.43).

Overall, there were several regions on the South Core Banks with notable bird communities. The northernmost 3 mi of the island supported large numbers of gulls, Black-bellied Plovers, Ruddy Turnstones, Red Knots, and Piping Plovers relative to other areas of the island's ocean beaches. The beach between this region and the Great Island Cabin Area, at mile 30, was used relatively little by all species except for Willets and American Oystercatchers. The beach adjacent to the Great Island Cabin Area frequently hosted large, mixed-species flocks of gulls, terns, and various shorebirds, usually Sanderlings, Willets, Black-bellied Plovers, and Ruddy Turnstones. The beach between miles 33.5 and 41 had large numbers of Black-bellied Plovers, Semipalmated Plovers, Sanderlings, and Ruddy Turnstones compared to other areas, except for those near inlets. The area composed of segments 43.5, 44, the point, and the point closure was frequently used as a roosting site by terns and gulls. Shallow pools were occasionally located in the point closure and we observed several shorebird species, including Least Sandpipers, Pectoral Sandpipers (*Calidris melanotos*), Greater Yellowlegs (*Tringa melanoleuca*) and Lesser Yellowlegs (*Tringa flavipes*), along their edges. The beach between miles 44.5 and 46 had the smallest numbers of shorebirds of any portion of the island. Only two species, Piping Plovers and Ruddy Turnstones, were abundant in this area relative to other areas. The Power Squadron Spit was characterized by a large diversity and abundance of birds. We regularly observed large flocks of gulls, terns, pelicaniformes, and shorebird species roosting at high tides, as well as plovers and sandpipers foraging there during low tides.

Tide influenced the abundance of some shorebirds on the ocean beaches. Overall shorebird numbers on the ocean beach, as well as those of Sanderlings, Black-bellied Plovers, and Ruddy Turnstones were greater at high tides than during rising tides tide. We did not find a statistically significant difference between Semipalmated Plover, Willet, American Oystercatcher, Red Knot, and Piping Plover numbers at high and rising tide, but there was some evidence that Semipalmated Plovers, Red Knots, and Piping Plovers were more abundant in some areas at high tide (Figs. 2.35, 2.36, 2.44, 2.45, 2.47, 2.48). In general, the segments comprising the Power Squadron Spit and segments between miles 35 and 41 supported more birds during high tide than during low tide levels. Terns and pelicaniformes were more abundant during high tide at segment 47. We did not identify any areas where shorebird abundance was greater during low tides than during high tides.

Many of the same shorebird species for which tide appeared to influence abundance used dry sand microhabitats more during high tides than during rising tides (Fig. 2.36). This preference was most pronounced for Black-bellied Plovers, Semipalmated Plovers, Red Knots, Piping Plovers, and American Oystercatchers (Figs. 2.70 – 2.74). The proportions of detections in the dry sand was greater during high tide than during rising tide for Sanderlings, Ruddy Turnstones, and Willets, but these differences were not as large as for other species (Figs. 2.75 – 2.77). The greater abundance, greater use of dry sand at high tide, and the infrequency of encounters with shorebirds foraging in the dry sand microhabitat lead us to conclude that some shorebirds use South Core Banks' ocean beach as a roosting site during high tide.

Our data show that total shorebird abundance was similar among daylight hours but that hourly patterns existed for some species. Sanderlings were most abundant in the morning and afternoon (Fig. 2.15). American Oystercatcher, Red Knot, Piping Plover, and Semipalmated Plover numbers varied with daylight hour, but the variation in abundance within some hours was very large and, therefore, no clear patterns were distinguishable (Figs. 2.16 and 2.17). The abundance of four shorebird species, Ruddy Turnstones, Black-bellied Plovers, Willets, and Wilson's Plovers appeared constant throughout the day (Figs. 2.15 – 2.17). Gull and tern numbers followed the same pattern of increasing until noon and then decreasing until 14:00, when their patterns diverged (Fig. 2.14).

In general, the numbers of people and vehicles on South Core Banks' ocean beach increased throughout the fall, and after 6 September visitor abundance corresponded closely with vehicle abundance (Fig. 2.11). The total number of vehicles present on the beaches was relatively constant across daylight hours, but the number of stationary vehicles peaked at noon and 16:00 (Fig. 2.14). Most vehicles on the beach were stationary ORVs, and they were not evenly dispersed along the beach (Fig. 2.59). The distribution of ATVs and ORVs were similar except that ATV numbers were smaller (Figs. 2.59 and 2.63). Vehicle users favored the southern end of the island, including the area between the point and mile 46, segments near mile 35.5, segments near the Great Island Cabin Area, and the northernmost tip of the island. Vehicles were relatively sparse on the beach between miles 29 and 23.5. The distribution of moving vehicles did not follow that of stationary ones, and they were most abundant on the beach between miles 30 and 33.5 and at the segments near the point (Fig. 2.64). Vehicles were mostly located on dry sand, but a small proportion was in the wet sand microhabitat (Figs. 2.81 and 2.82).

We found considerable overlap in the distributions of birds and recreationists on South Core Banks. The numbers of visitors and vehicles on the island increased throughout the season while Willets, Sanderlings, and Black-bellied Plovers remained abundant (Figs. 2.7 and 2.11). Tern numbers generally declined as vehicle numbers increased, but terns remained present throughout the season (Fig. 2.6). Gull numbers increased almost in unison with visitor numbers (Figs. 2.6 and 2.11).

Our descriptions of the spatial distribution of birds among segments show little evidence of segregation between birds and vehicles. In fact, visitors, vehicles, and some bird species were abundant in the same places at the same times. Gull numbers were largest in areas with high visitor abundance, and shorebirds were relatively common on the beach adjacent to the Great Island Cabin Area (mile 30, Figs. 2.49 and 2.59). There is, however, a possibility that segregation occurred within our segments. Shorebird species that were common on the beaches (i.e. Willets, Ruddy Turnstones, and Sanderlings) were primarily found in the swash zone, while vehicles were usually located in the dry sand (Figs. 2.75 – 2.77). We also observed roosting flocks of terns at cape point that were within the same beach segment as vehicles, but positioned away from them.

Although our surveys provided a large data set that was useful for describing patterns in shorebird, pedestrian, and vehicle abundance, we recognize several important limitations in our data. Dinsmore et al. (1998) reported that the largest numbers of shorebirds were on the Outer Banks during July and August. We detected large numbers of Semipalmated Plovers and Black-bellied Plovers early on, which suggests that a late summer peak is likely at South Core Banks. We did not survey in these months, so we did not sample the complete migration season. Nevertheless, we sampled a large portion of fall migration.

Our sampling effort was fairly well distributed among high and low tides, years, and segments, but not weeks or daylight hours (Figs. 2.2 – 2.4). Our description is most appropriate for the months of September and October because that is when we did most of our surveys. Surveys from August were all from 2007 and surveys from November were mostly from 2005, so differences in the distribution of birds among years are confounded with differences among weeks.

Most of the species that we examined use habitats other than the ocean beach, such as mudflats and sound-side beaches. Our total counts from complete surveys and our island abundance indices are, therefore, a larger proportion of the true island abundance for species that primarily use ocean beaches. Finally, many shorebirds are known to be active both diurnally and nocturnally (Burger 1984, Burger and Gochfeld 1991b), but we were only able to survey during daylight. There may be patterns of habitat use related to daylight that we were unable to identify.

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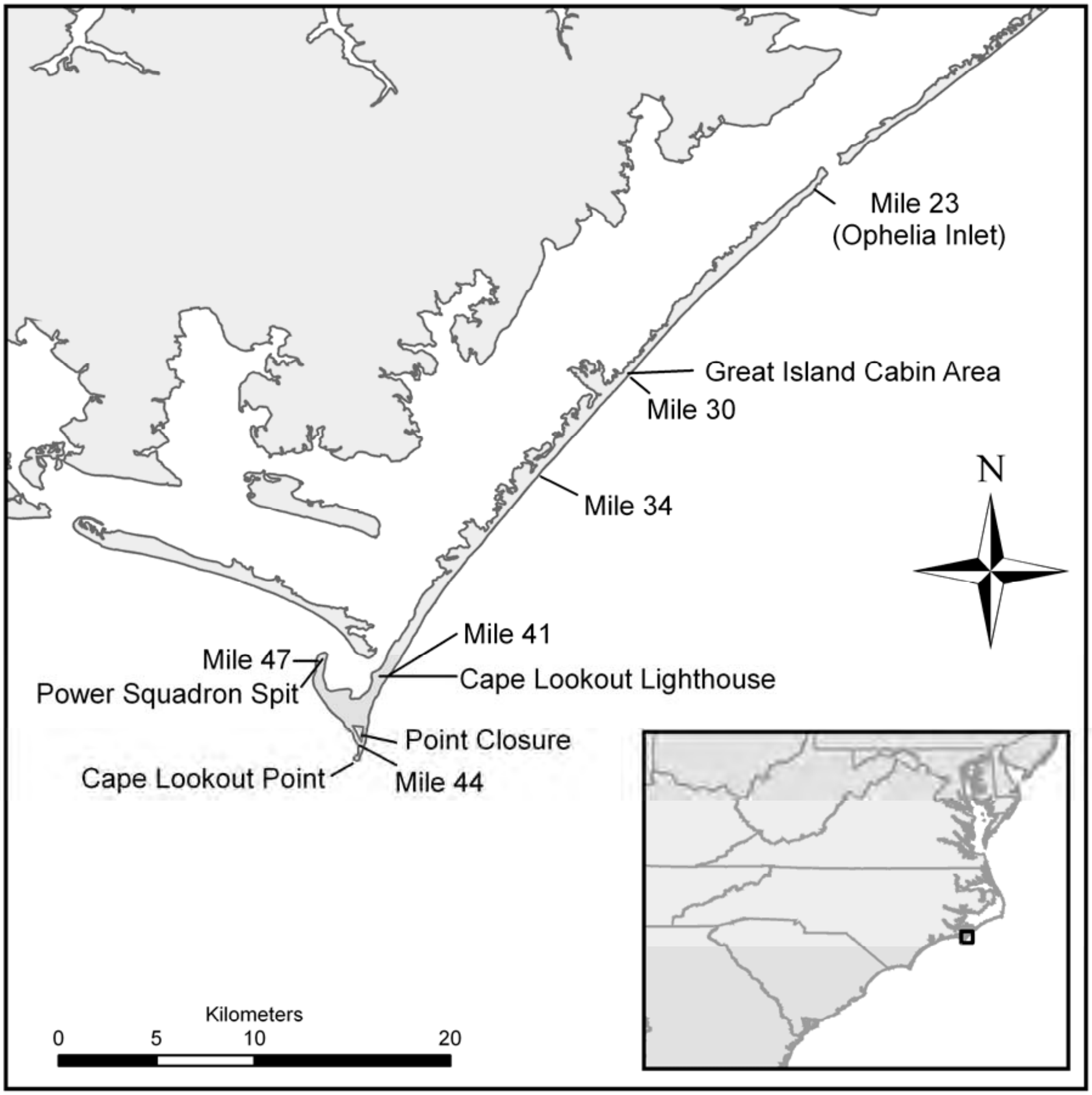

Figure 2.1. Map of South Core Banks, NC. The miles that are labeled correspond with Cape Lookout National Seashore's (CALO) mile marker system. A new inlet was created at mile 23 during Hurricane Ophelia in September 2005.

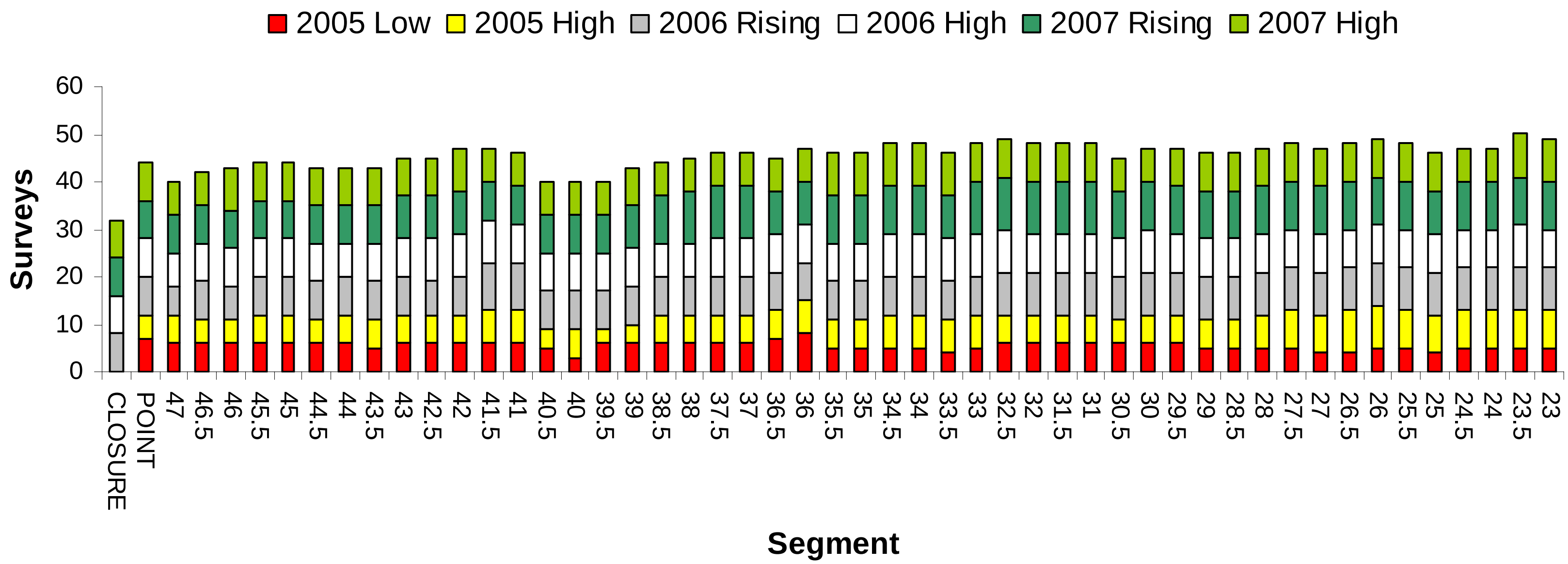

Figure 2.2. The number of surveys performed at beach segments on South Core Banks, NC for each year and tide. Segment names denote where the segment's northern edge falls within Cape Lookout National Seashore's mile marker system. Low tide was from 2 h before until 2 h after peak low tide. Rising tide was from peak low tide to 4 h after peak low tide. High tide was from 2 h before until 2 h after peak high tide.

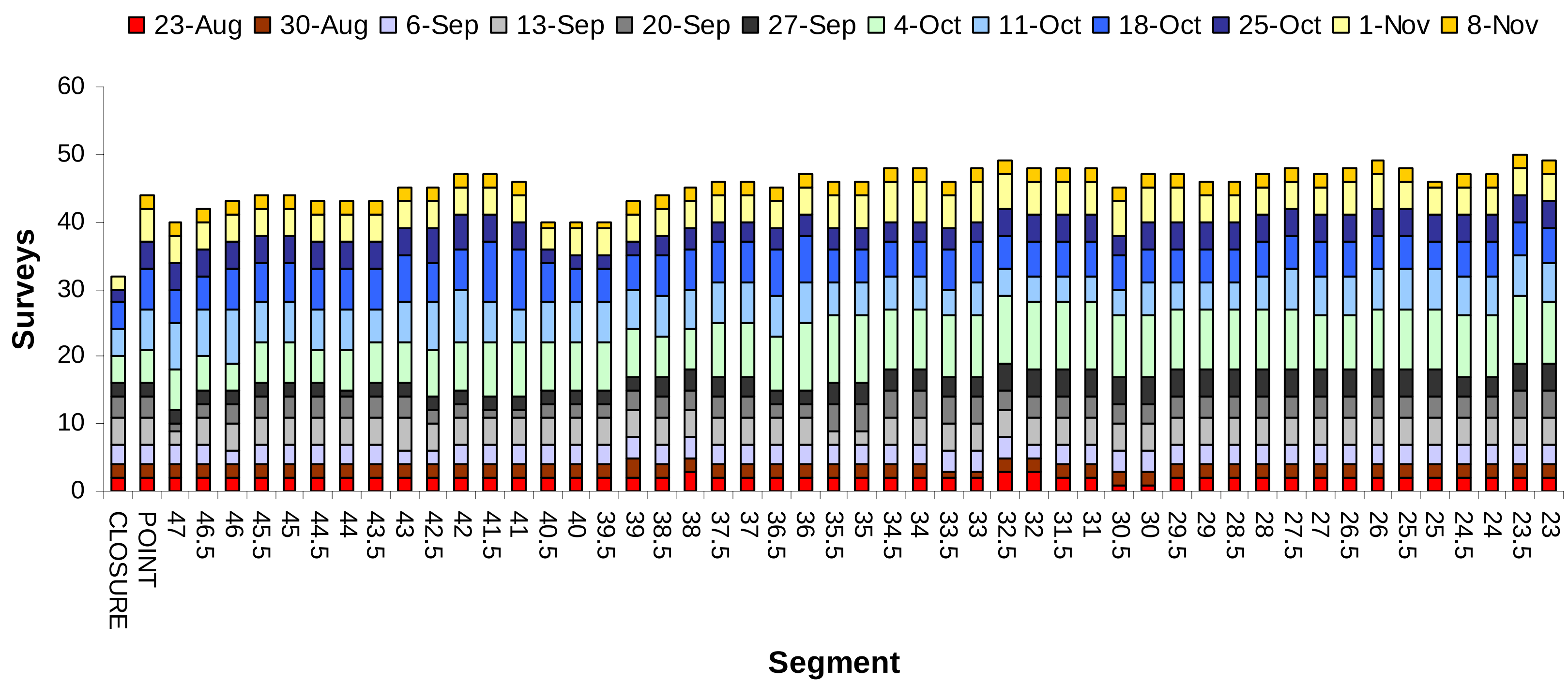

Figure 2.3. The number of surveys performed at beach segments on South Core Banks, NC for each week. Weeks in the same month are colored with shades of the same color (August – Red, September – black/gray, October – blue/green, November – yellow/orange). Weeks were named after the date of the first day of the week. Segment names denote where the segment's northern edge falls within Cape Lookout National Seashore's mile marker system.

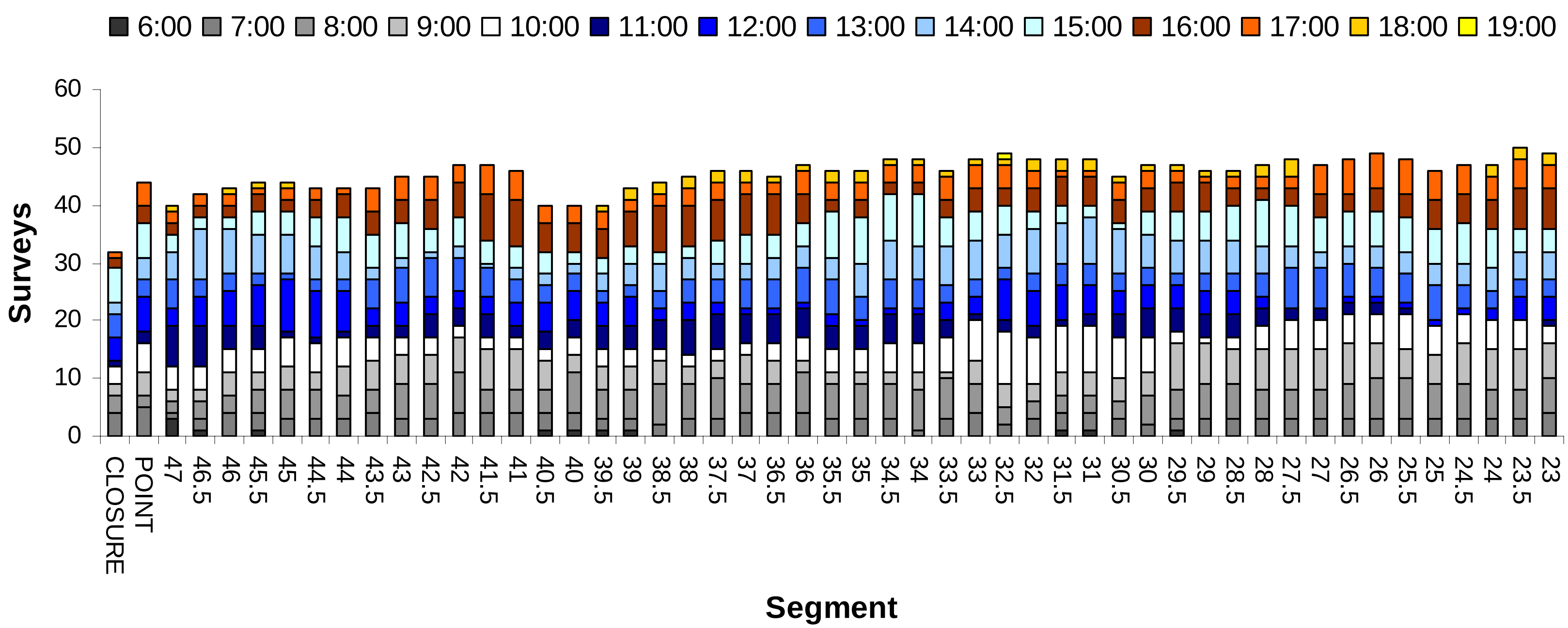

Figure 2.4. The number of surveys performed at beach segments on South Core Banks, NC for each daylight hour EST. Hours during the morning are shades of grey, hours at midday are shades of blue, and hours during the evening are shades of red or yellow. Segment names denote where the segment's northern edge falls within Cape Lookout National Seashore's mile marker system.

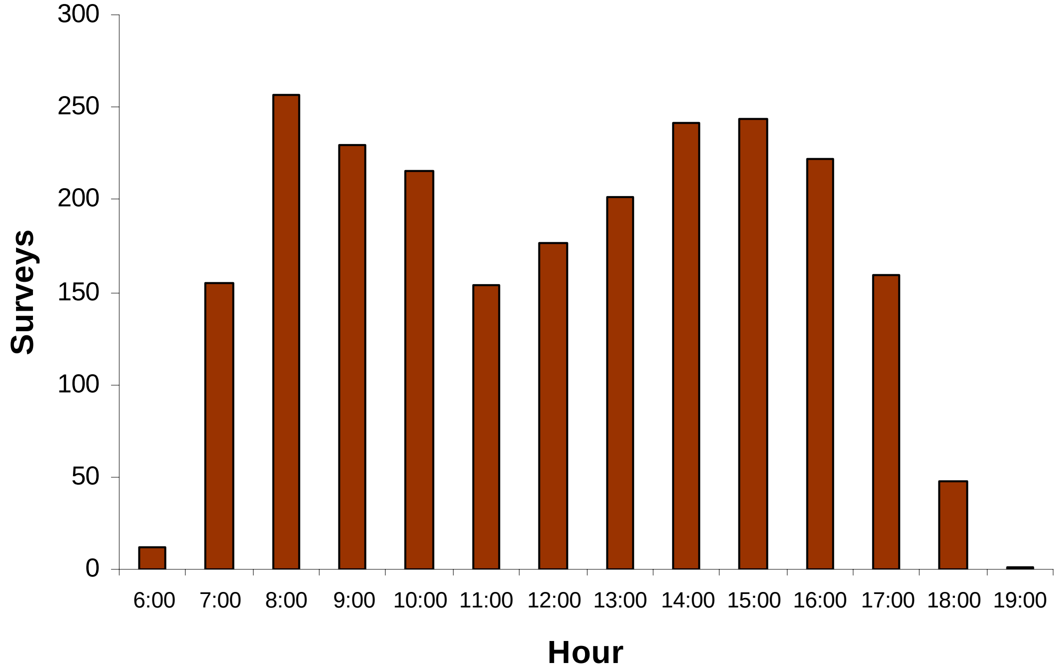

Figure 2.5. Sample size of surveys for each daylight hour EST. Surveys were assigned to hour bins based on their start time.

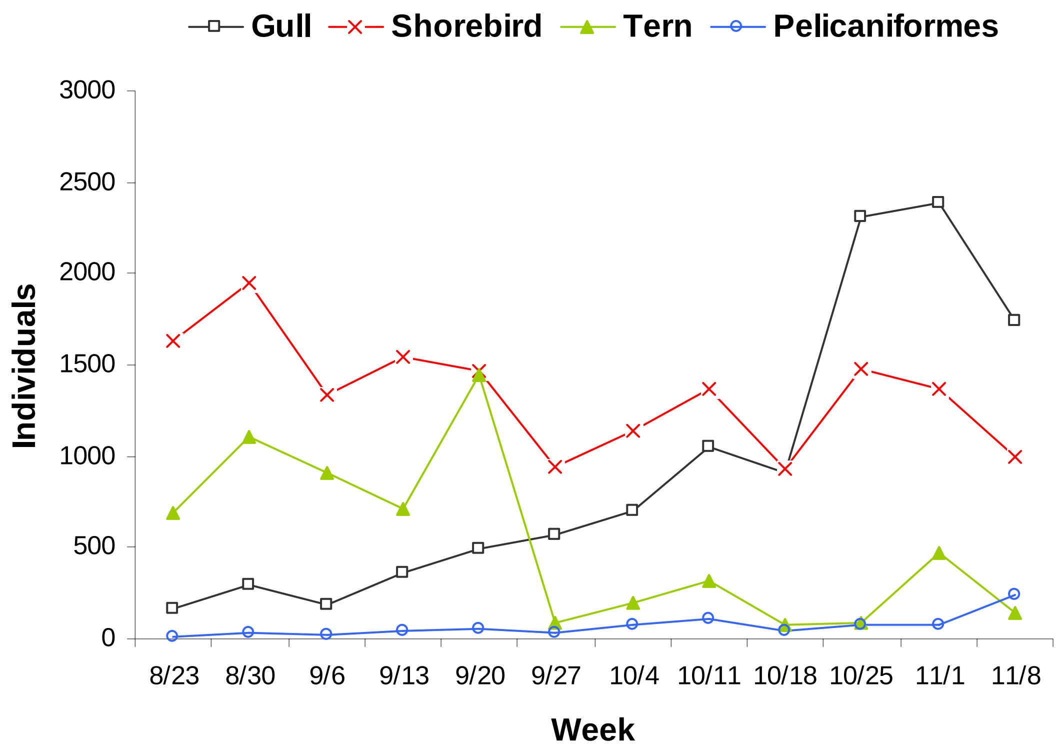

Figure 2.6. The abundance of gulls, shorebirds, terns, and pelicaniformes (Brown Pelicans, Double-crested Cormorants) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included, detections of flying birds were excluded, and one site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

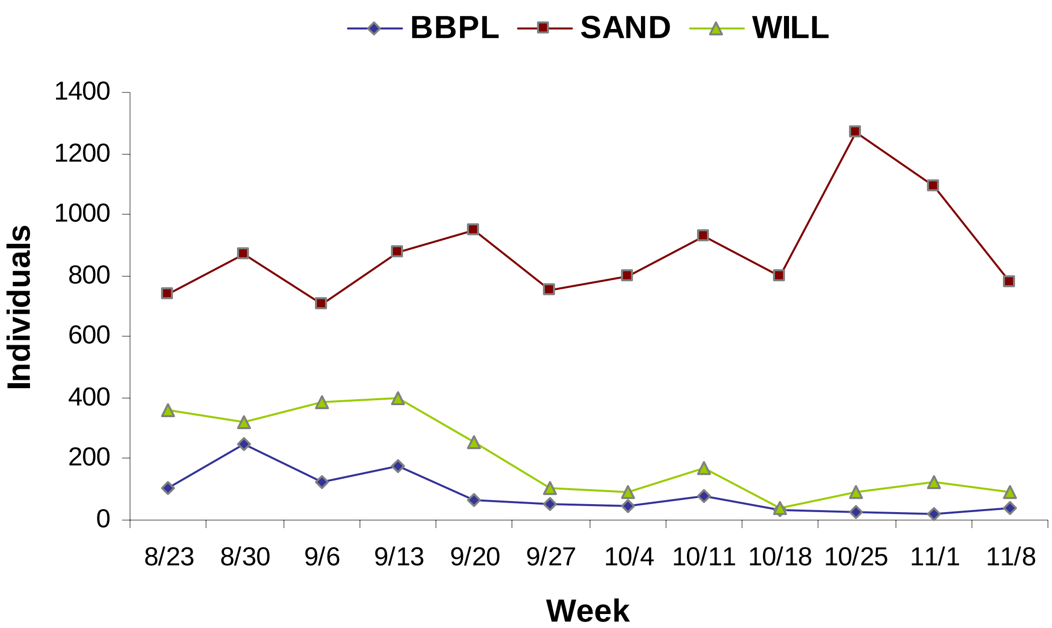

Figure 2.7. The abundance of Black-bellied Plovers (BBPL), Sanderlings (SAND), and Willets (WILL) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included, detections of flying birds were excluded, and one site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

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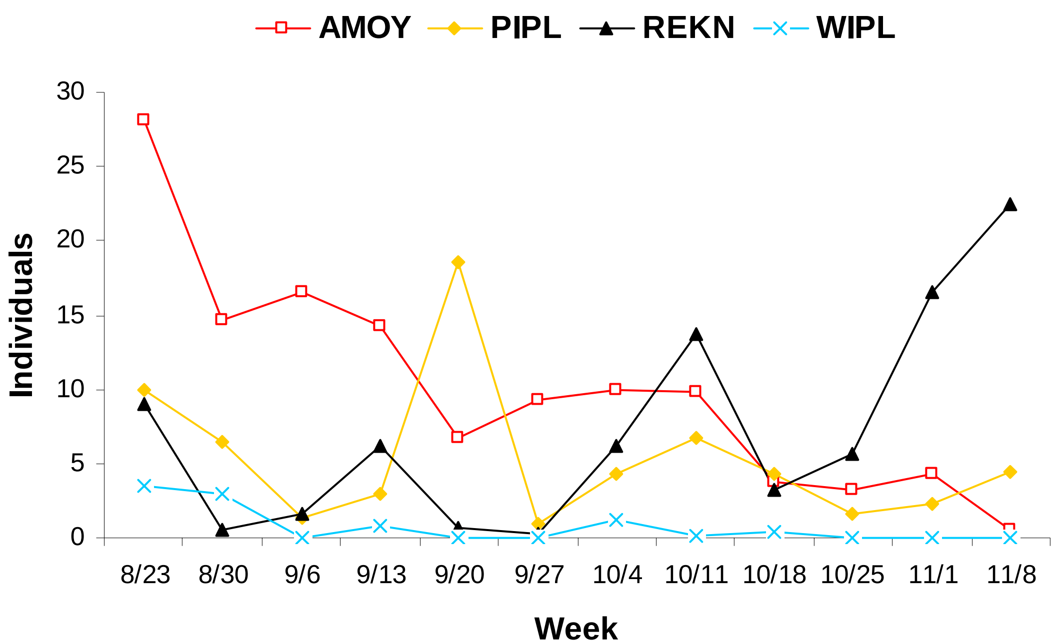

Figure 2.8. The abundance of American Oystercatchers (AMOY), Piping Plovers (PIPL), Red Knots (REKN), and Wilson's Plovers (WIPL) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included, detections of flying birds were excluded, and one site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

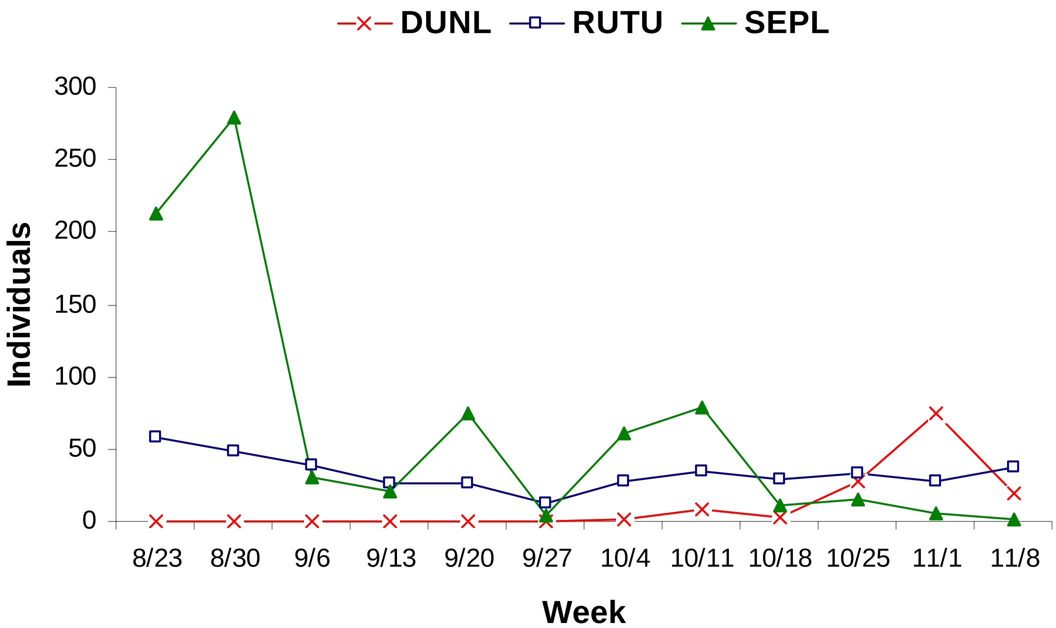

Figure 2.9. The abundance of Dunlins (DUNL), Ruddy Turnstones (RUTU), and Semipalmated Plovers (SEPL) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included, detections of flying birds were excluded, and one site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

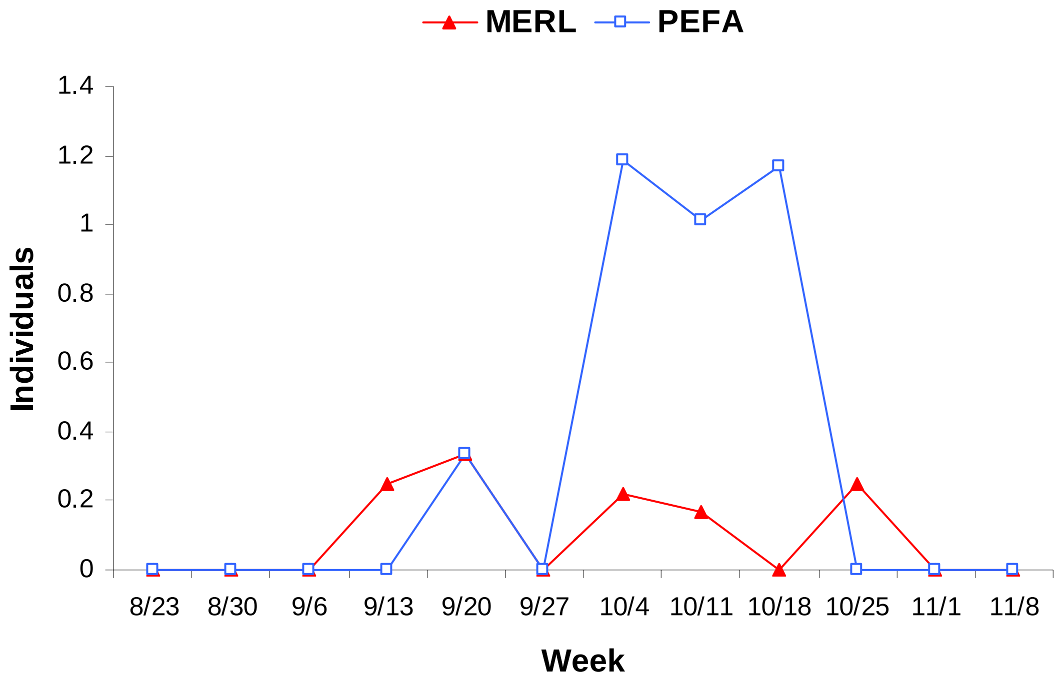

Figure 2.10. The abundance of Merlins (MERL) and Peregrine Falcons (PEFA) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included, detections of flying birds were excluded, and one site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

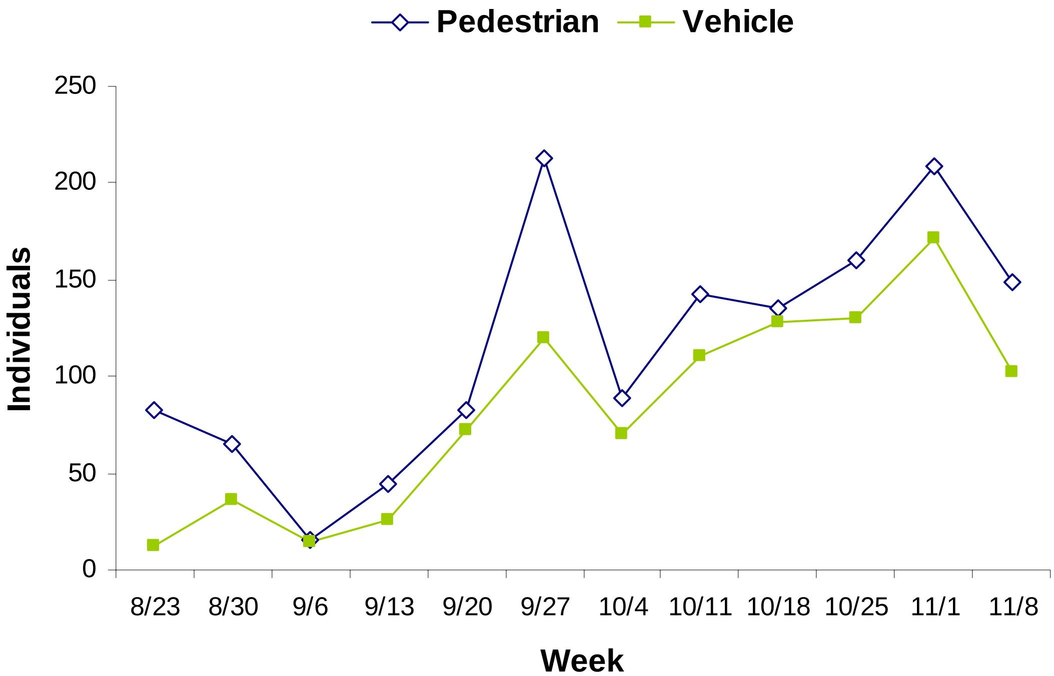

Figure 2.11. The abundance of pedestrians (moving or stationary) and all vehicles (moving or stationary ORVs or ATVs) at South Core Banks, North Carolina during fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included. One site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

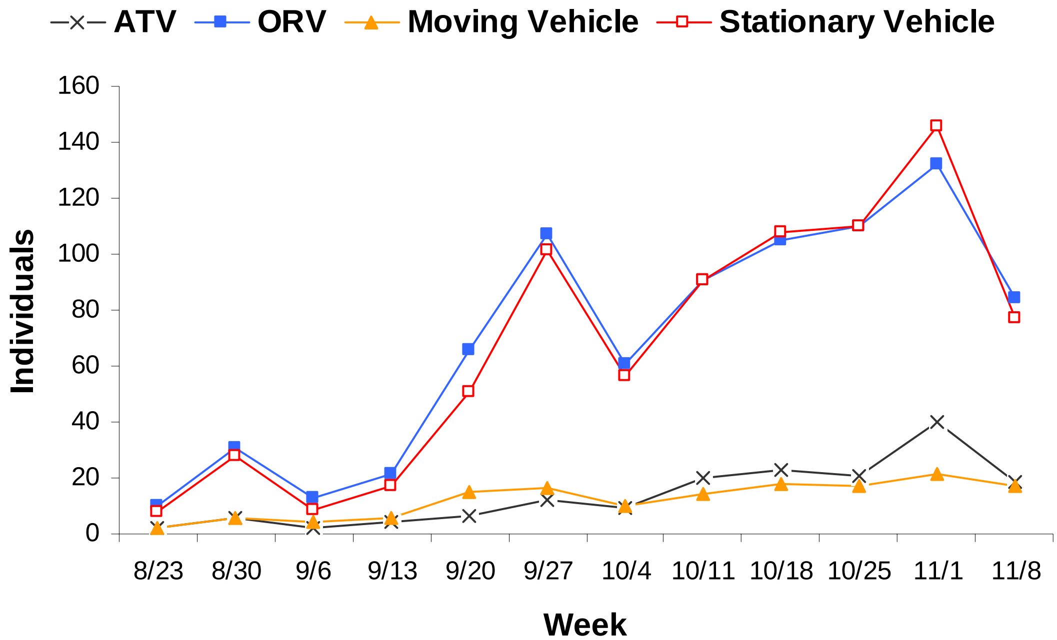

Figure 2.12. The abundance of ATVs (moving or stationary), ORVs (moving or statrionary), moving vehicles (moving ATVs or ORVs), and stationary vehicles (stationary ATVs or ORVs) at South Core Banks, North Carolina for fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included. Dates on the x-axis are the first day of the week.

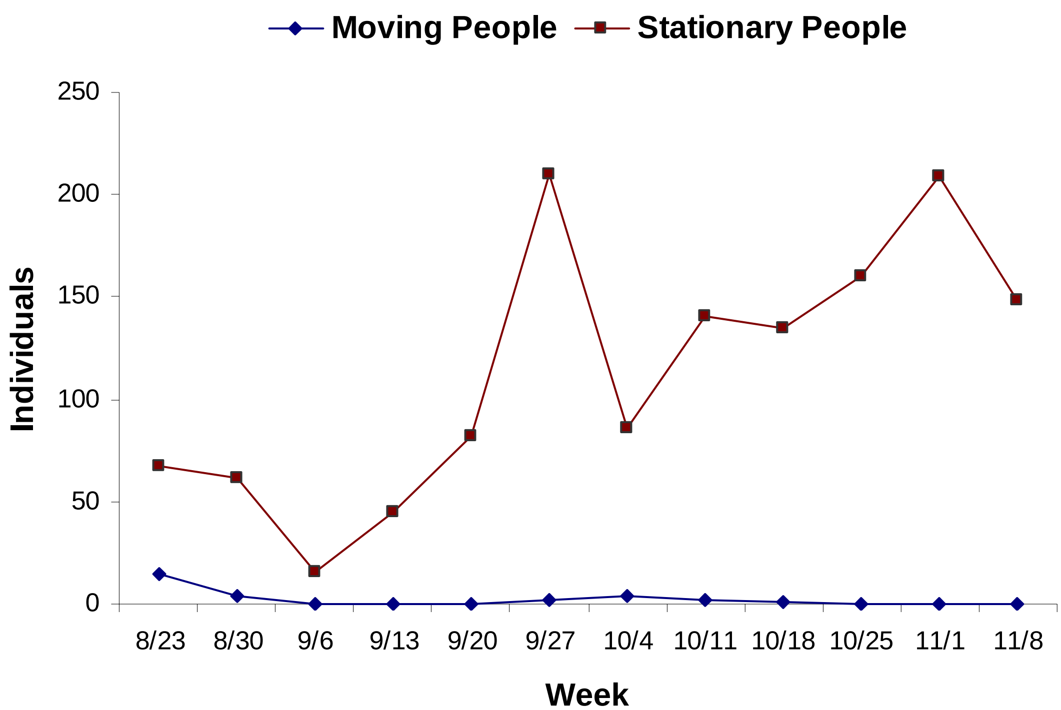

Figure 2.13. The abundance of moving people (runners, joggers, and walkers) and stationary people at South Core Banks, North Carolina for fall weeks. We used the sum of average abundance from all beach segments as an index of abundance on the whole island for each week. Data from 2005, 2006, and 2007 were included. One site, a vehicle exclosure at the upper beach at cape point, was never surveyed during the week of 8 November. Dates on the x-axis are the first day of the week.

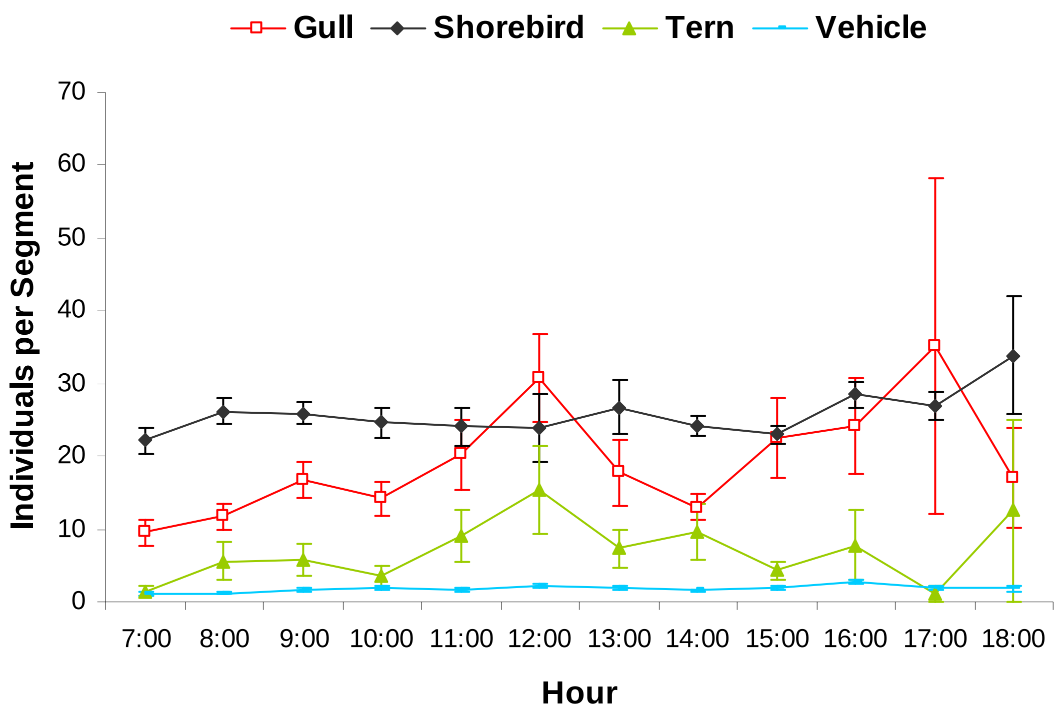

Figure 2.14. The average number of gulls, shorebirds, terns and vehicles (ORVs and ATVs combined) counted per segment survey for each daylight hour EST. Surveys from all tide levels, segments, years, dates, and observers were included, but we excluded detections of flying birds from this summary. Error bars represent one standard error, and 6:00 and 19:00 left out due to small sample sizes.

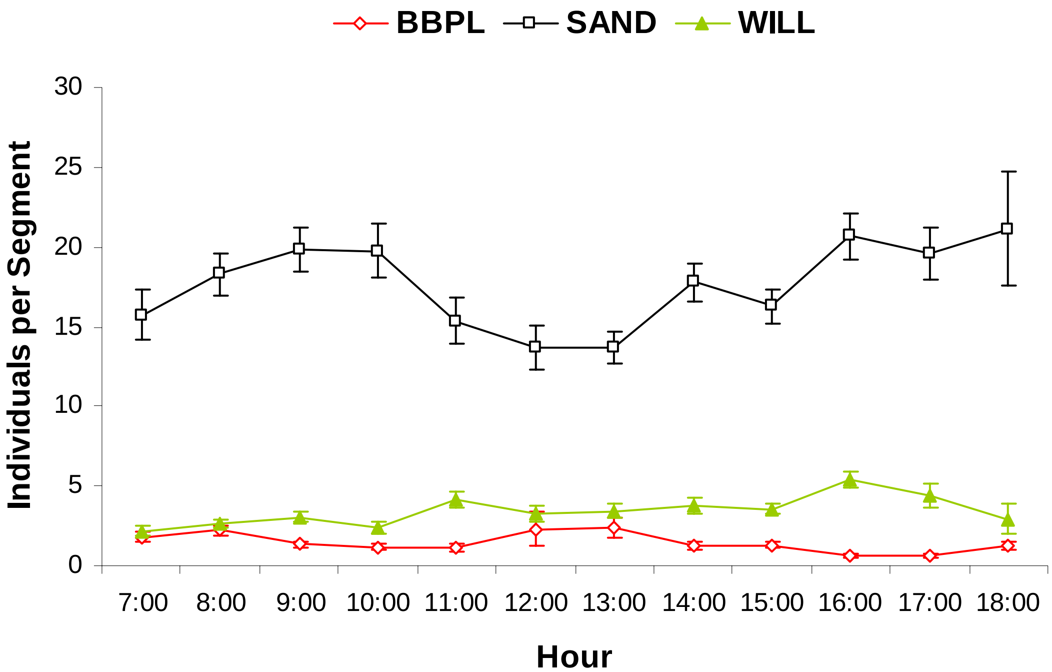

Figure 2.15. The average number of Black-bellied Plovers (BBPL), Sanderlings (SAND), and Willets (WILL) counted per segment survey for each daylight hour EST. Surveys from all tide levels, segments, years, dates, and observers were included, but we excluded detections of flying birds from this summary. Error bars represent one standard error, and 6:00 and 19:00 left out due to small sample sizes.

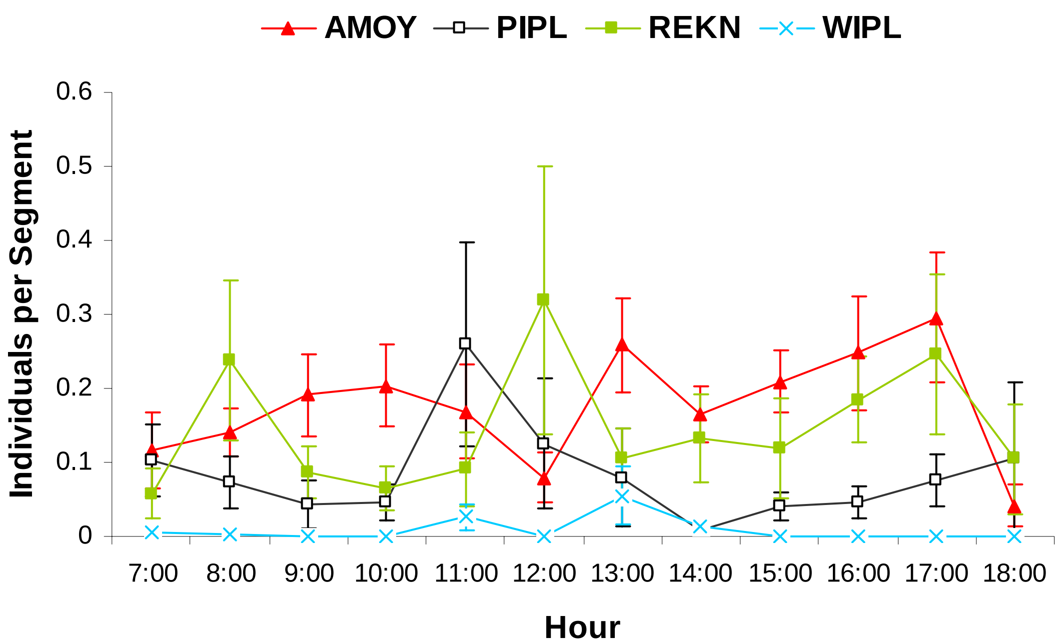

Figure 2.16. The average number of American Oystercatchers (AMOY), Piping Plovers (PIPL), Red Knots (REKN), and Wilson's Plovers (WIPL) counted per segment survey for each daylight hour EST. Surveys from all tide levels, segments, years, dates, and observers were included, but we excluded detections of flying birds from this summary. Error bars represent one standard error, and 6:00 and 19:00 left out due to small sample sizes.

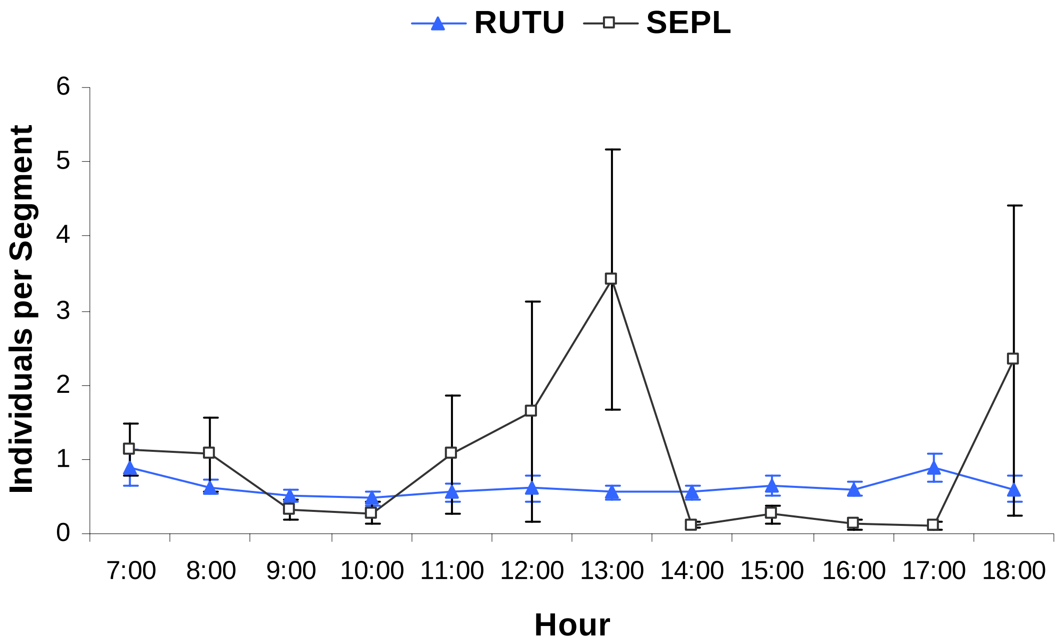

Figure 2.17. The average number of Ruddy Turnstones (RUTU) and Semipalmated Plovers (SEPL) counted per segment survey for each daylight hour EST. Surveys from all tide levels, segments, years, dates, and observers were included, but we excluded detections of flying birds from this summary. Error bars represent one standard error, and 6:00 and 19:00 left out due to small sample sizes.

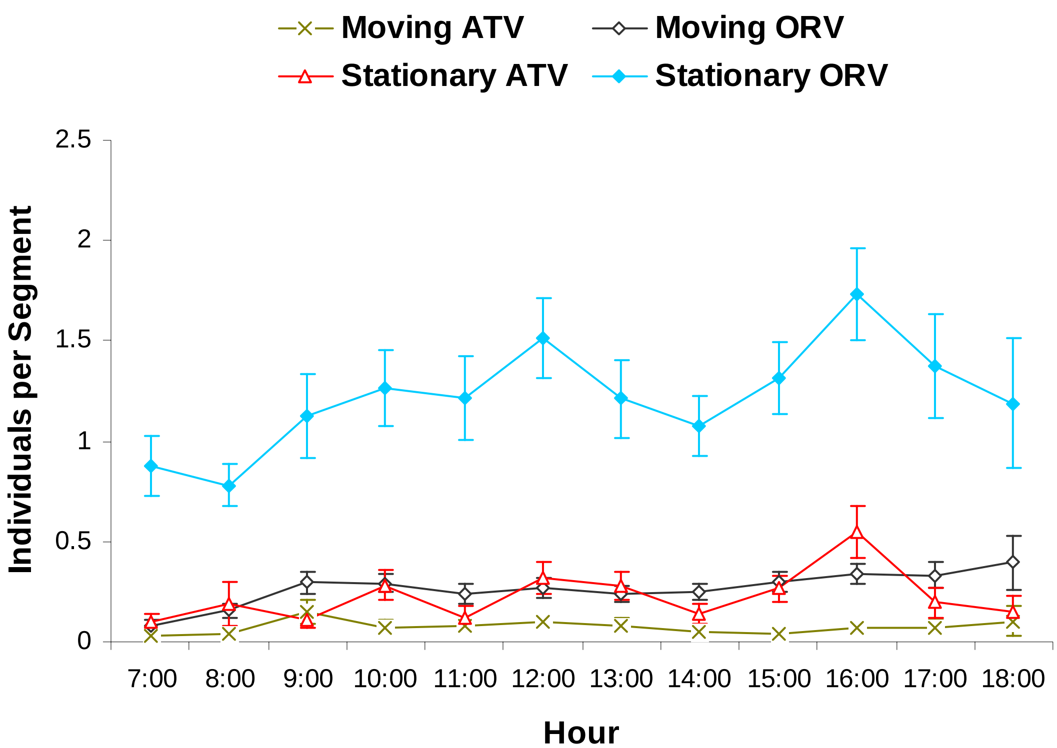

Figure 2.18. The average number of moving ATVs, stationary ATVs, moving ORVs, and stationary ORVs counted per segment survey for each daylight hour EST. Surveys from all tide levels, segments, years, dates, and observers were included, but we excluded detections of flying birds from this summary. Error bars represent one standard error, and 6:00 and 19:00 left out due to small sample sizes.

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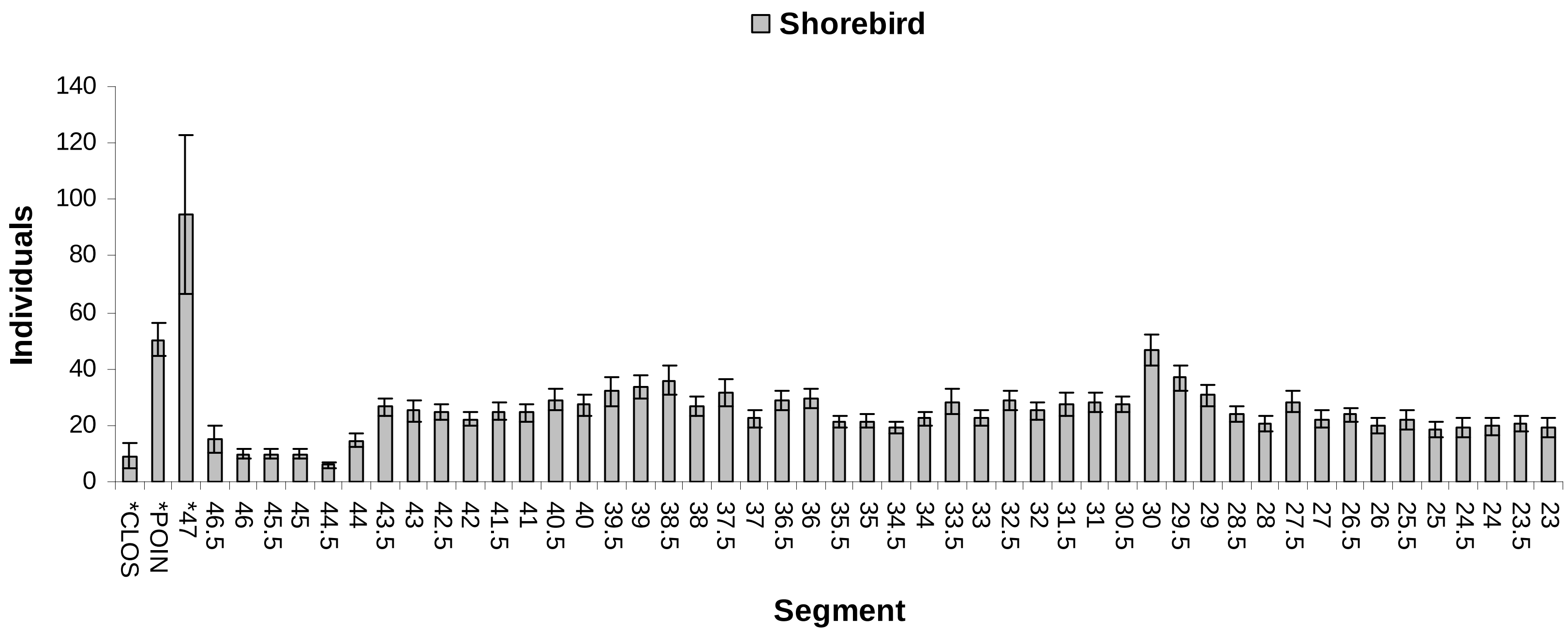

Figure 2.19. Average shorebird abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

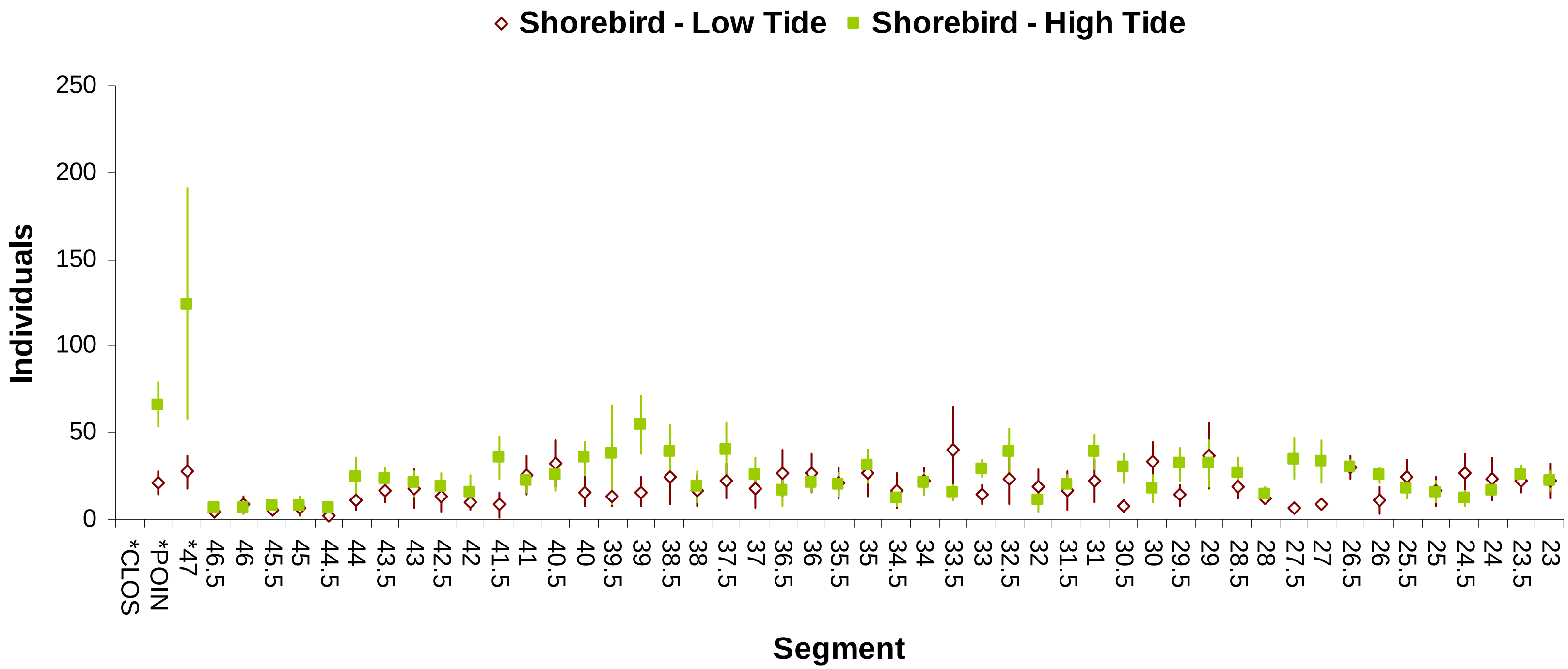

Figure 2.20. Average shorebird abundance with standard error bars for beach segments on South Core Banks, NC during high and rising tide levels in 2006 and 2007. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

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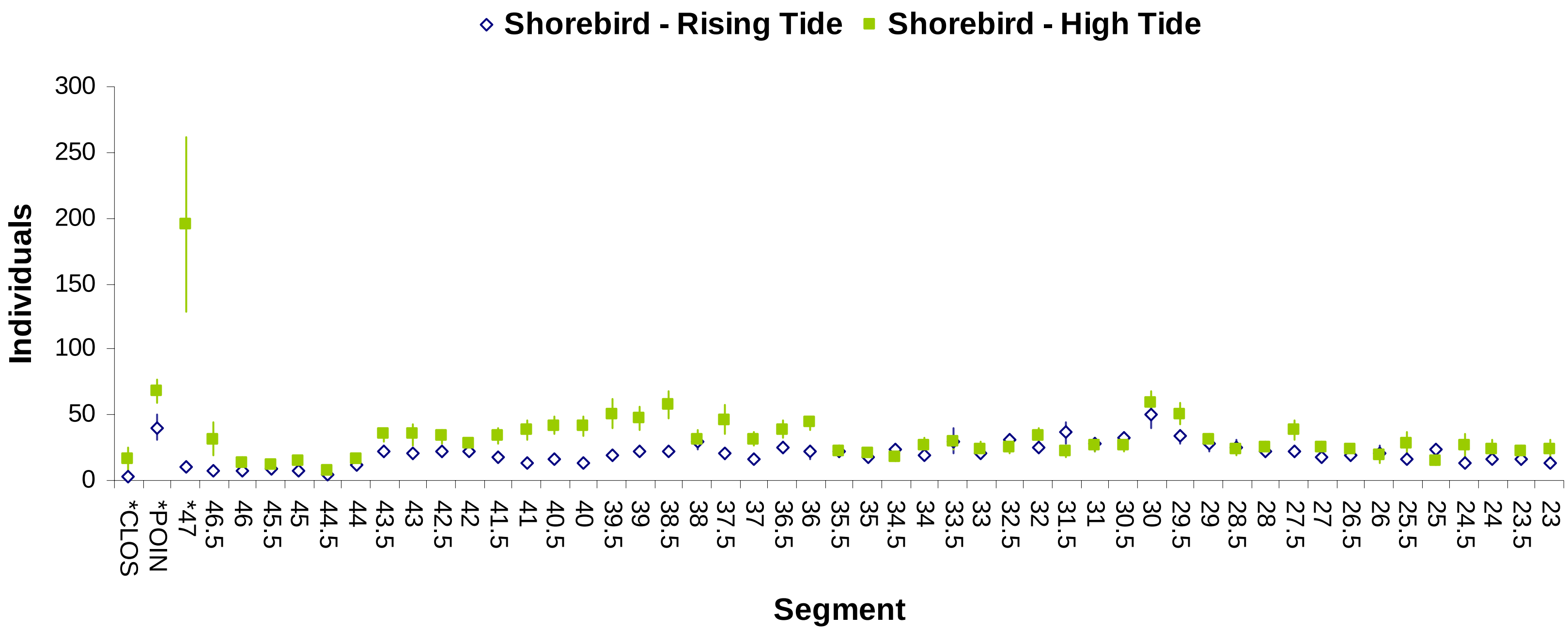

Figure 2.21. Average shorebird abundance at beach segments on South Core Banks, NC during low and high tide levels in 2005. Lines illustrate the standard error bars. Low tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

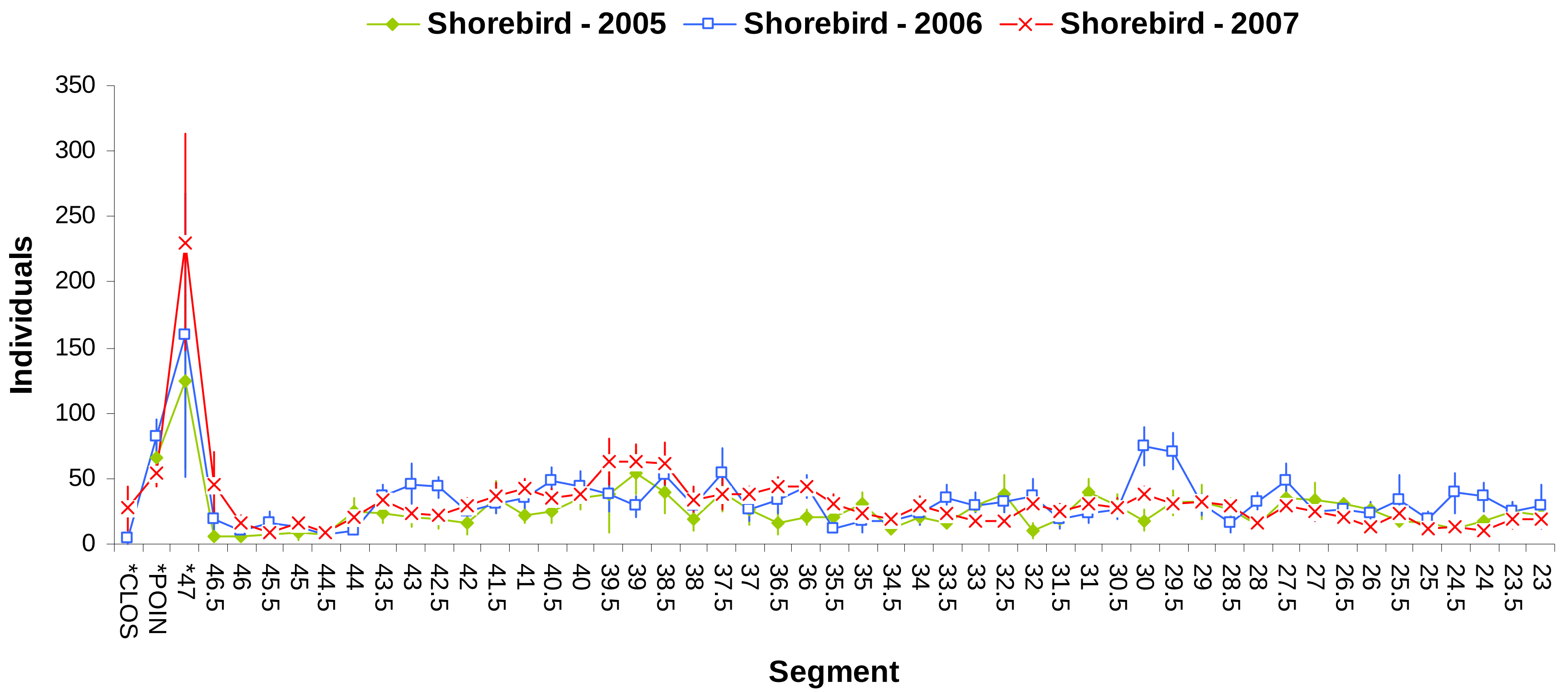

Figure 2.22. Average shorebird abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.
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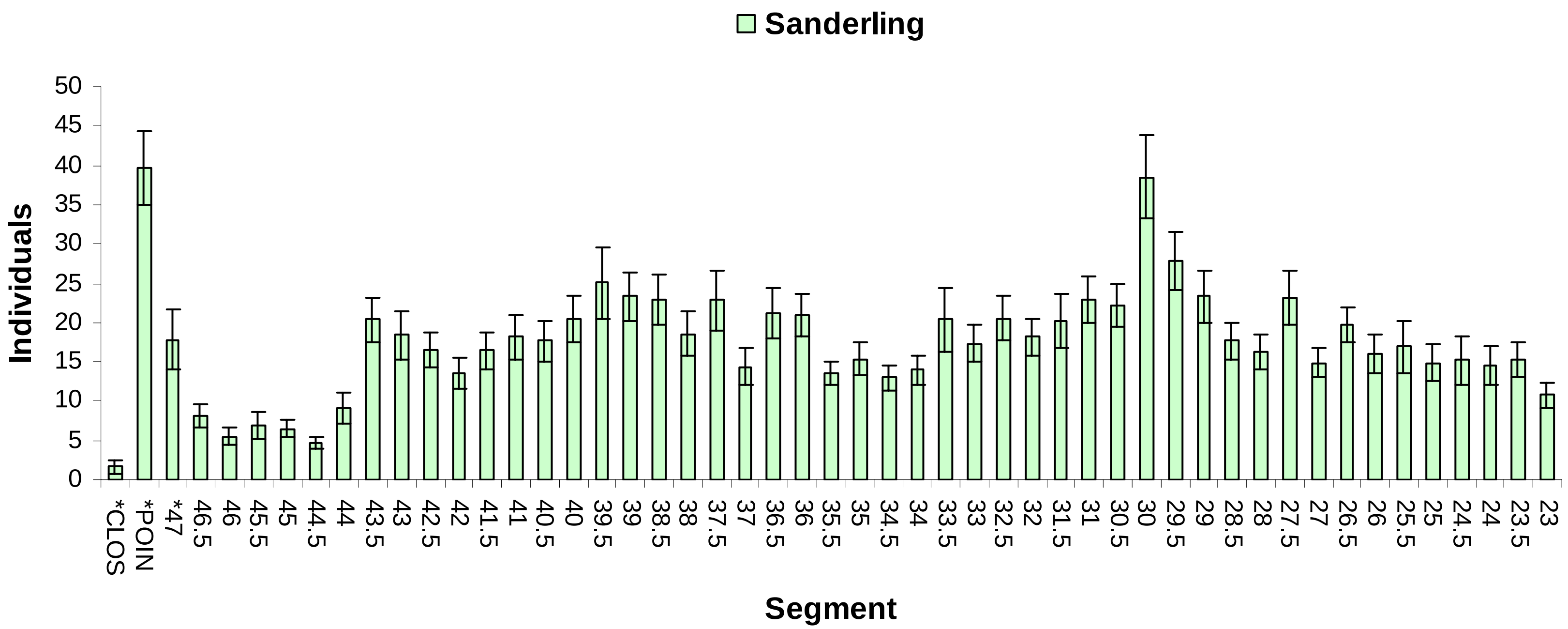

Figure 2.23. Average Sanderling abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

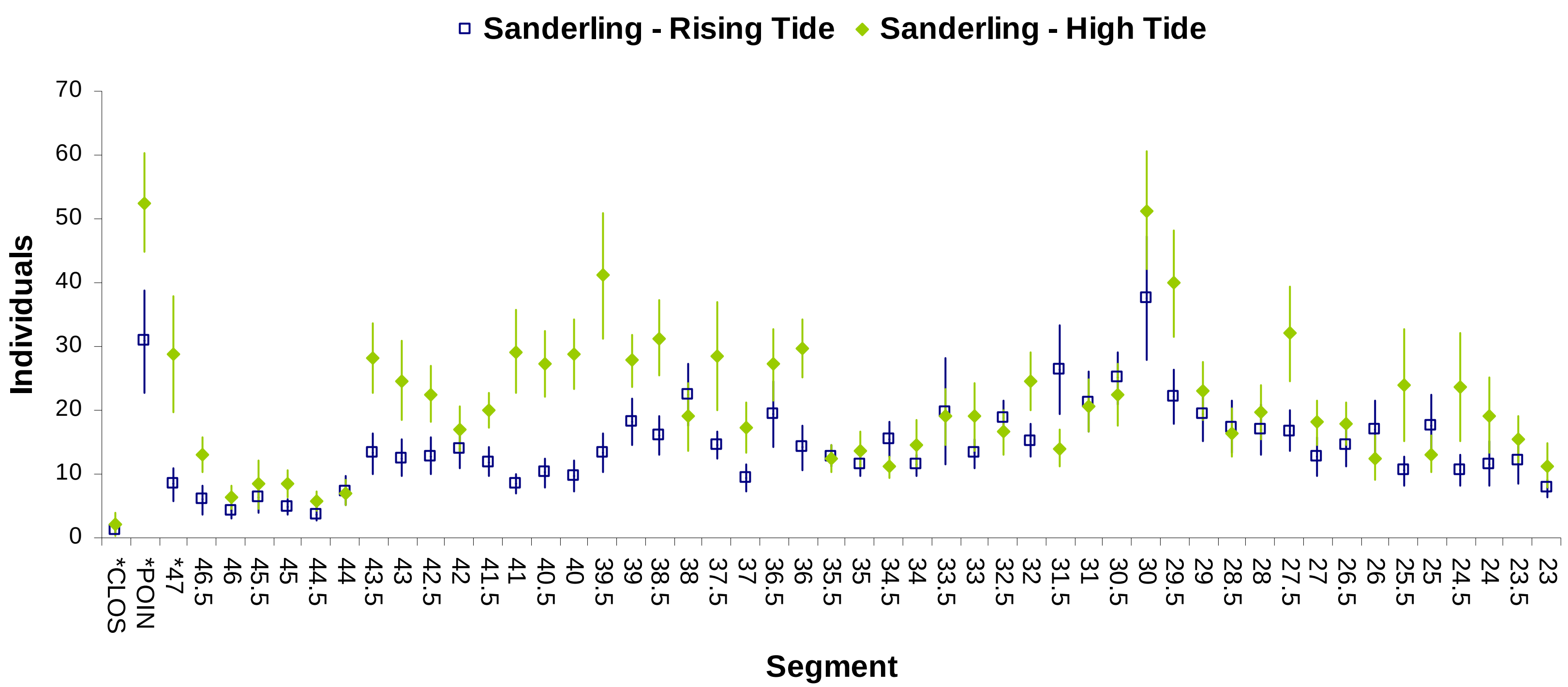

Figure 2.24. Average Sanderling abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

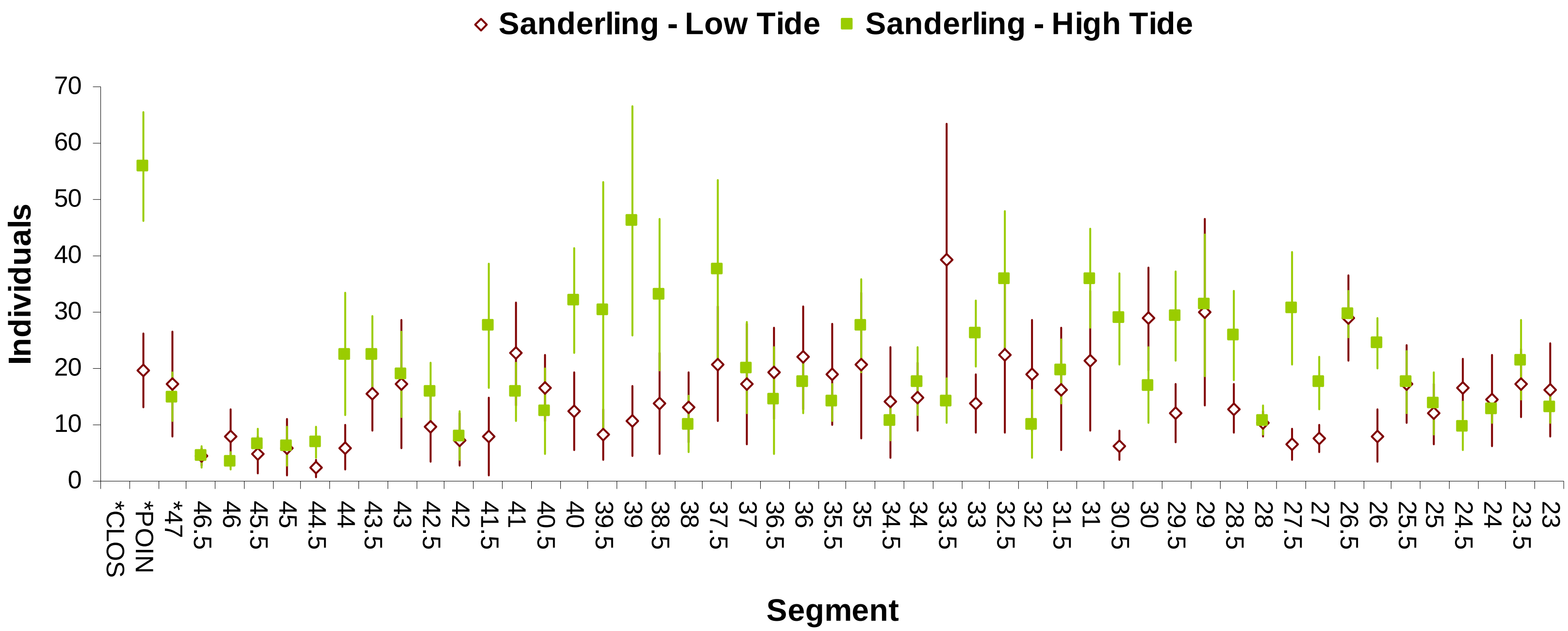

Figure 2.25. Average Sanderling abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Low tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

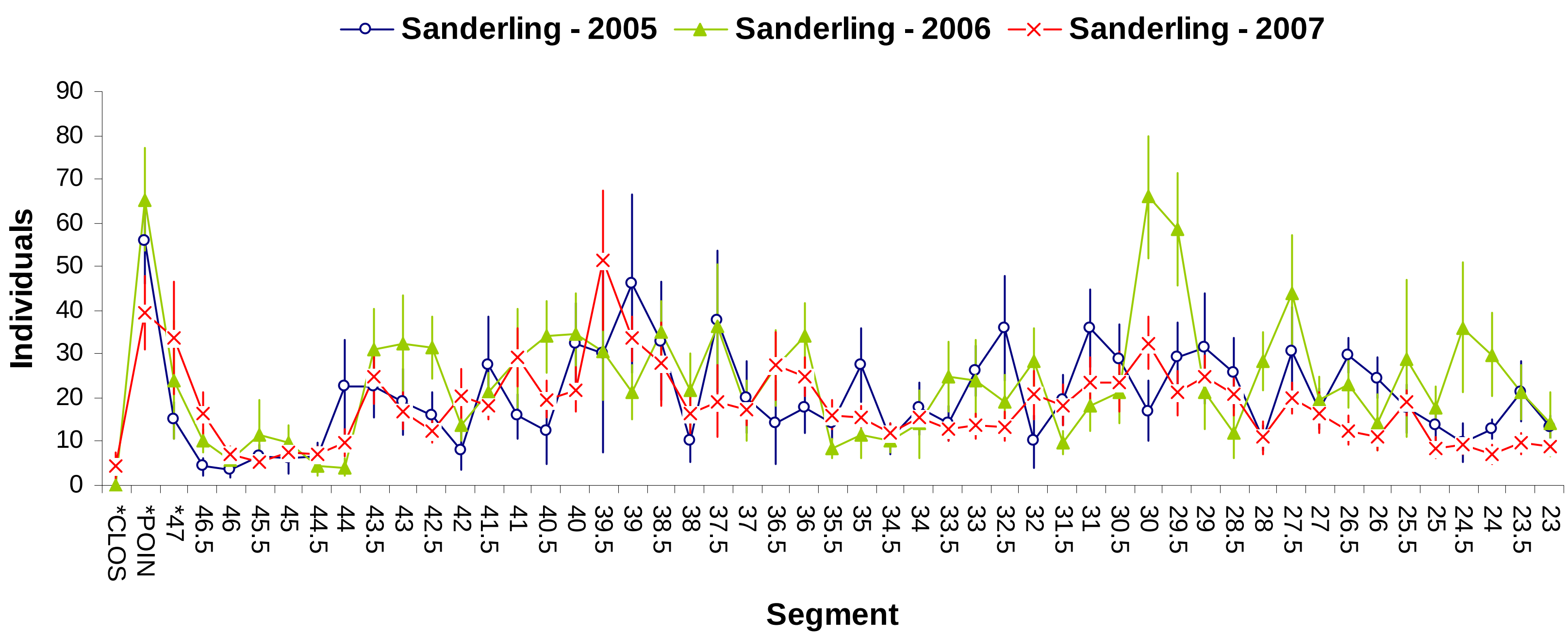

Figure 2.26. Average Sanderling abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

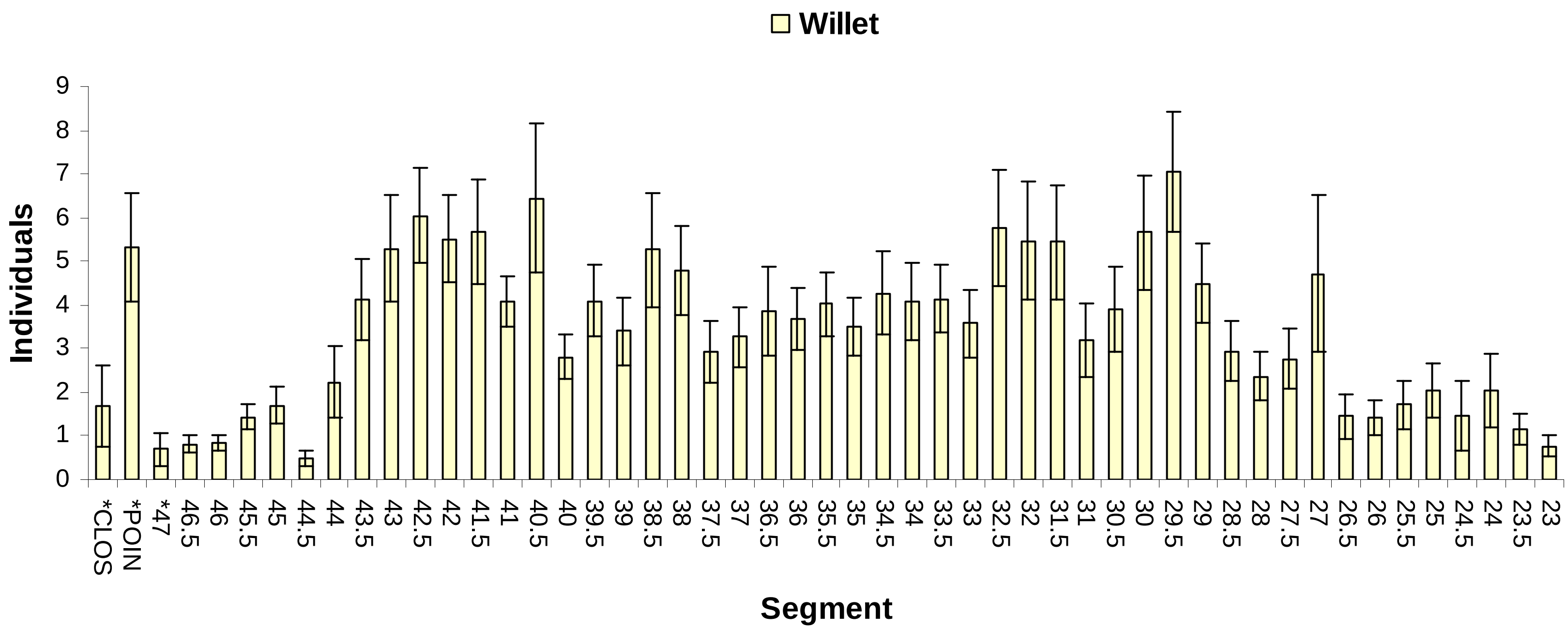

Figure 2.27. Average Willet abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

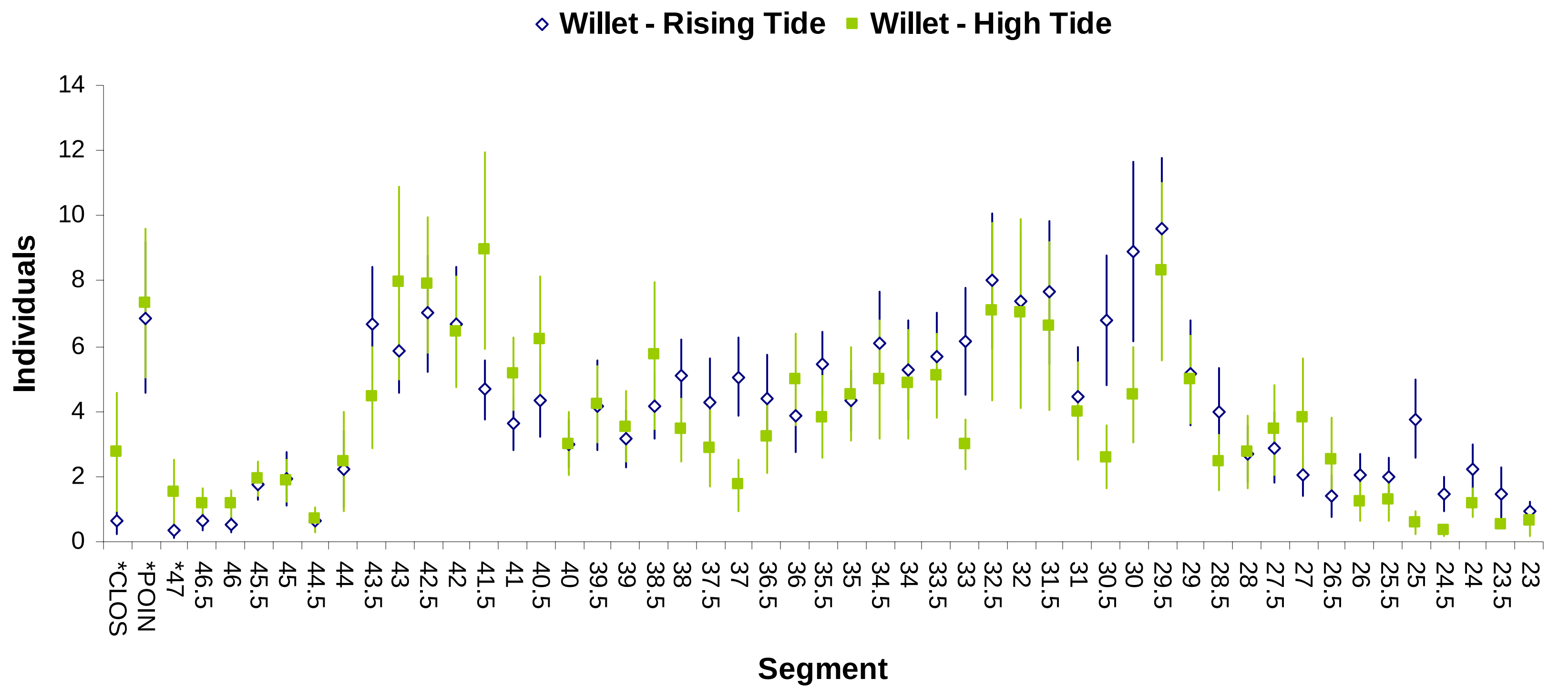

Figure 2.28. Average Willet abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

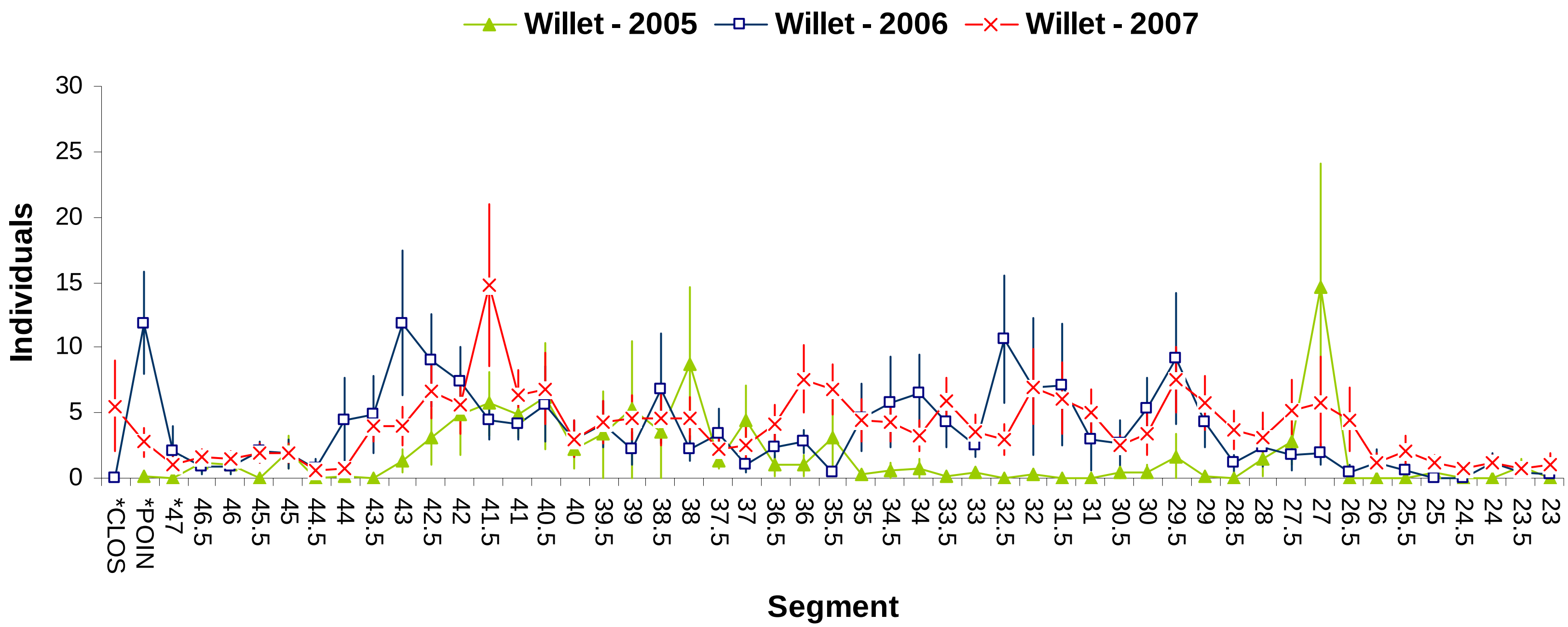

Figure 2.29. Average Willet abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

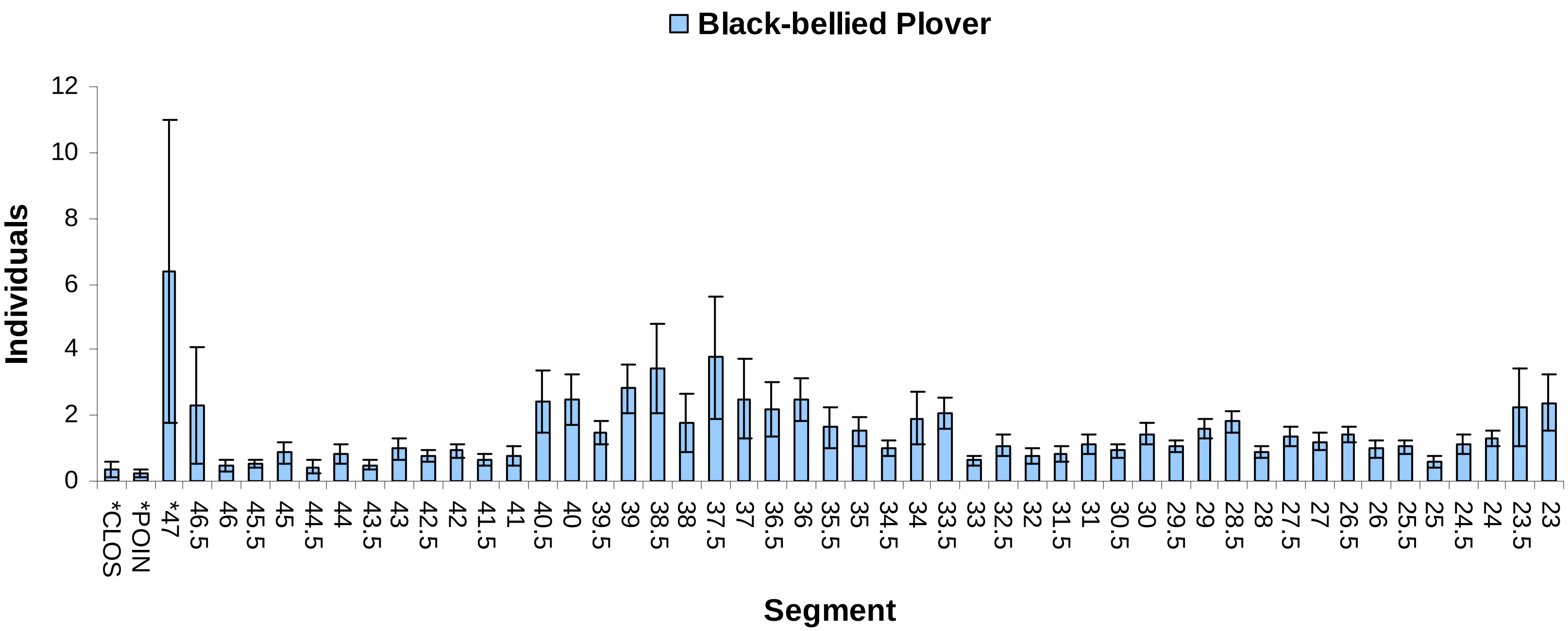

Figure 2.30. Average Black-bellied Plover abundance at beach segments on South Core Banks, NC with standard error bars. We named segments after their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

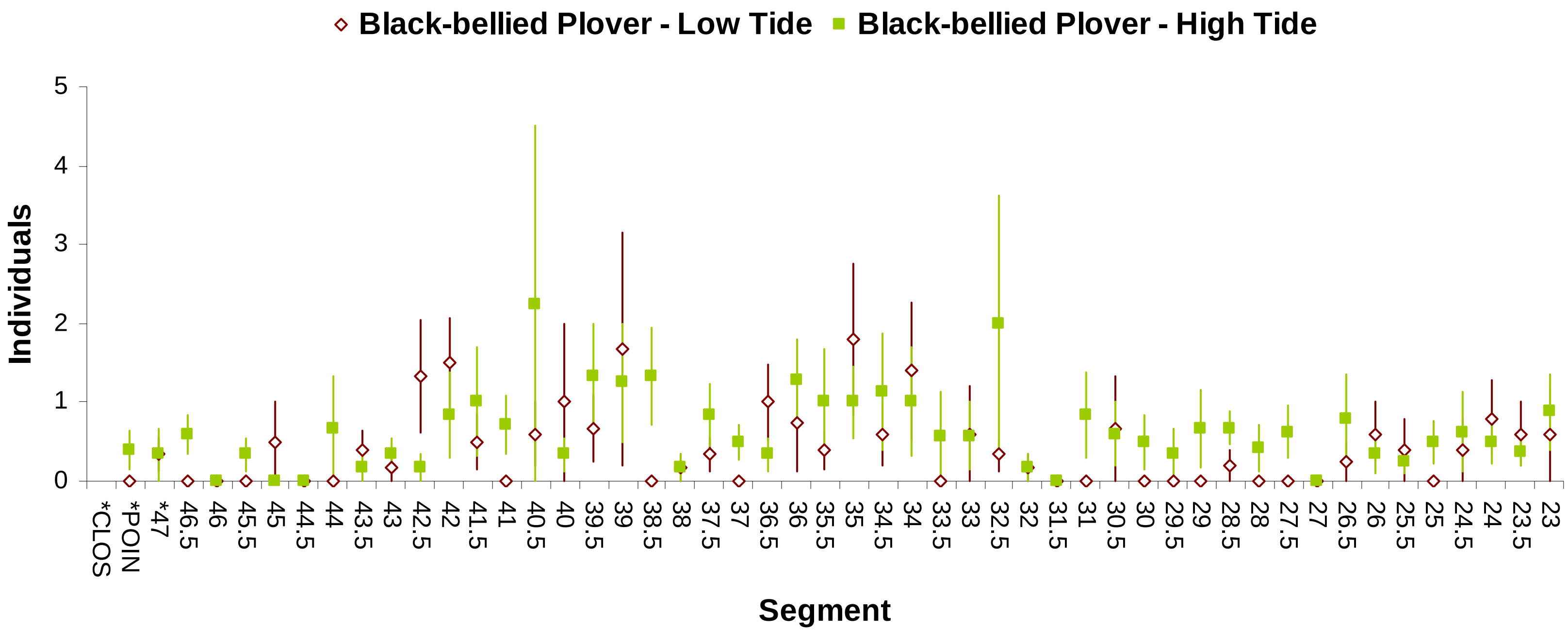

Figure 2.31. Average Black-bellied Plover abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Low tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

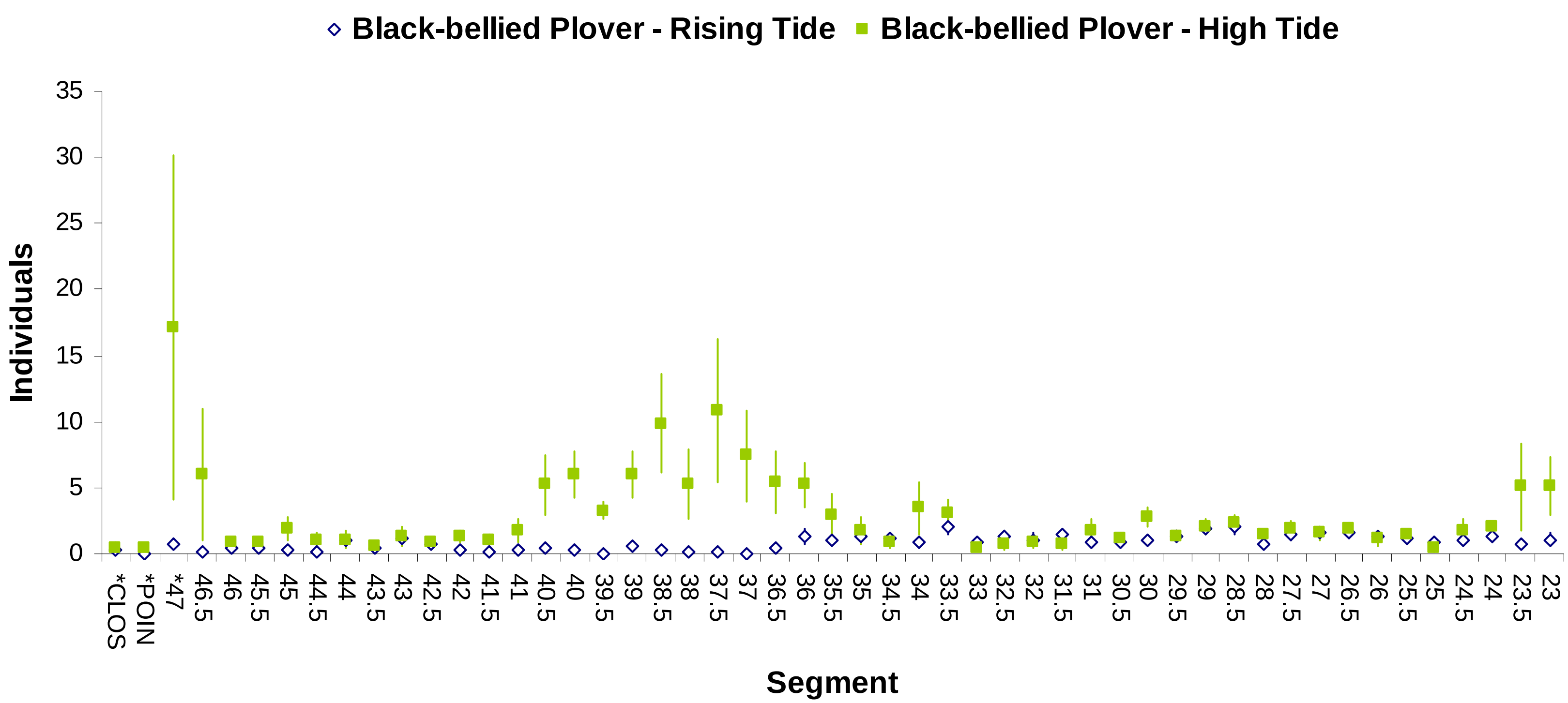

Figure 2.32. Average Black-bellied Plover abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

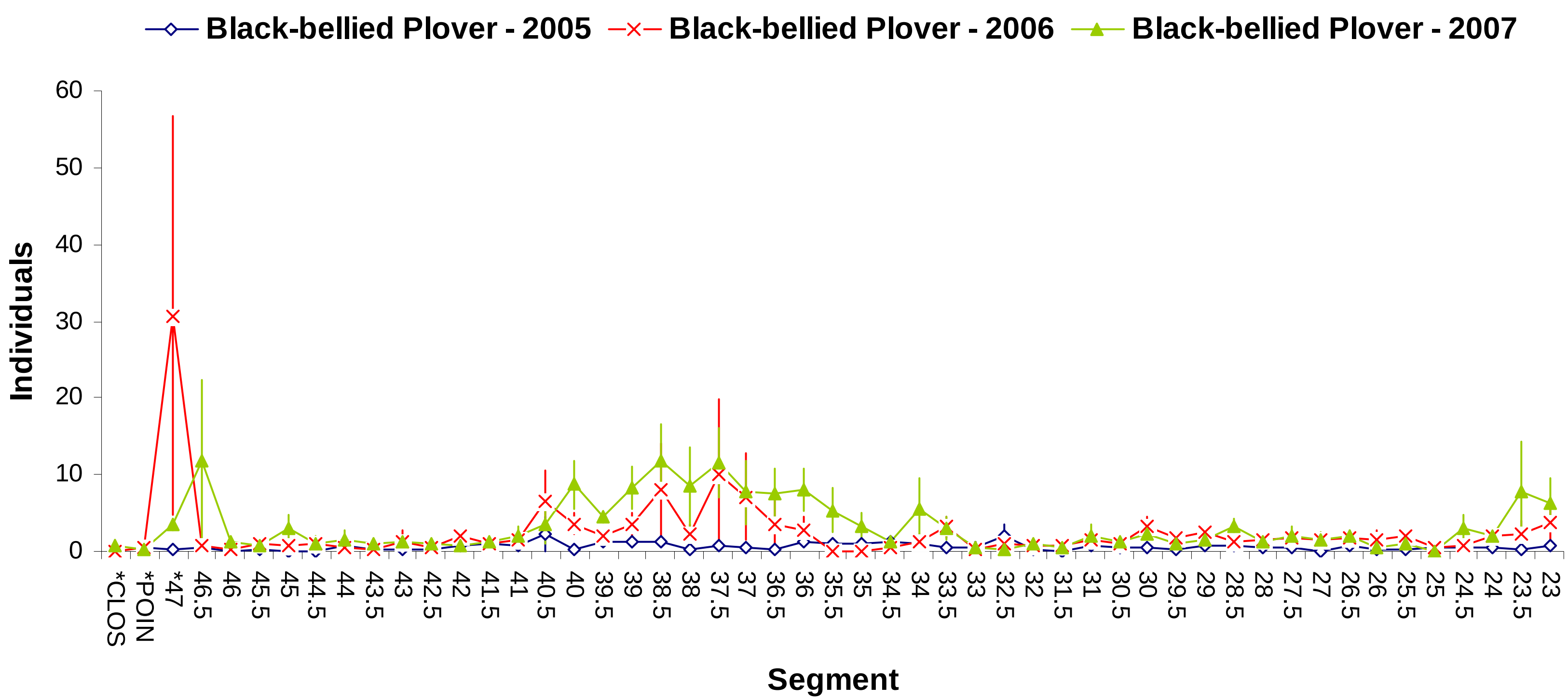

Figure 2.33. Average Black-bellied Plover abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT, and CLOSURE had different dimensions and beach structure than other segments.

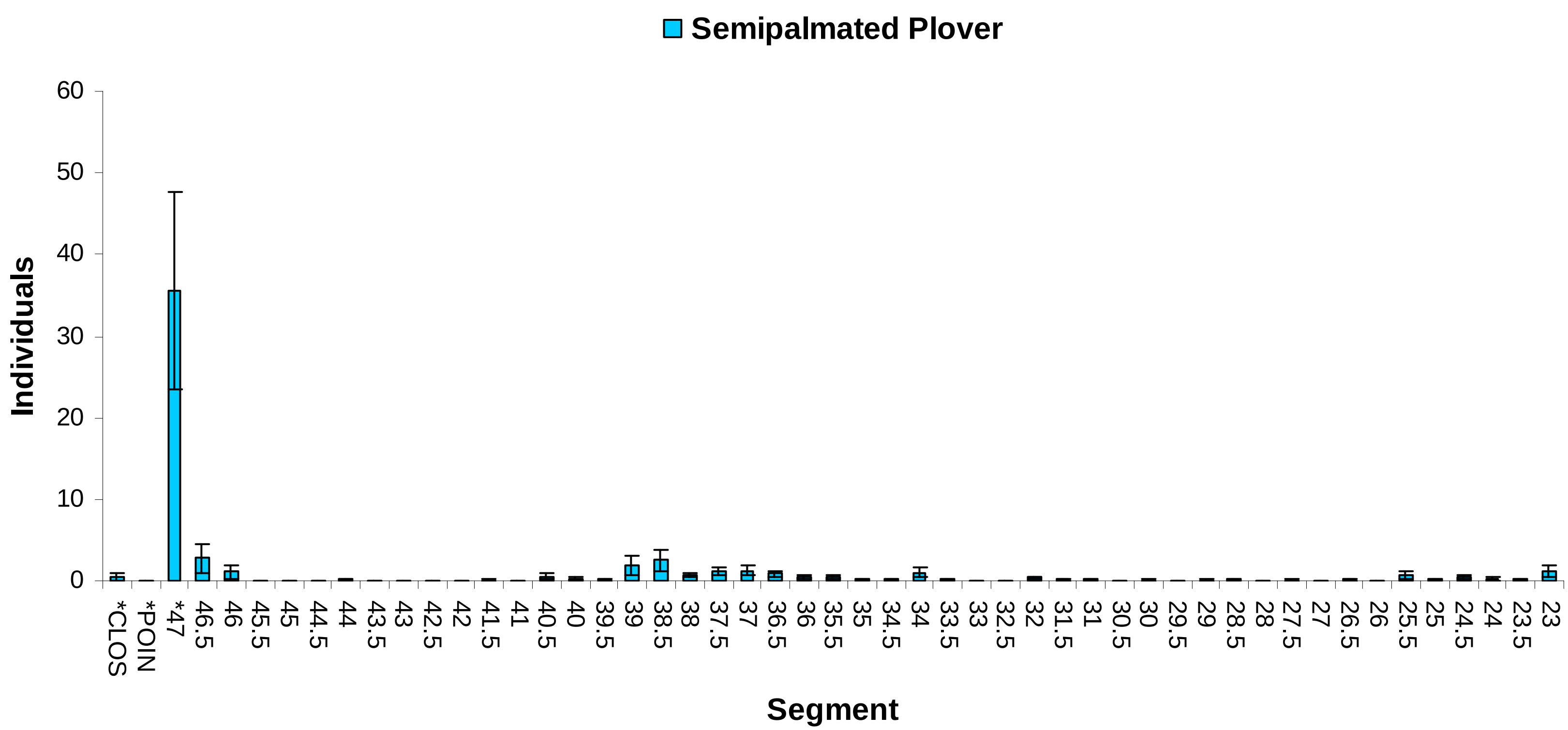

Figure 2.34. Average Semipalmated Plover abundance at beach segments on South Core Banks, NC with standard error bars. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

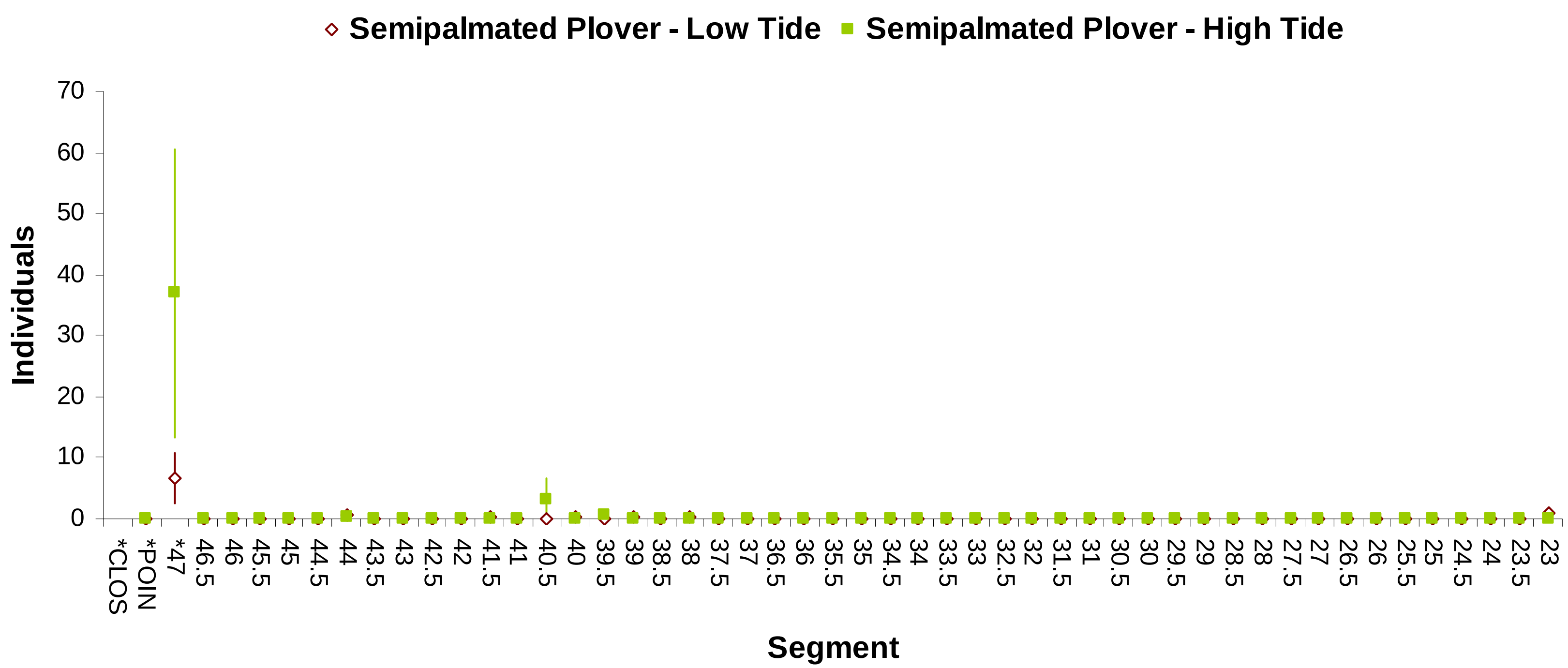

Figure 2.35. Average Semipalmated Plover abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

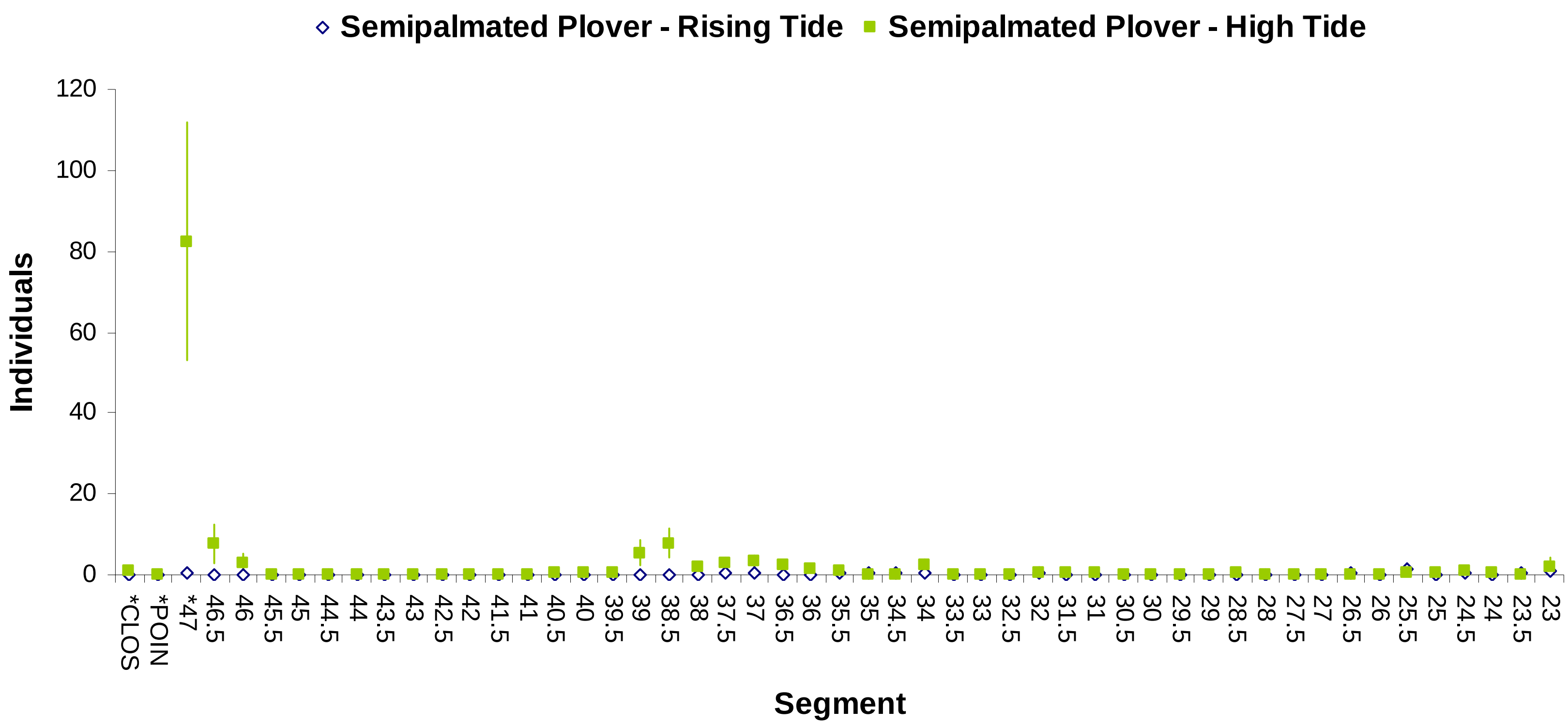

Figure 2.36. Average Semipalmated Plover abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

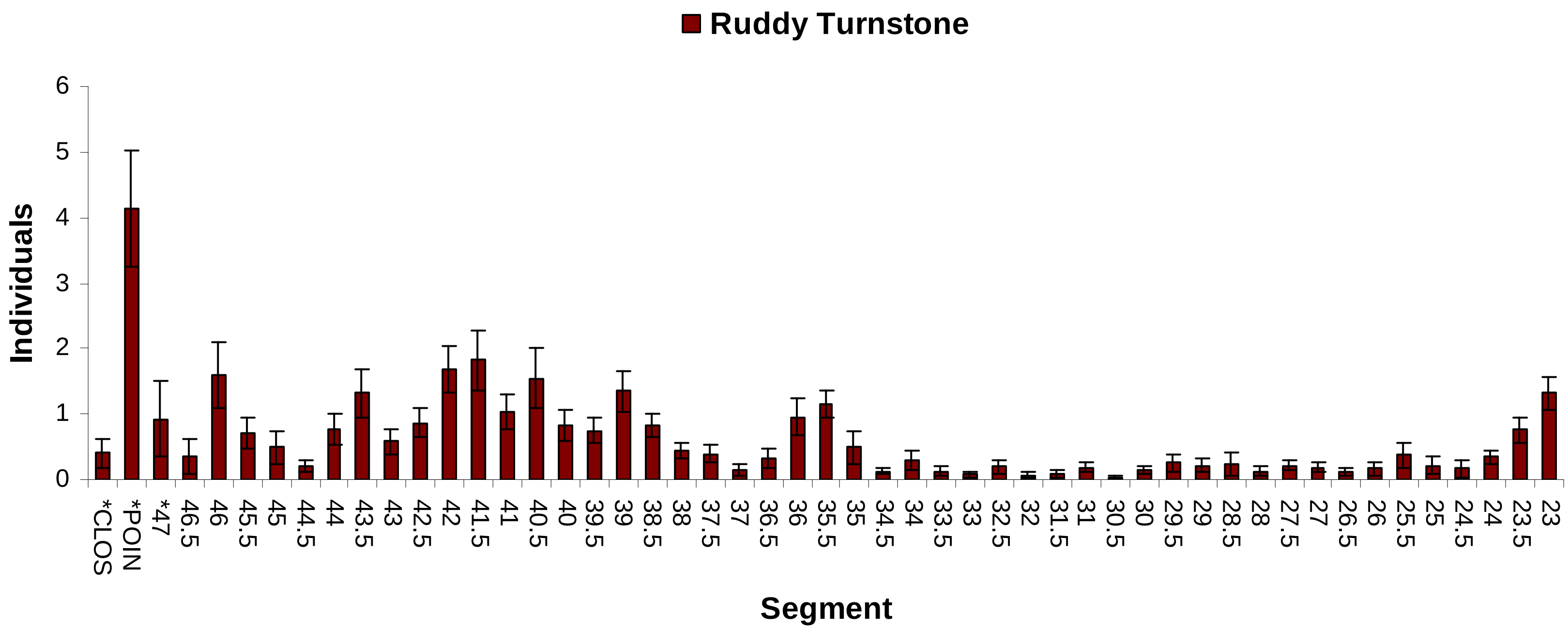

Figure 2.37. Average Ruddy Turnstones abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

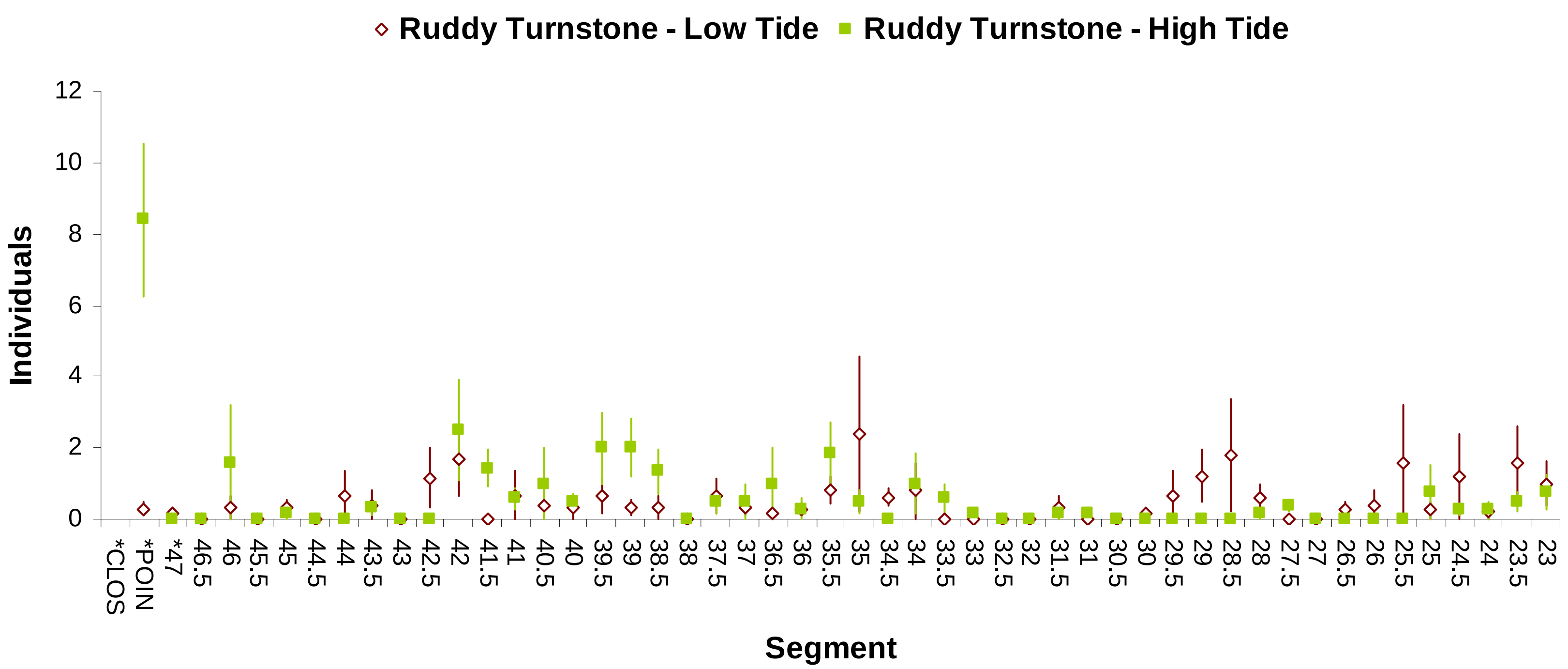

Figure 2.38. Average Ruddy Turnstone abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Low tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

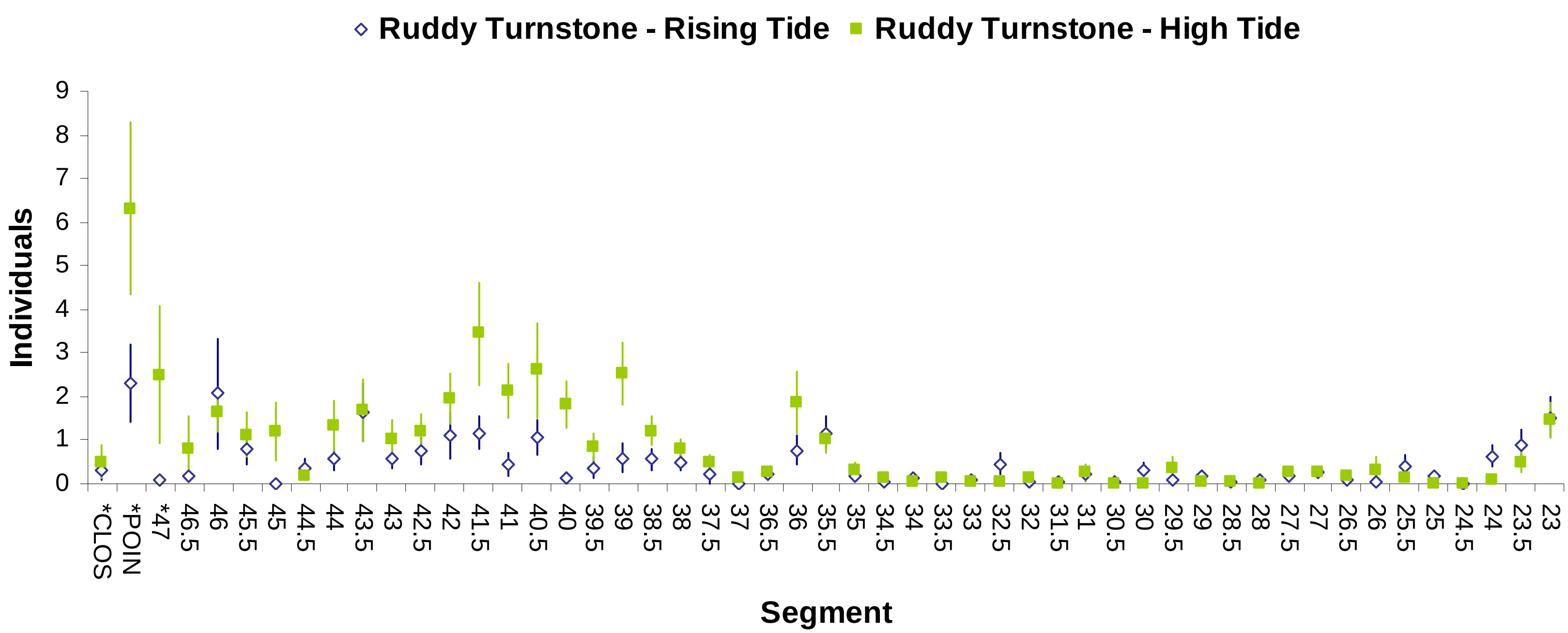

Figure 2.39. Average Ruddy Turnstone abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

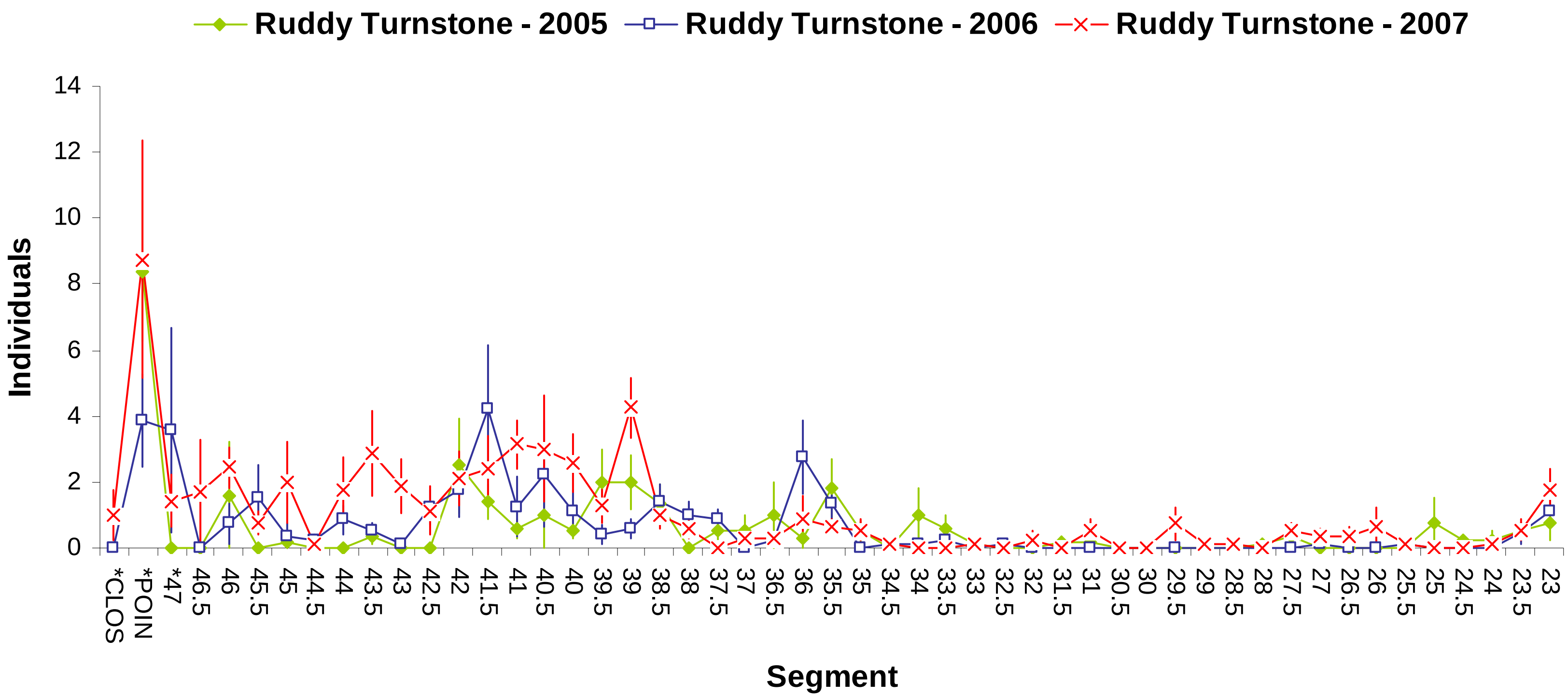

Figure 2.40. Average Ruddy Turnstone abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

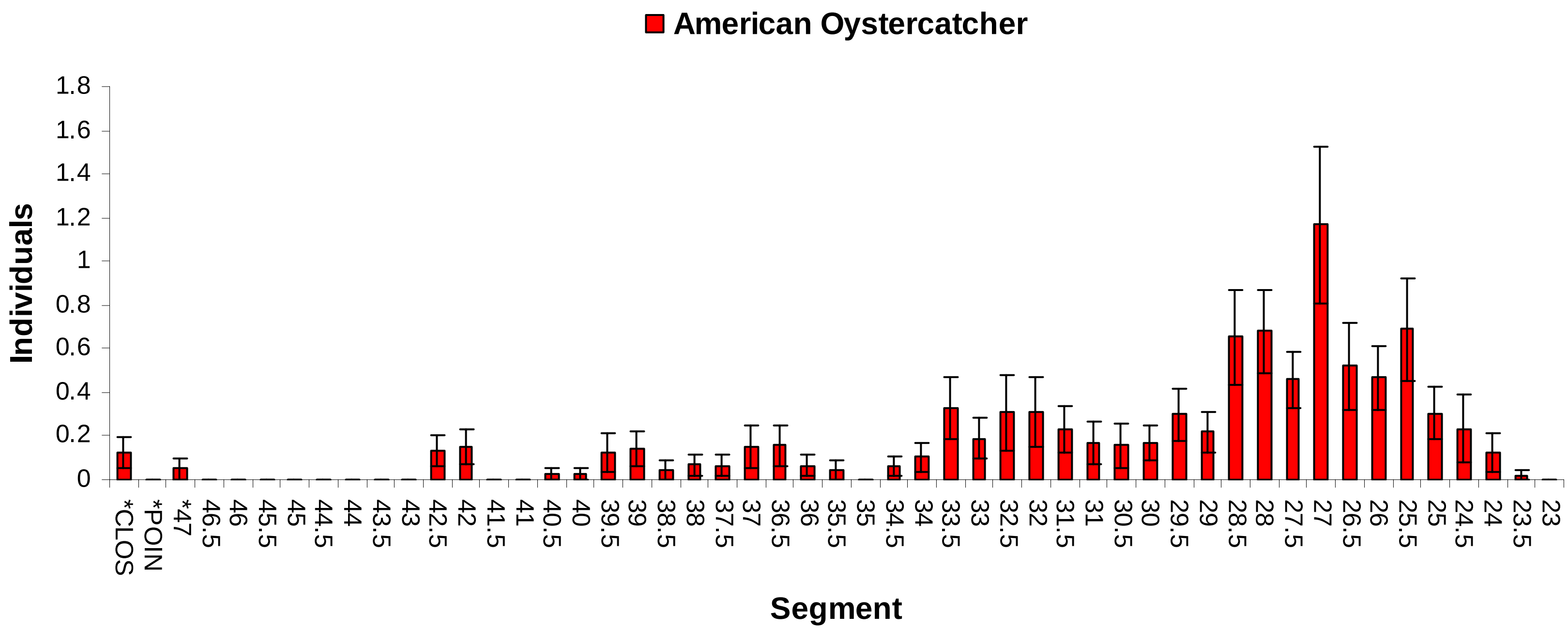

Figure 2.41. Average American Oystercatcher abundance at beach segments on South Core Banks, NC with standard error bars. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

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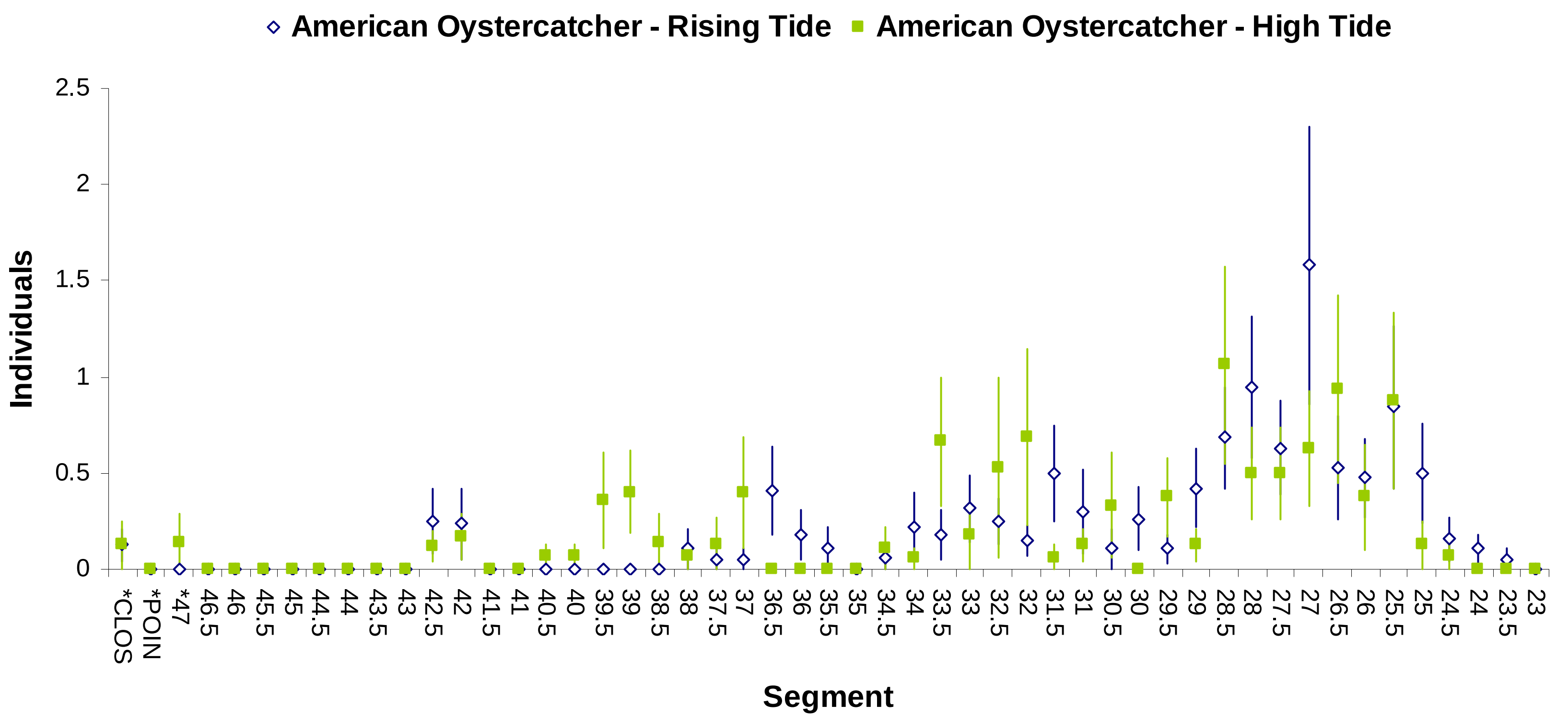

Figure 2.42. Average American Oystercatcher abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

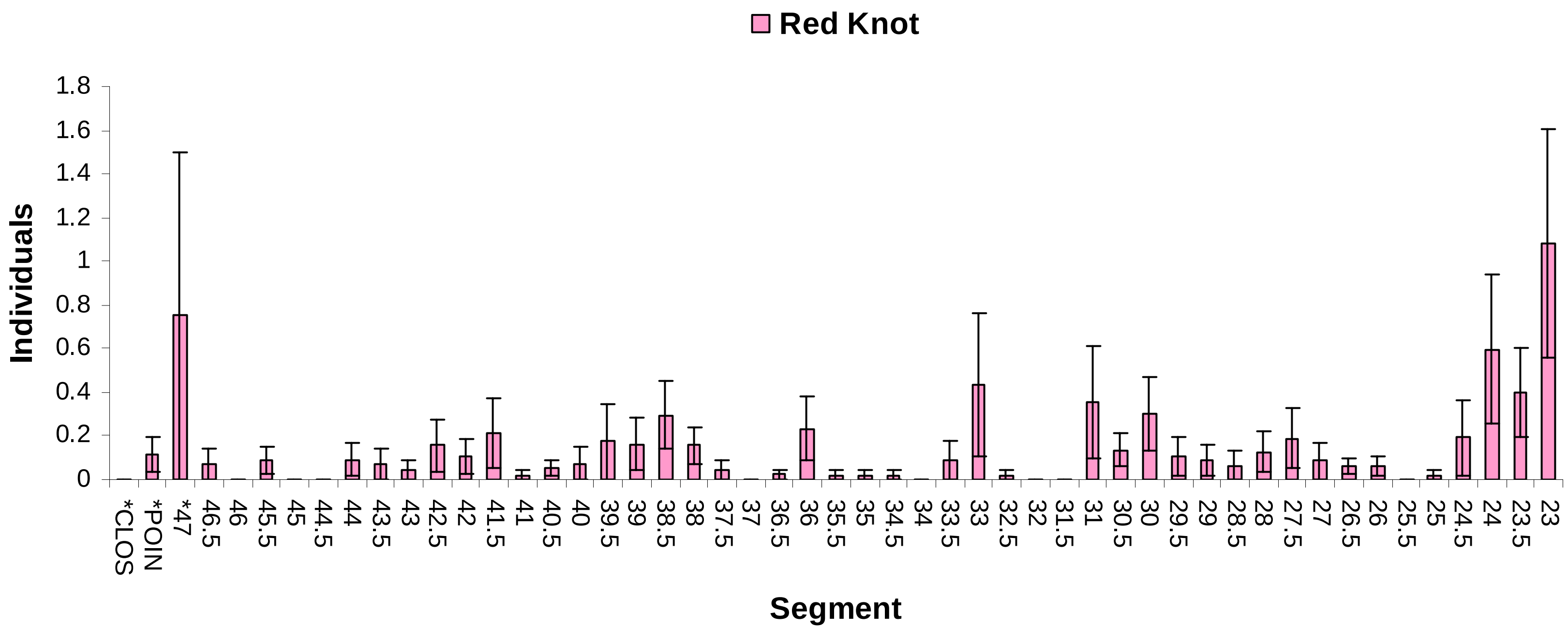

Figure 2.43. Average Red Knot abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

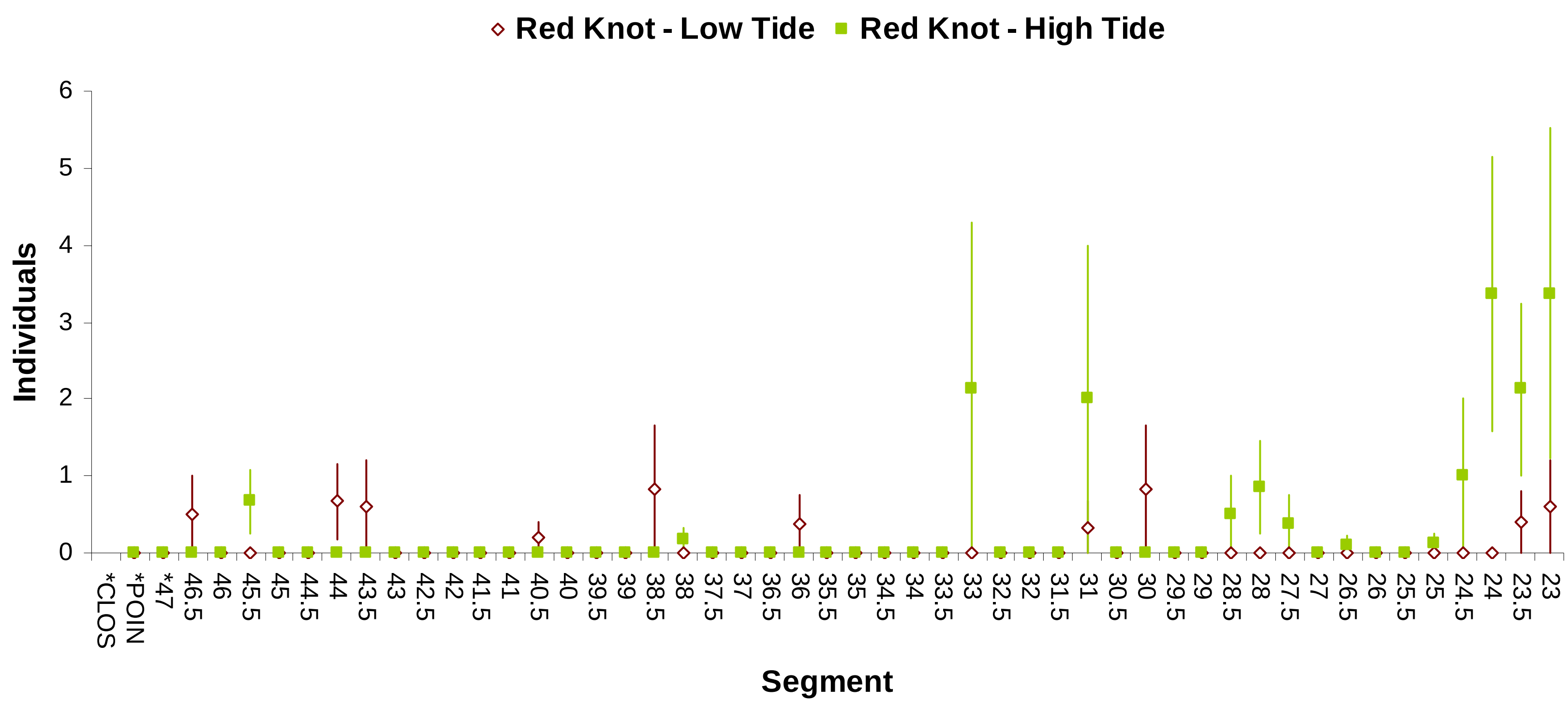

Figure 2.44. Average Red Knot abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Low tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

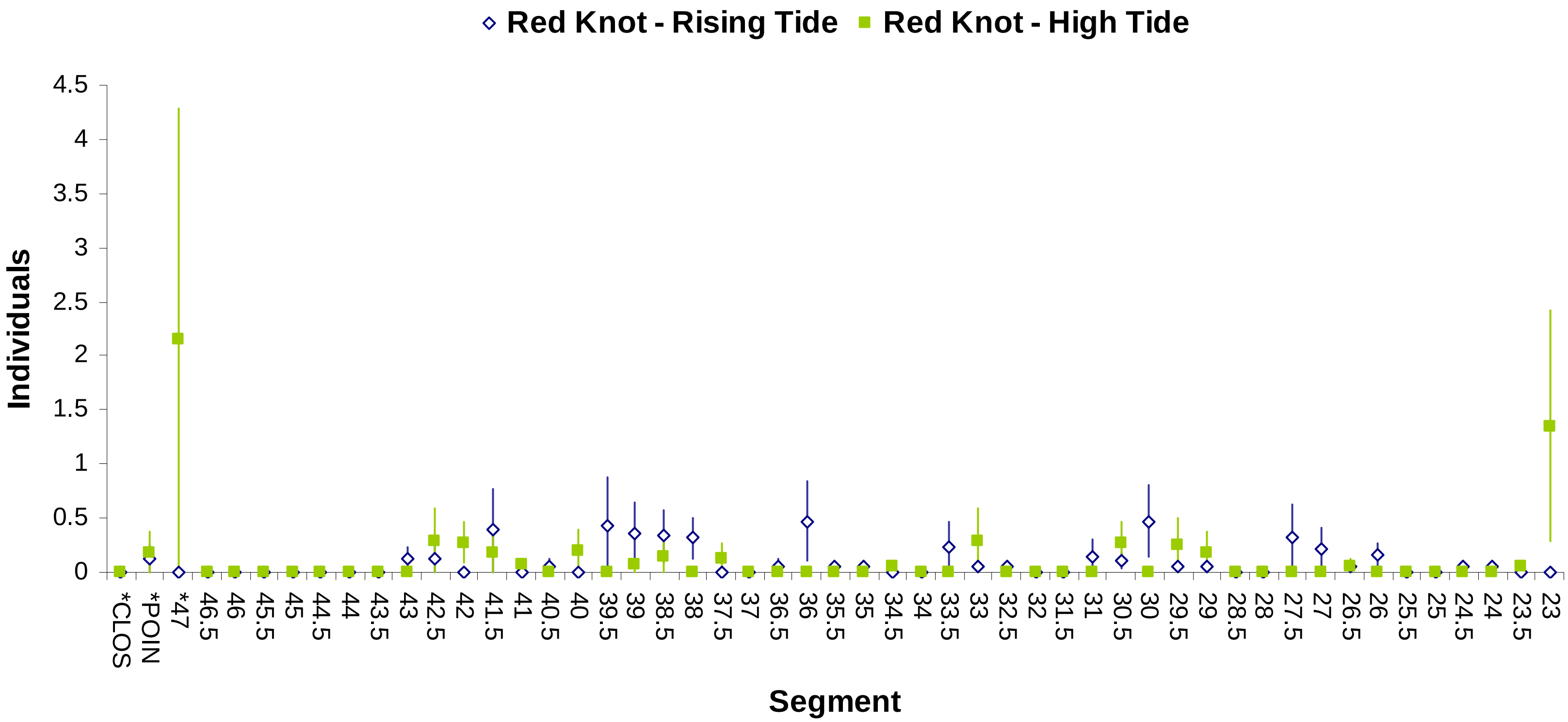

Figure 2.45. Average Red Knot abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

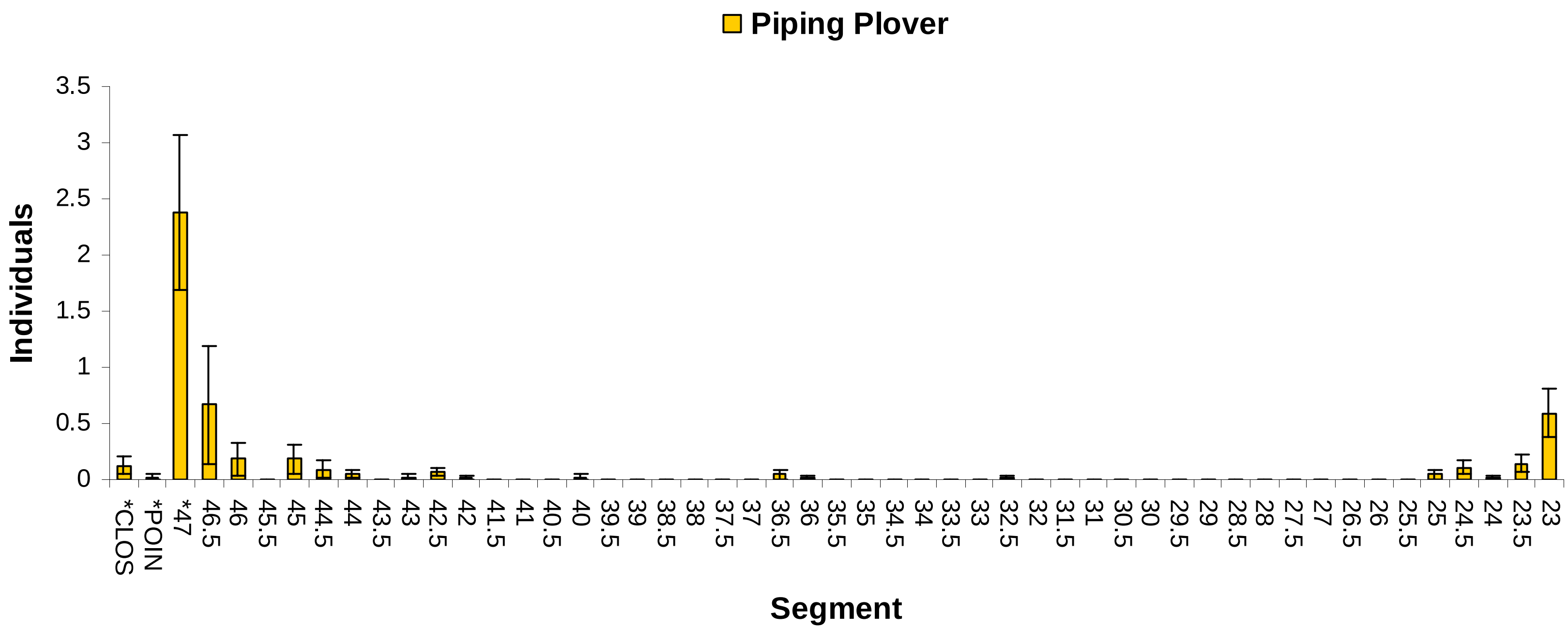

Figure 2.46. Average Piping Plover abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

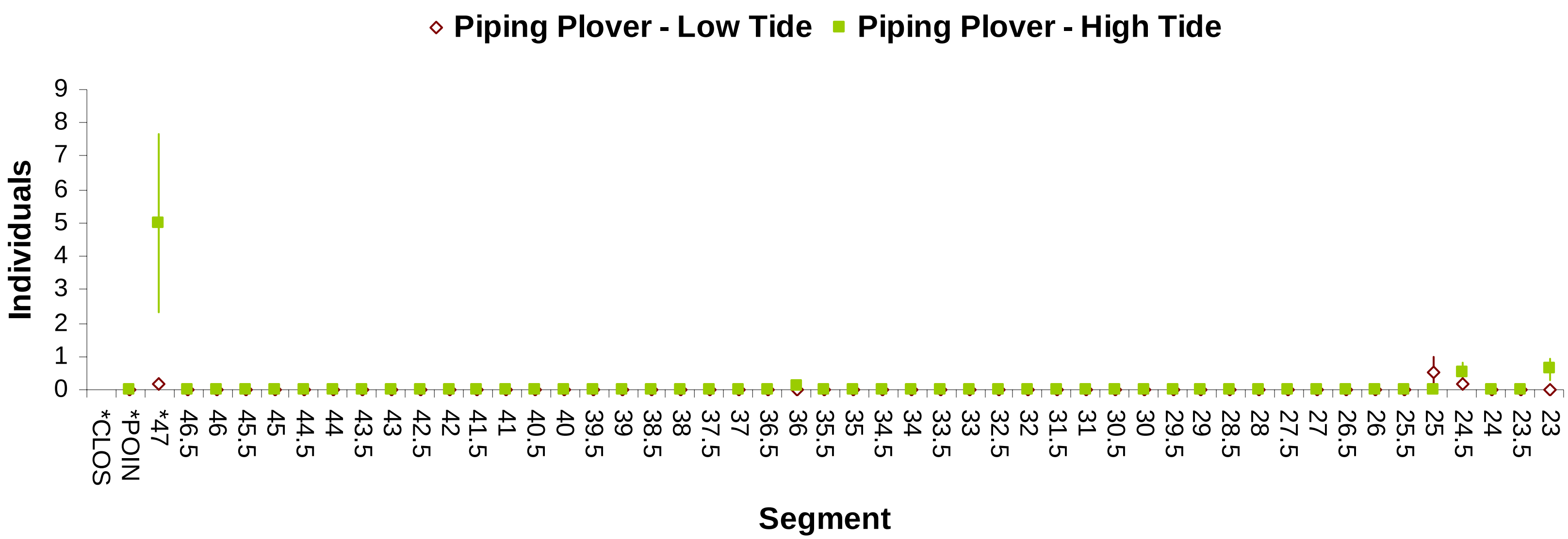

Figure 2.47. Average Piping Plover abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

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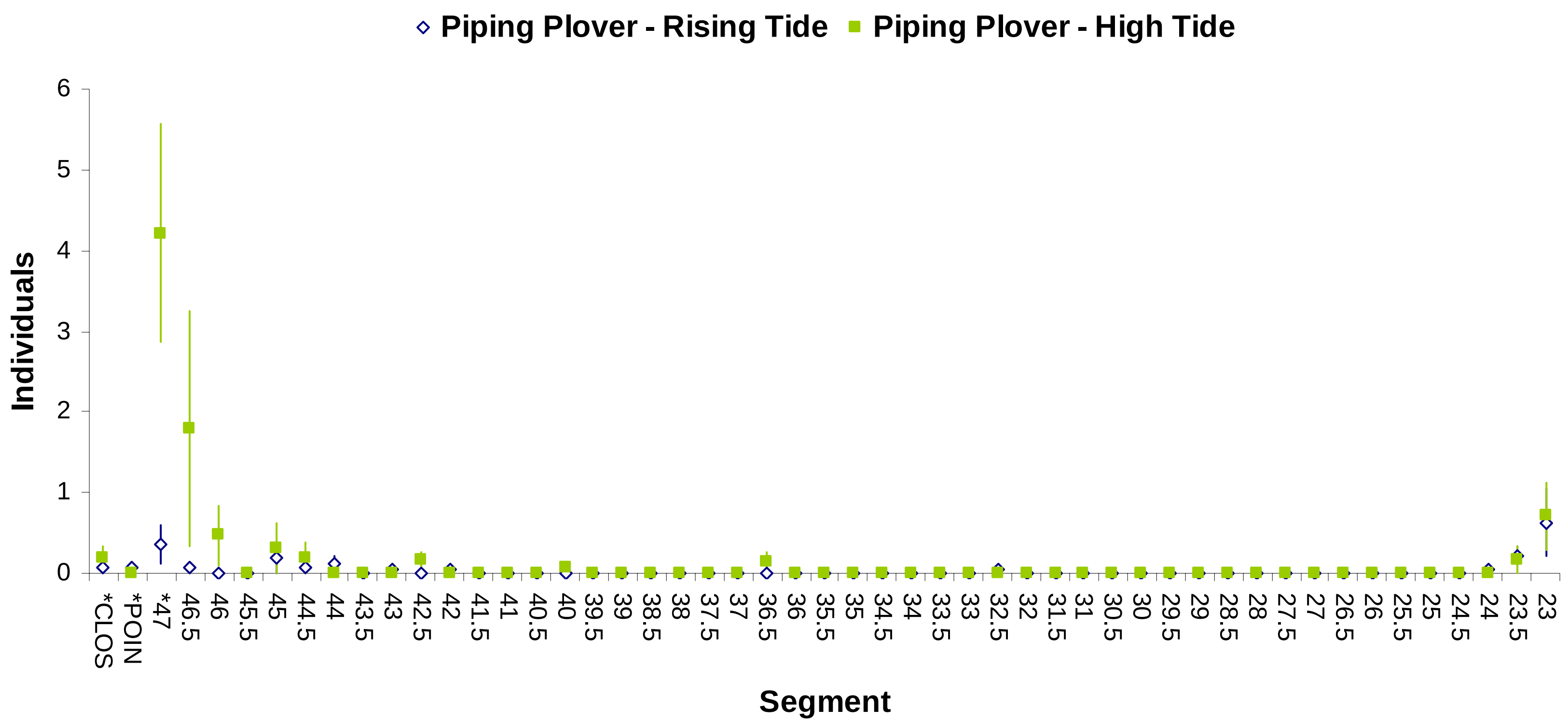

Figure 2.48. Average Piping Plover abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

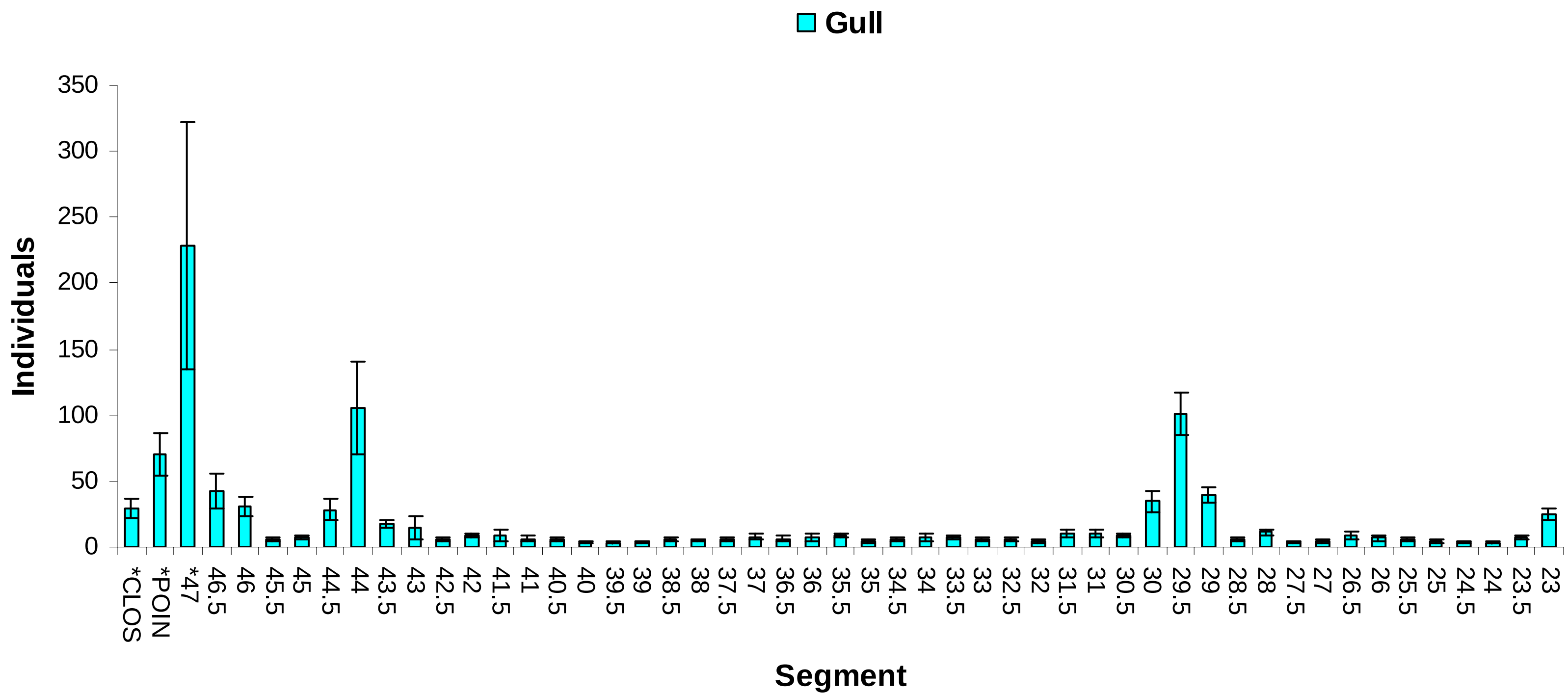

Figure 2.49. Average gull abundance at beach segments on South Core Banks, NC with standard error bars. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

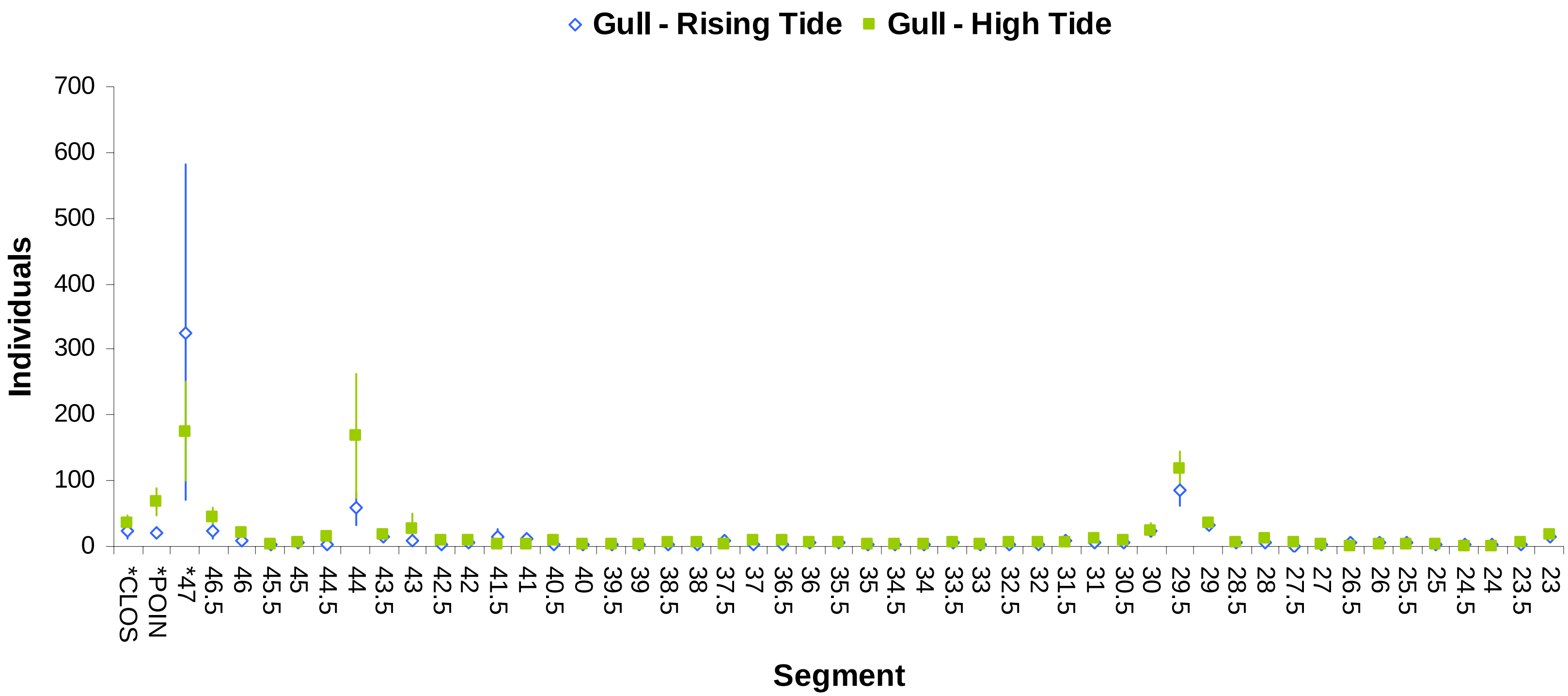

Figure 2.50. Average gull abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

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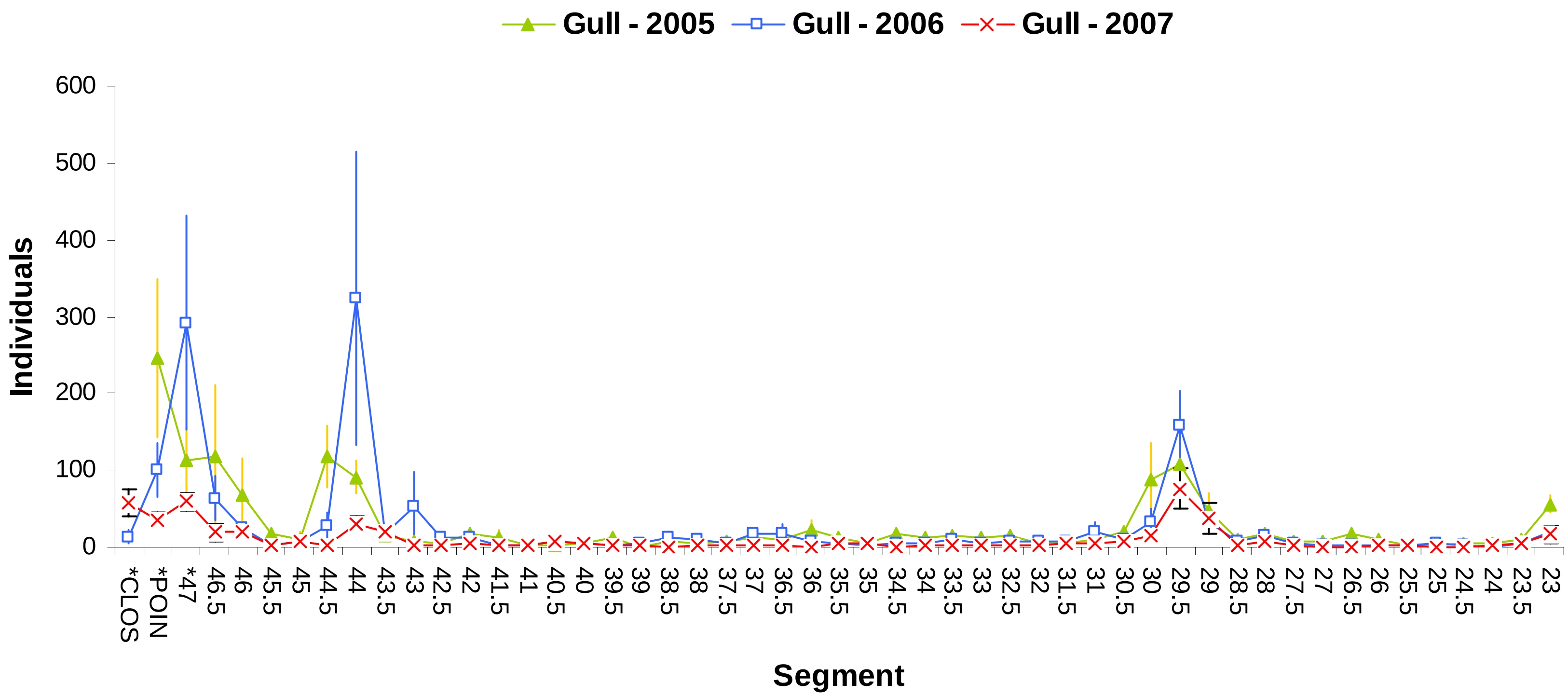

Figure 2.51. Average gull abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

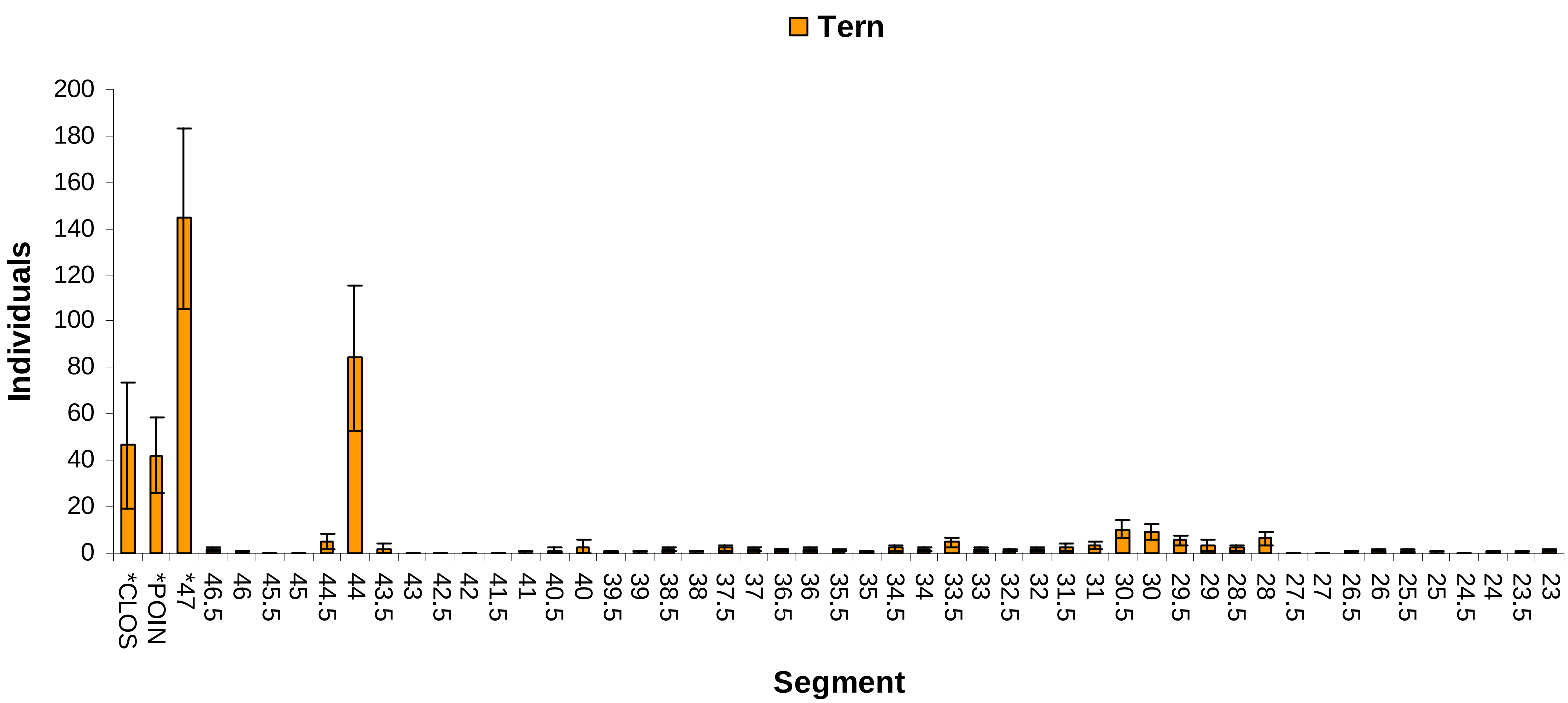

Figure 2.52. Average tern abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

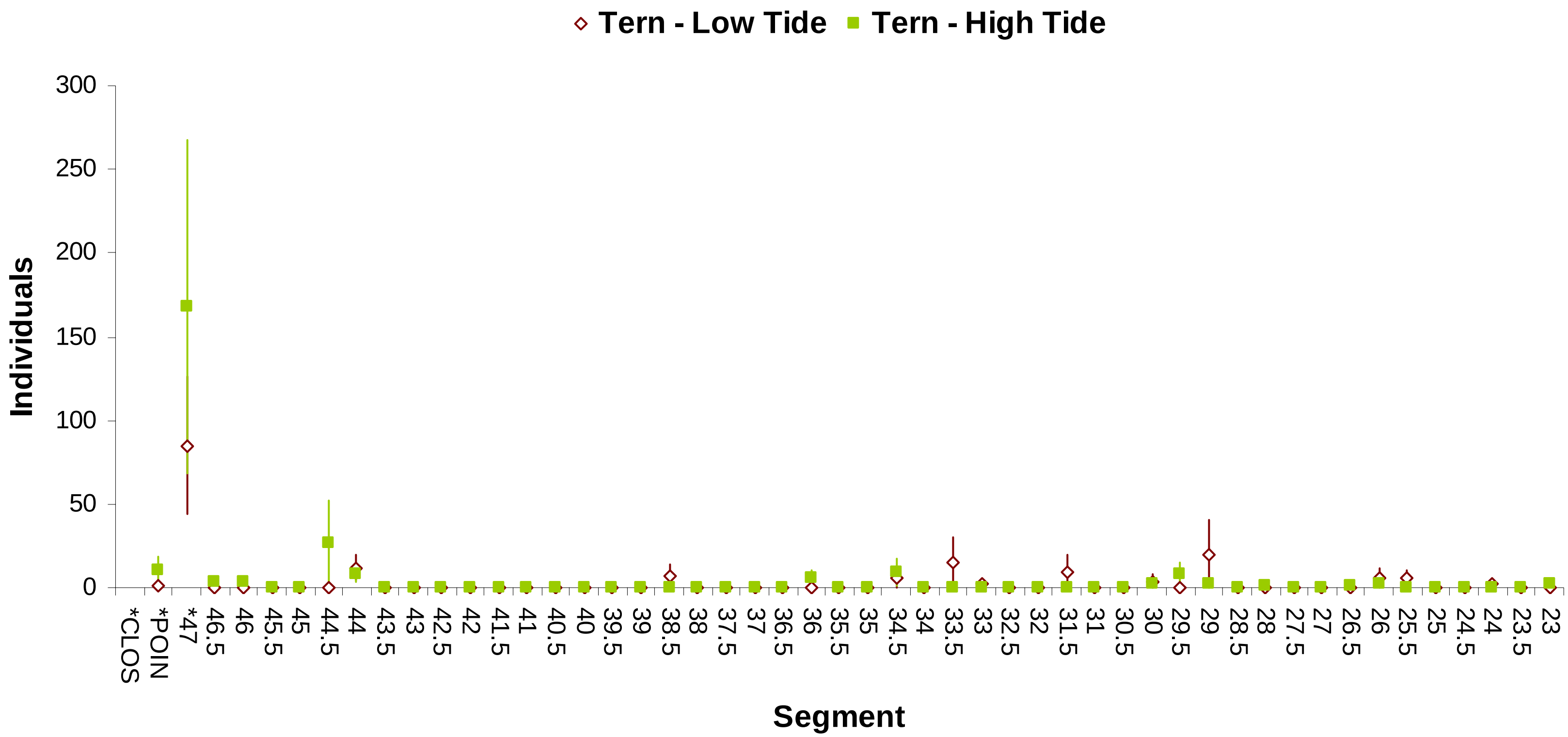

Figure 2.53. Average tern abundance at beach segments during low and high tide levels. Data from 2005 were used in this summary and lines illustrate the standard errors. Rising tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

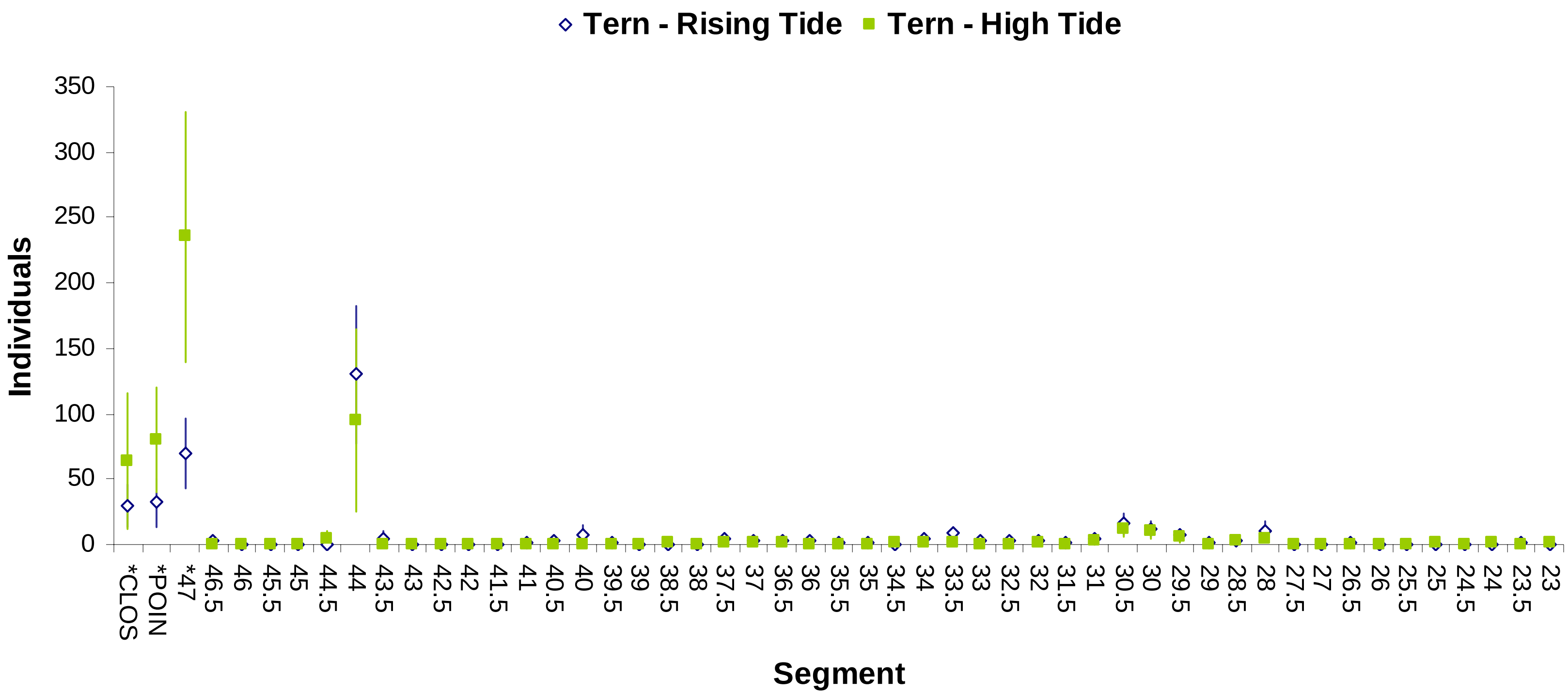

Figure 2.54. Average tern abundance at beach segments during high and rising tide levels. Data from 2006 and 2007 were used in this summary, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

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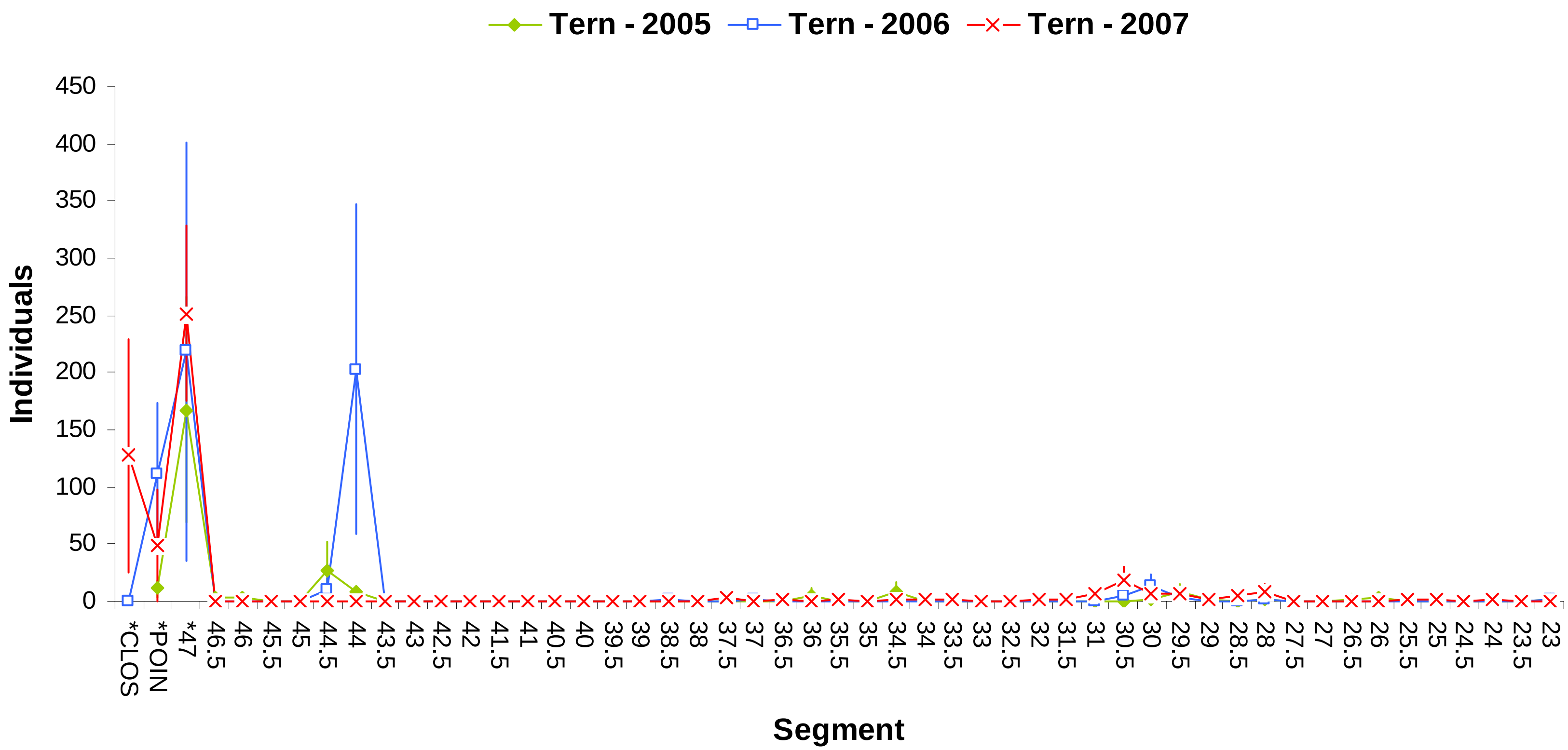

Figure 2.55. Average tern abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

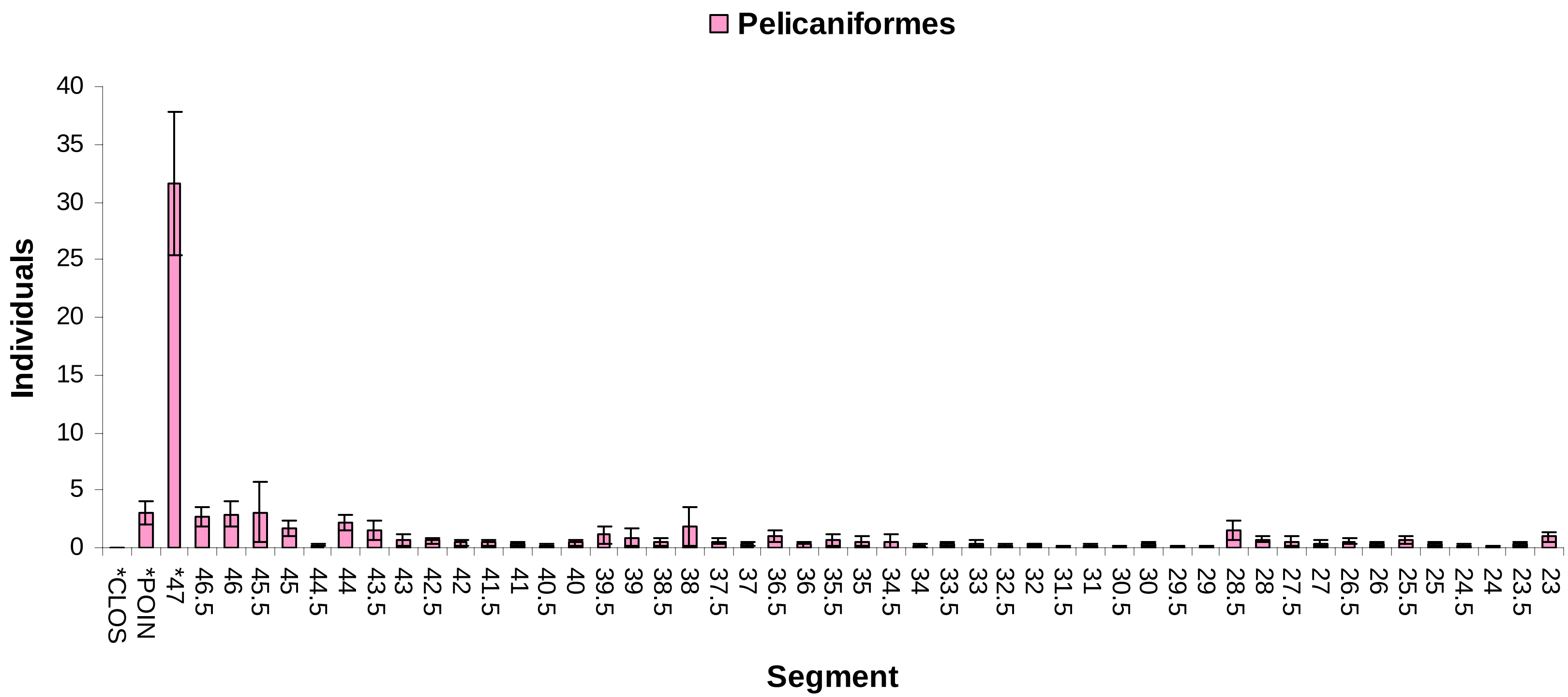

Figure 2.56. Average abundance of Brown Pelicans and Double-crested Cormorants (pelicaniformes) at beach segments on South Core Banks, NC with standard error bars. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

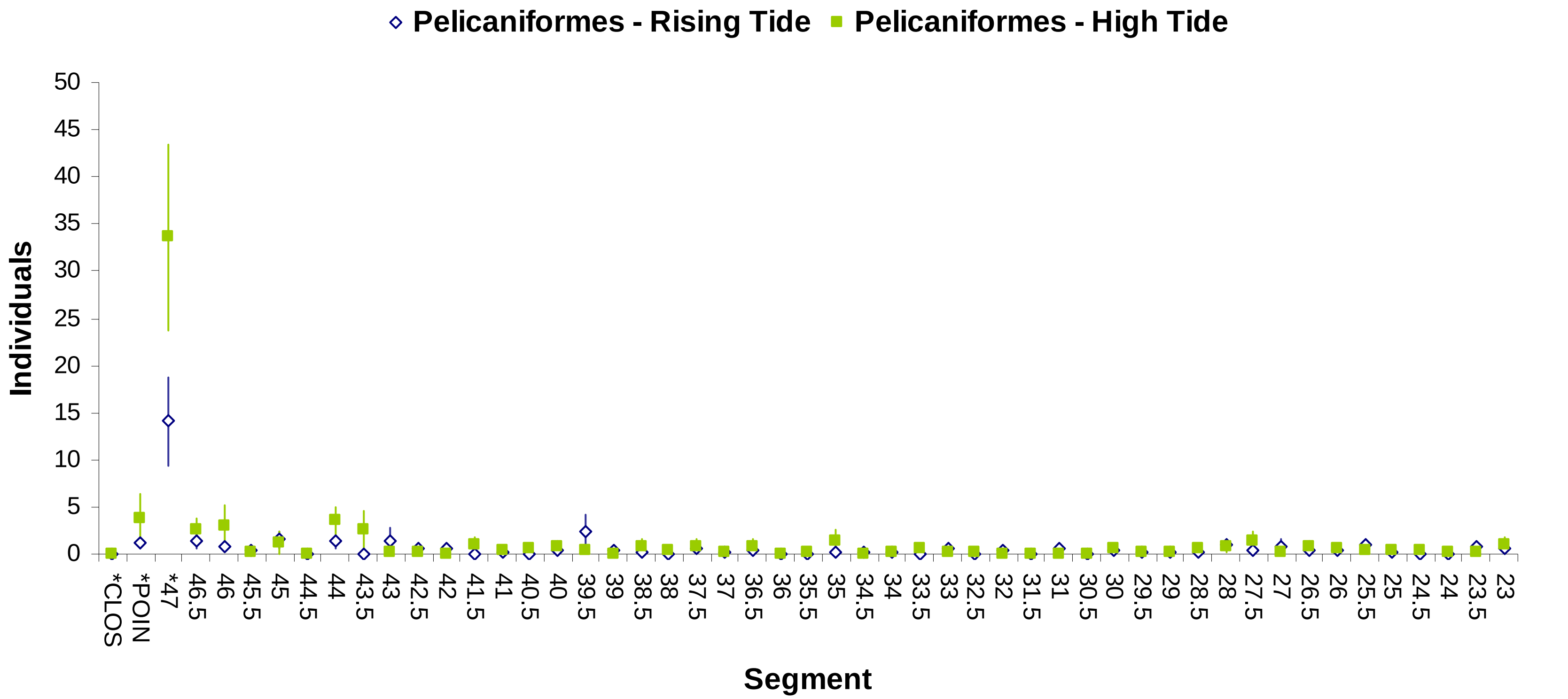

Figure 2.57. Average abundance of Brown Pelicans and Double-crested Cormorants (pelicaniformes) at segments during high and rising tides. Data from 2006 and 2007 were used, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

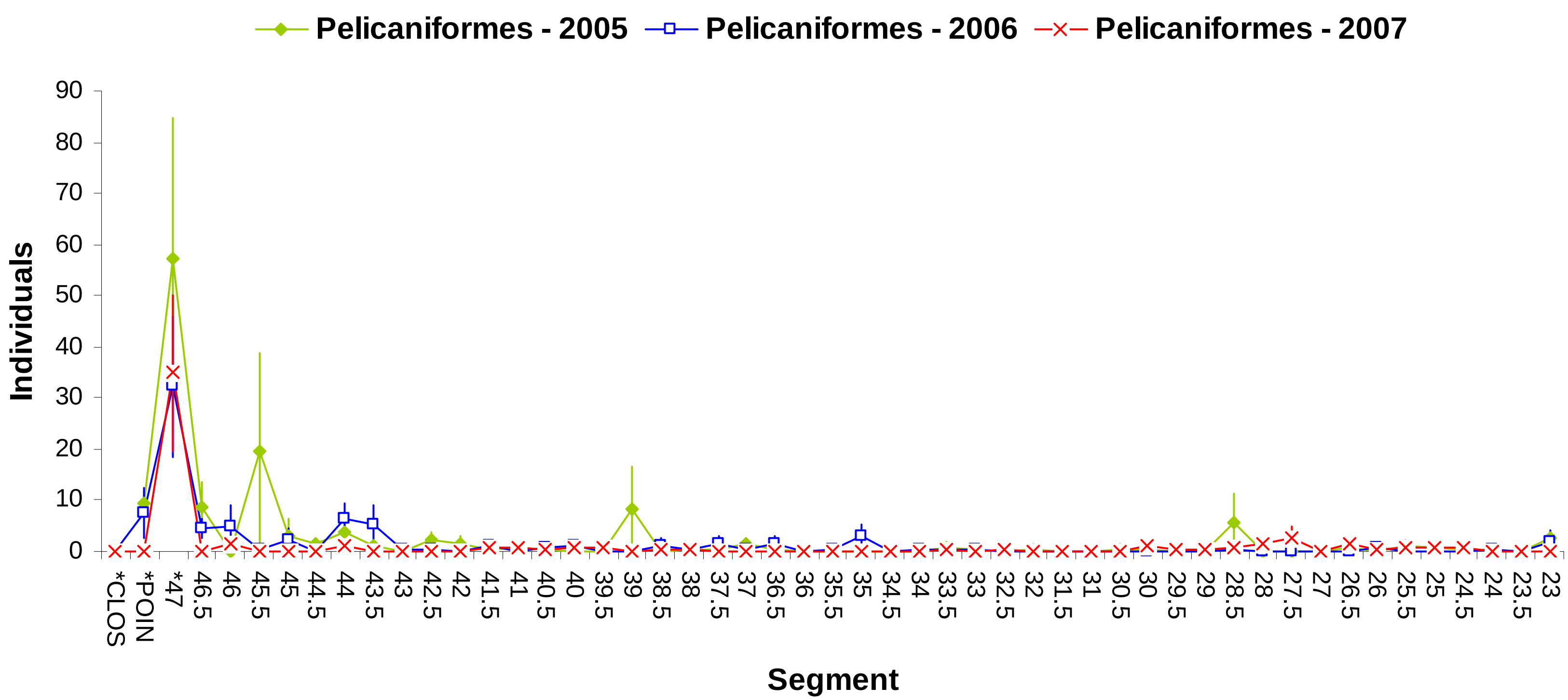

Figure 2.58. Average Brown Pelican and Double-crested Cormorant (pelicaniformes) abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

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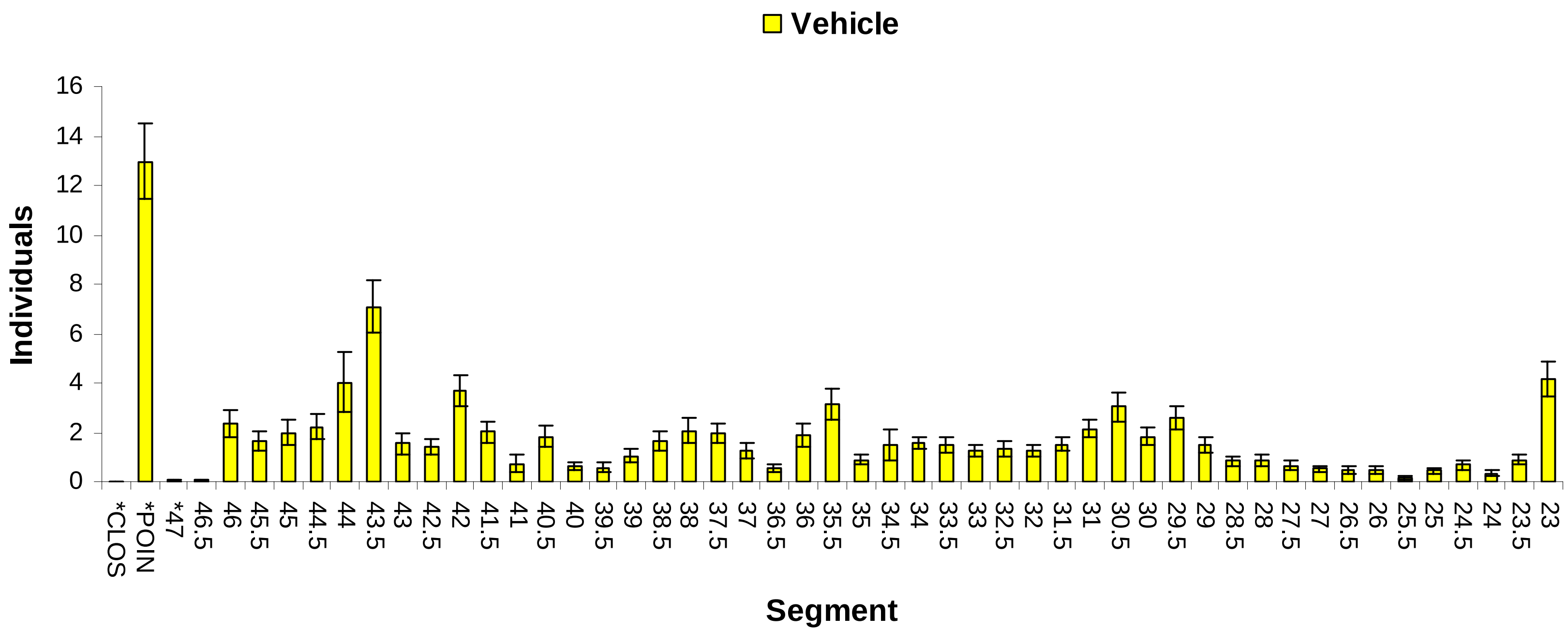

Figure 2.59. Average vehicle (ORVs and ATVs) abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long.

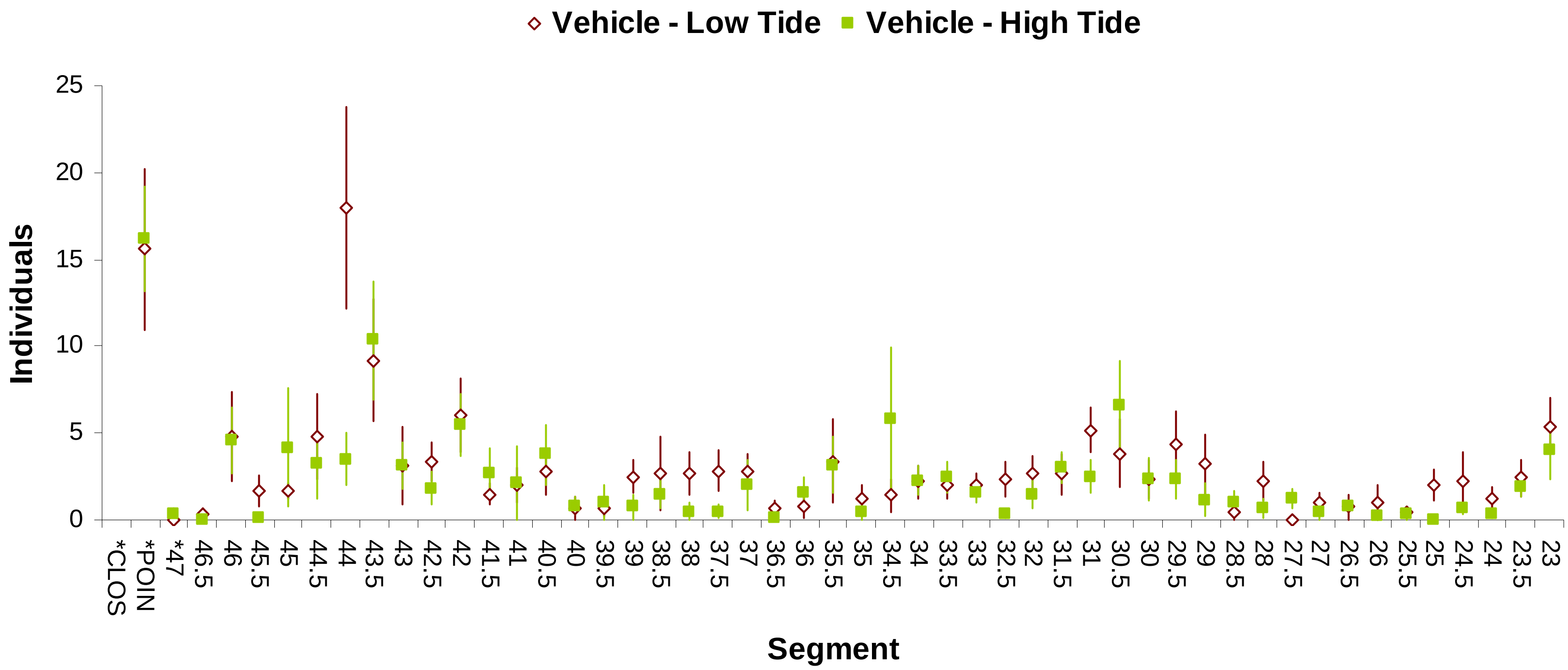

Figure 2.60. Average abundance of vehicles (ORVs and ATVs) at segments during low and high tides. Data from 2005 were used and lines illustrate the standard errors. Rising tide surveys were within 2 h of peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long.

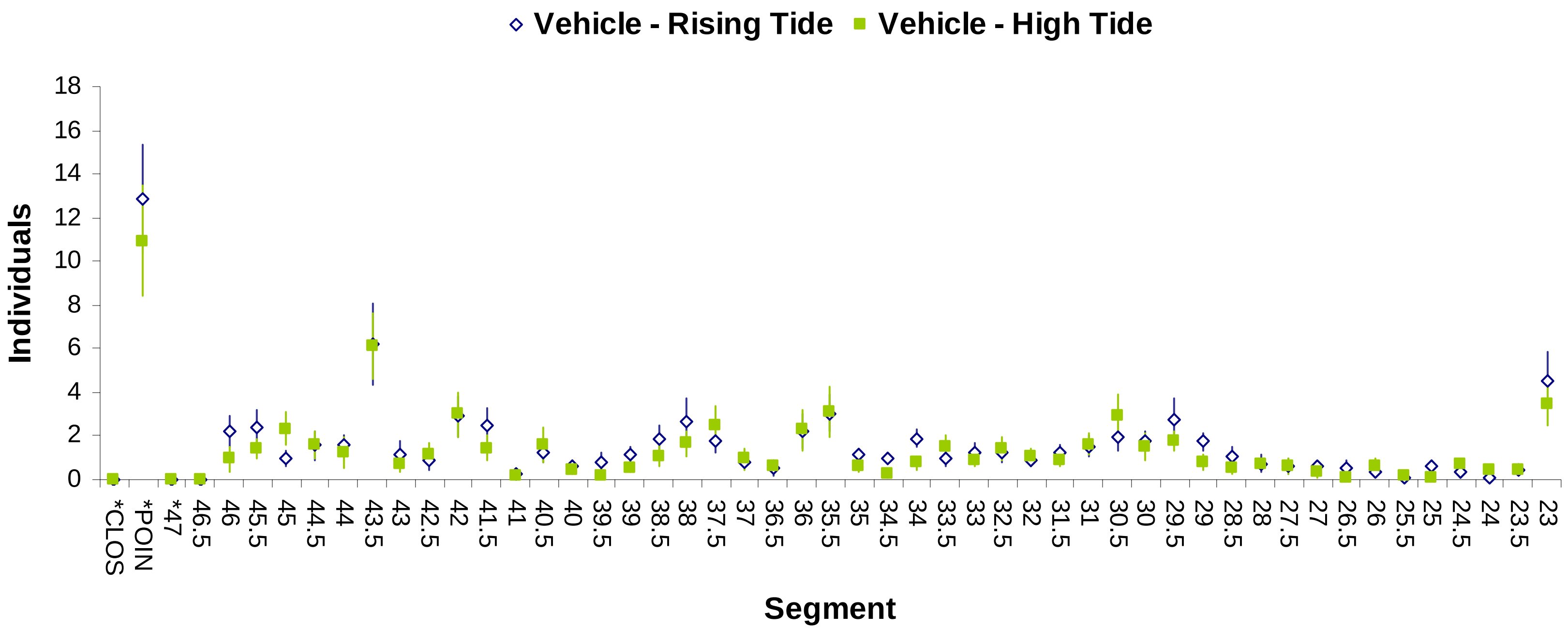

Figure 2.61. Average abundance of vehicles (ORVs and ATVs) at segments during high and rising tides. Data from 2006 and 2007 were used, and lines illustrate the standard errors. Rising tide surveys were within 4 h after peak low tide, and high tide surveys were within 2 h of peak high tide. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long. Segments 47, POINT, and CLOSURE had different dimensions and beach structure than other segments.

0076930

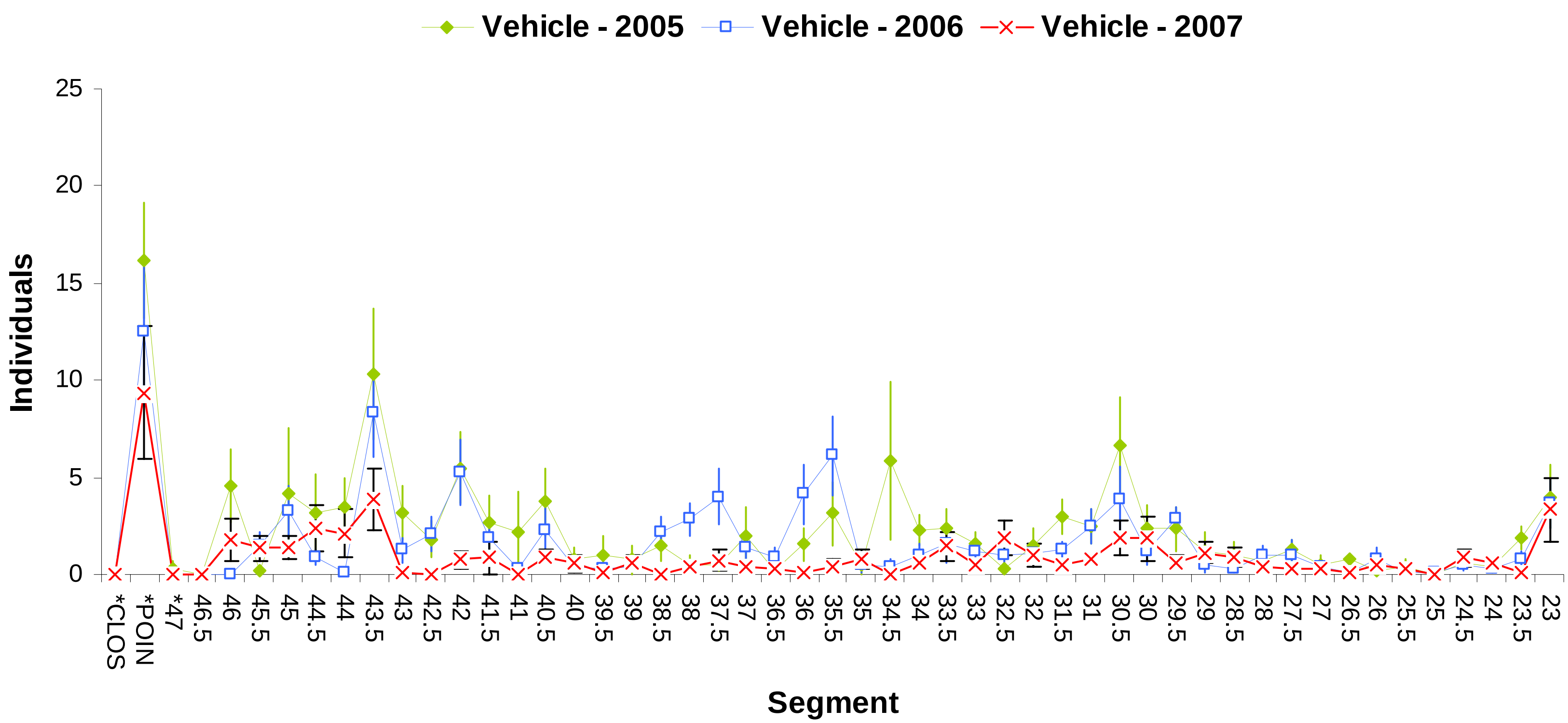

Figure 2.62. Average vehicle abundance at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments.

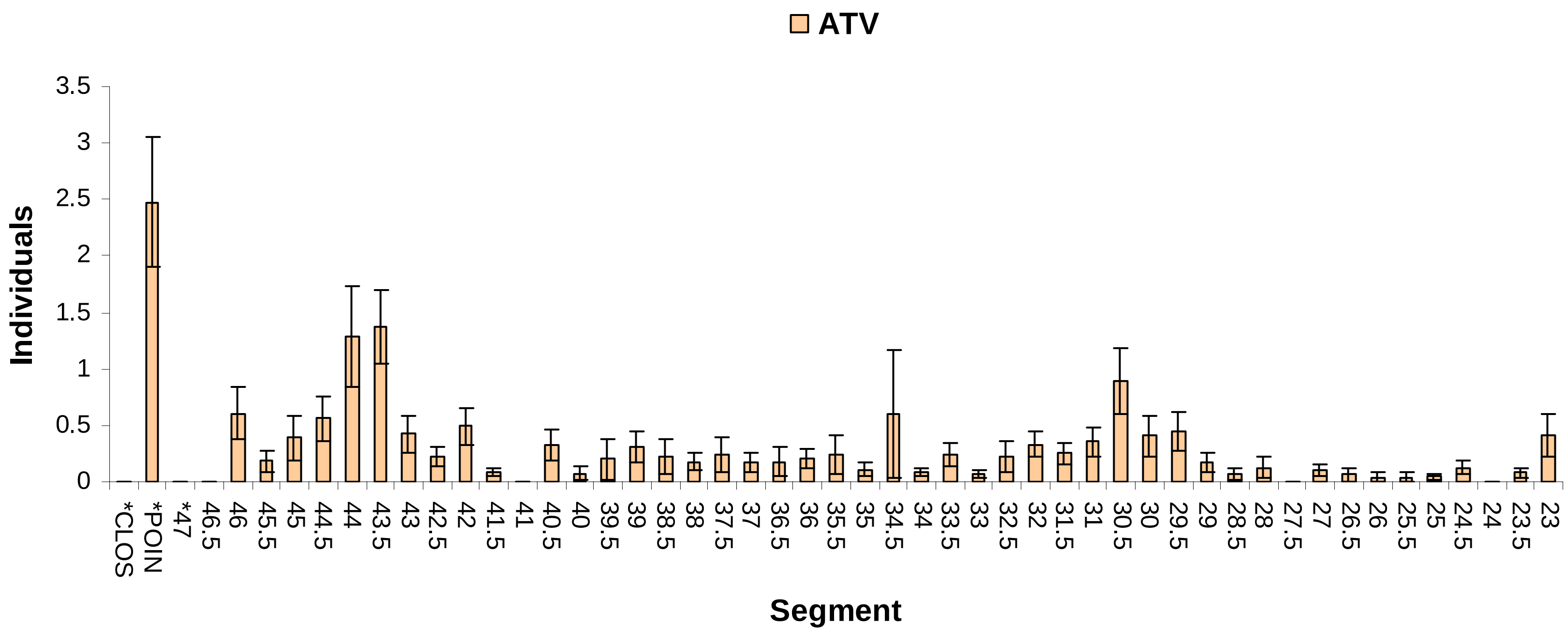

Figure 2.63. Average all-terrain vehicle (ATV) abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long.

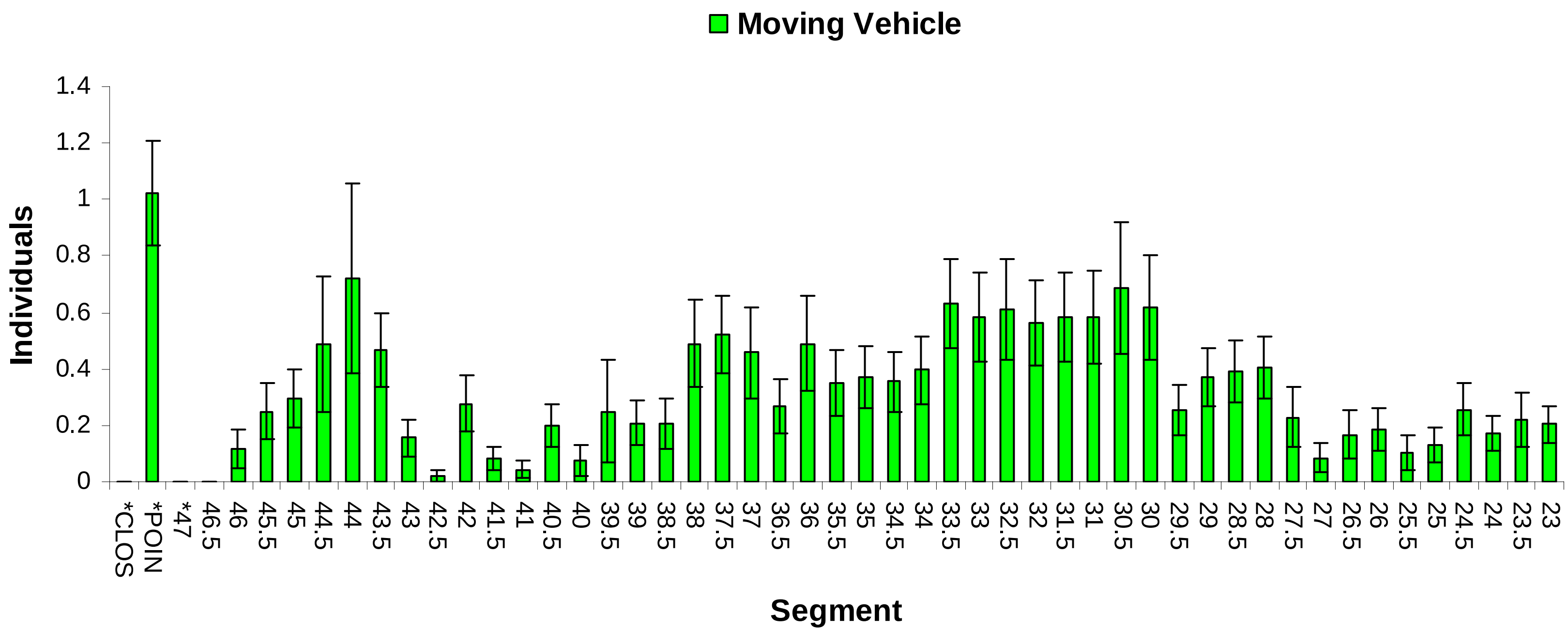

Figure 2.64. Average abundance of moving vehicles (ATVs and ORVs) at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segments 46.5, 47, and POIN were closed to vehicles. POINT varied from 0.2 to 0.5 mi long.

0076933

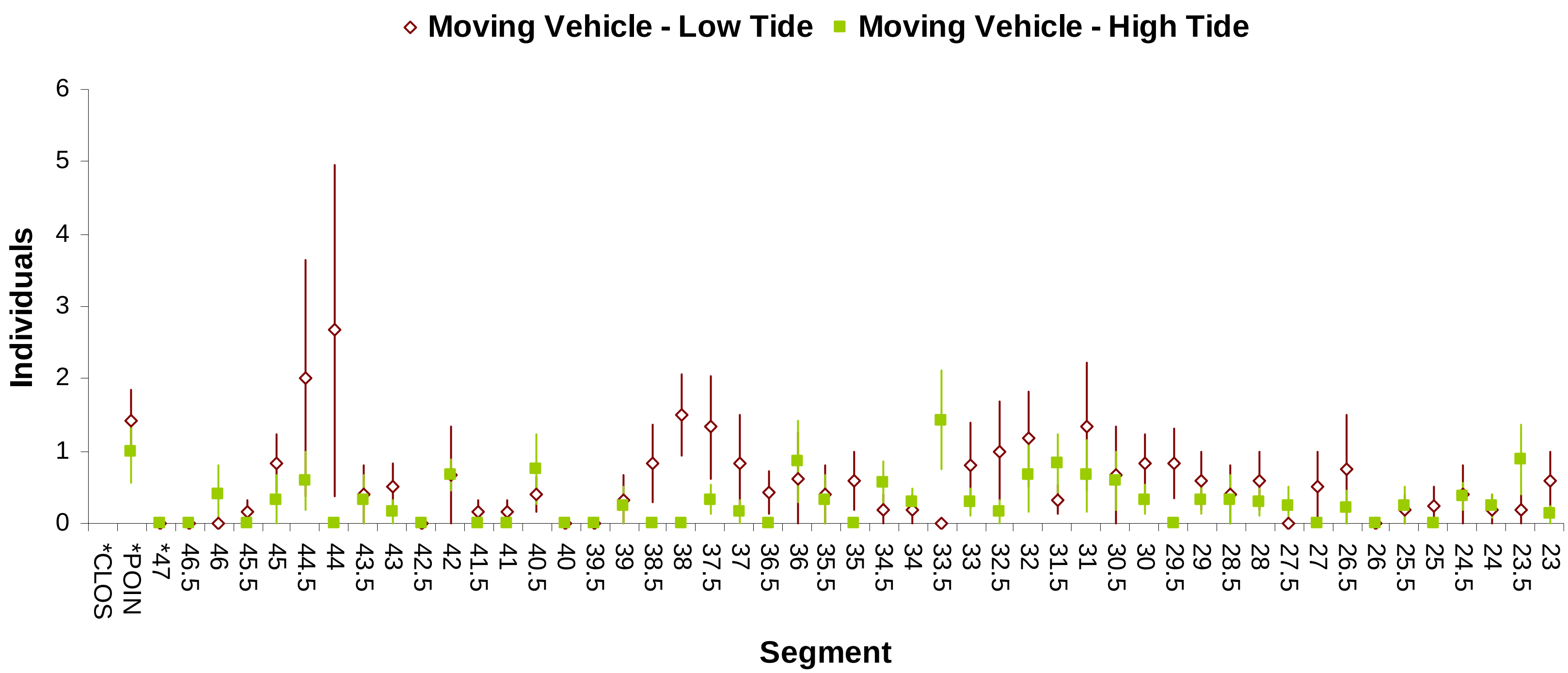

Figure 2.65. Average abundance of moving vehicles (ORVs and ATVs) at segments during low and high tides. We used data from 2005, and lines illustrate the standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

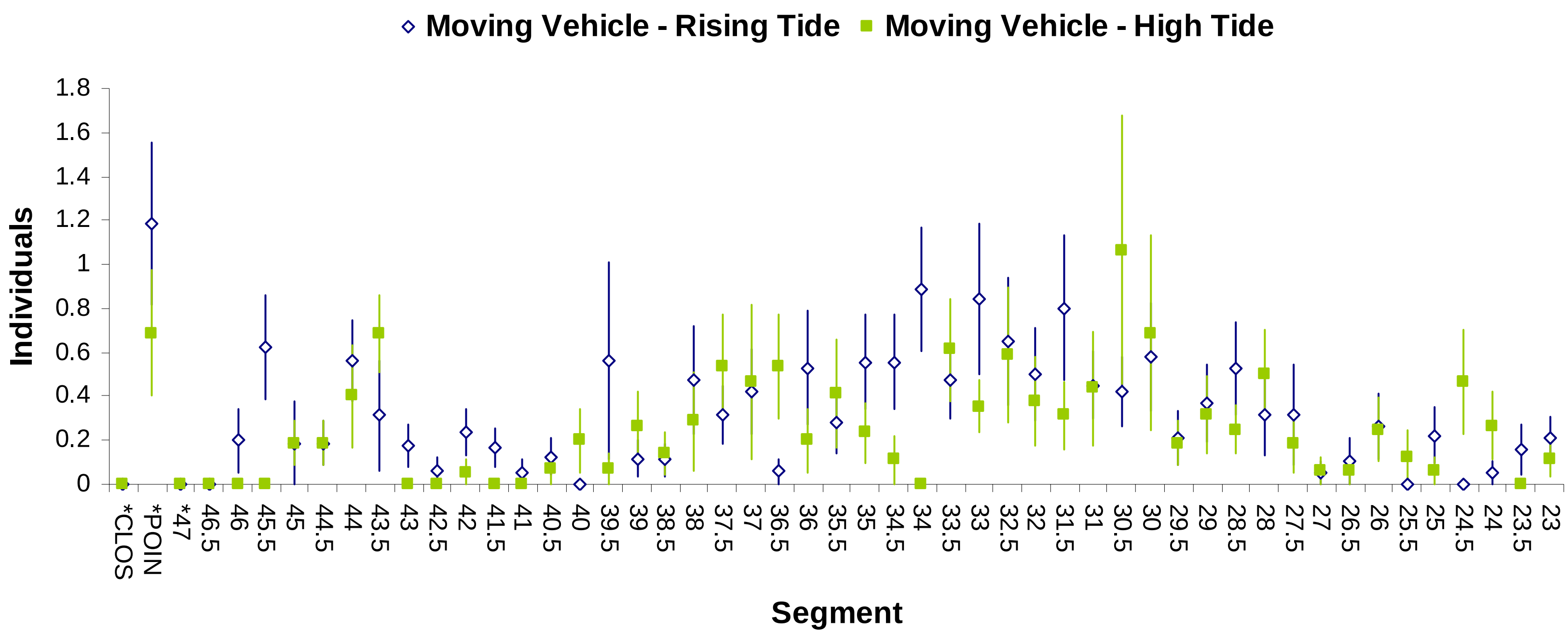

Figure 2.66. Average abundance of moving vehicles (ORVs and ATVs) at segments during rising and high tides. We used data from 2006 and 2007, and lines illustrate the standard error. Segments 47, POINT (Cape Lookout Point), and CLOSURE had different dimensions and beach structure than other segments.

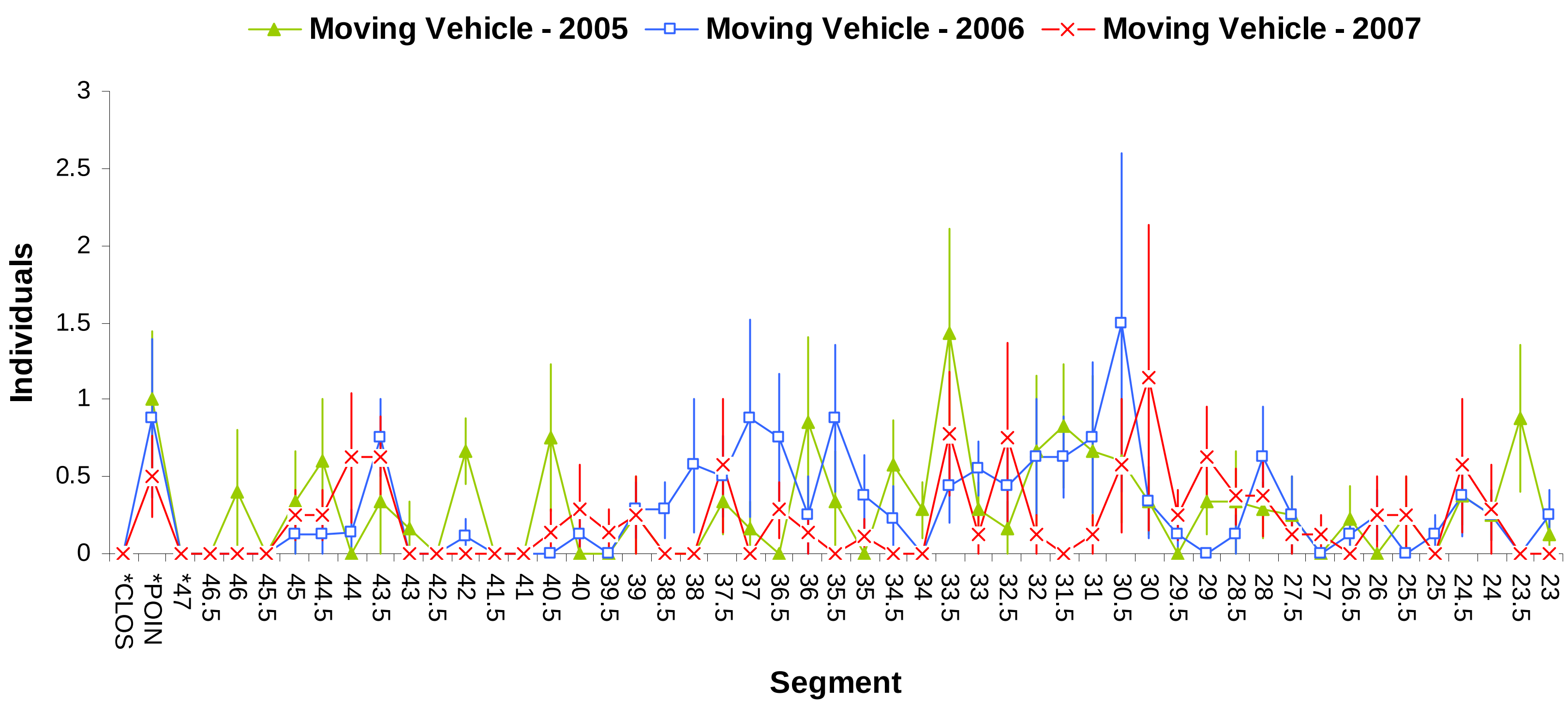

Figure 2.67. Average moving vehicle (ATVs and ORVs) counts at high tide from 2005, 2006, and 2007 for beach segments on South Core Banks, NC. Lines represent one standard error. Segments 46.5, 47, and POIN were closed to vehicles. Segments 47, POINT, and CLOSURE had different dimensions and beach structure than other segments.

0076936

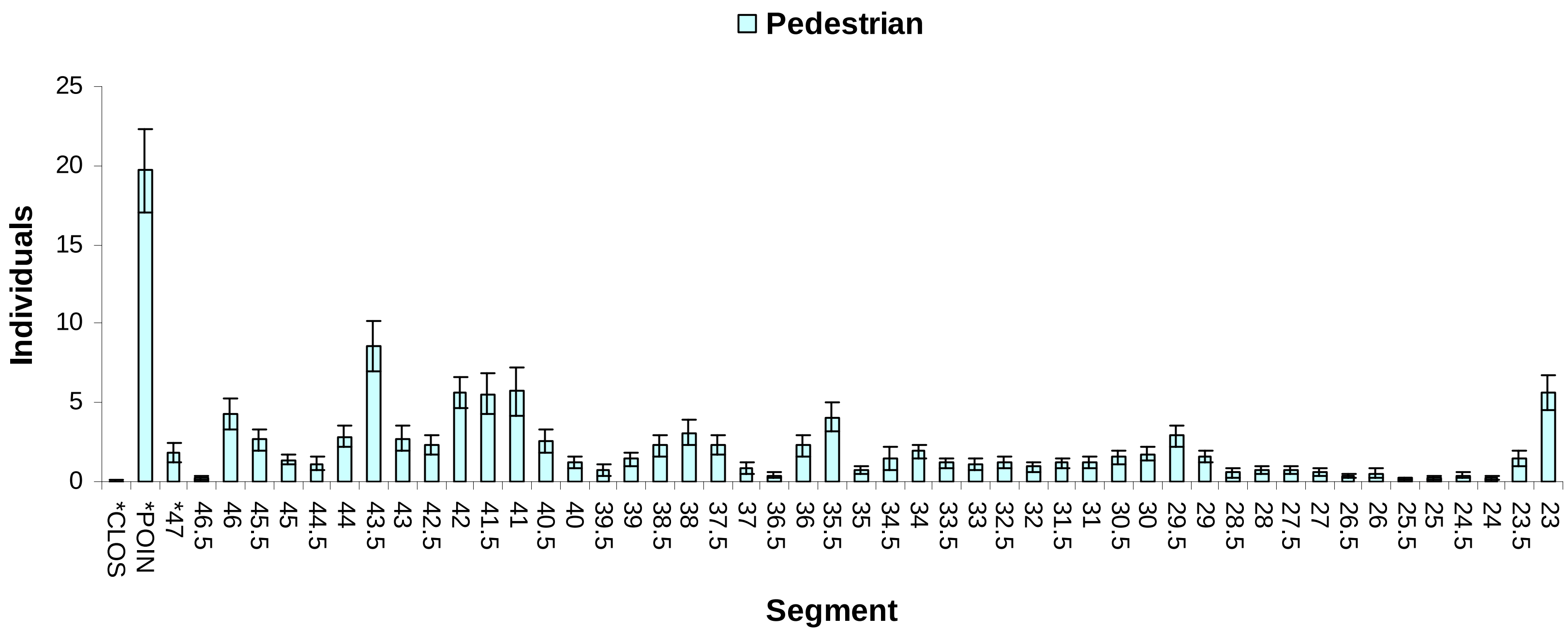

Figure 2.68. Average pedestrian abundance at beach segments on South Core Banks, NC with standard error bars. Segments were named by their northern edge's location in CALO's mile marker system. Segments 47, POINT (Cape Lookout Point), and CLOSURE (a vehicle exclosure on the back beach at Cape Lookout Point) had different dimensions and beach structure than other segments. Segment 47 was a large sand spit, POINT varied from 0.2 to 0.5 mi long with swash zones on two sides, and CLOSURE contained dry sand, some small dunes, and pools but no swash zone.

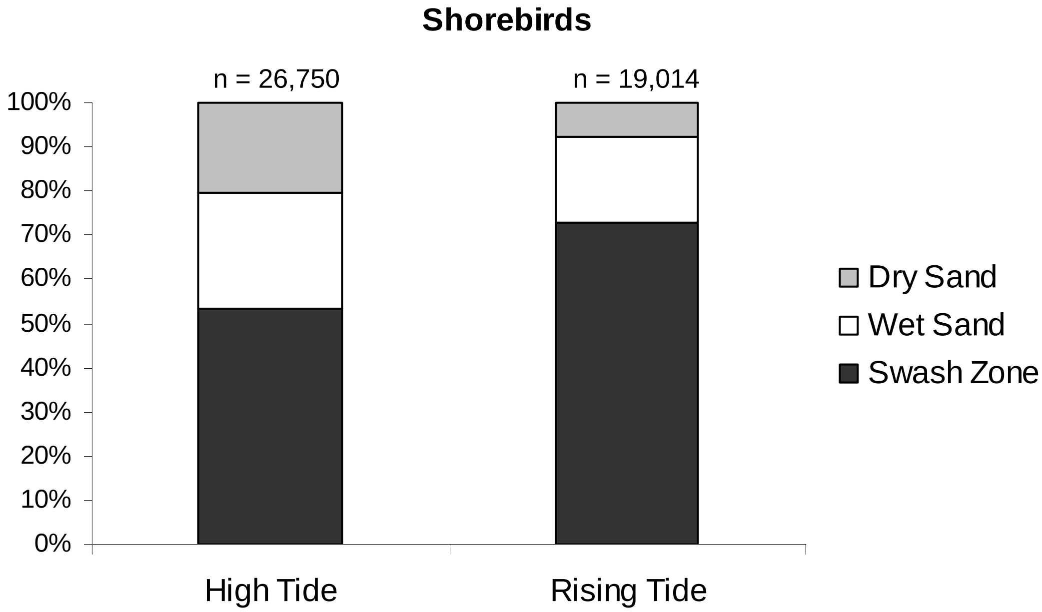

Figure 2.69. The proportions of total shorebird detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

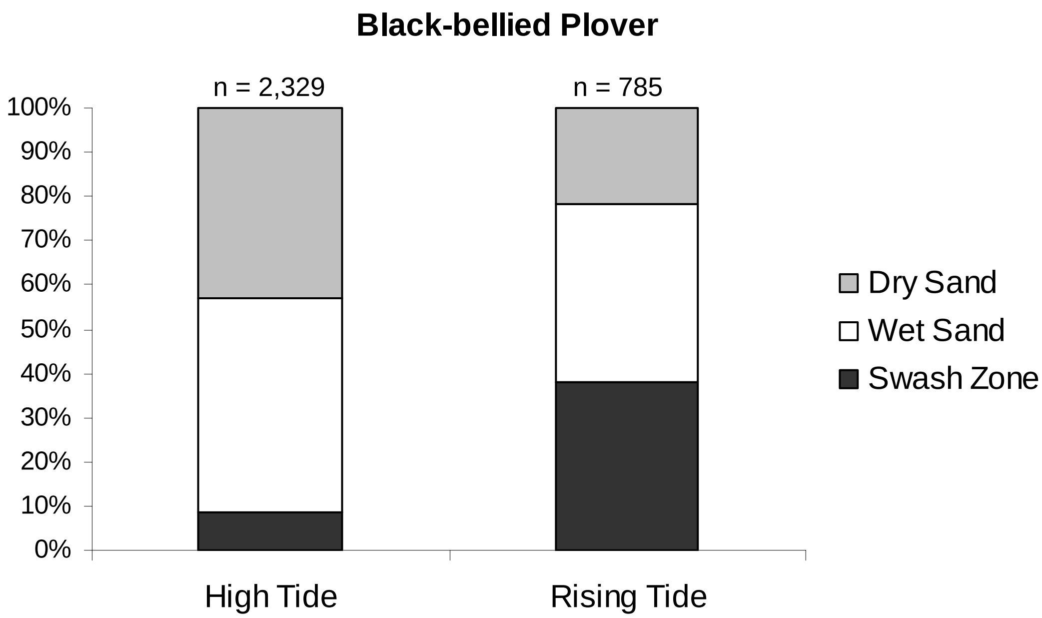

Figure 2.70. The proportions of total Black-bellied Plover detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

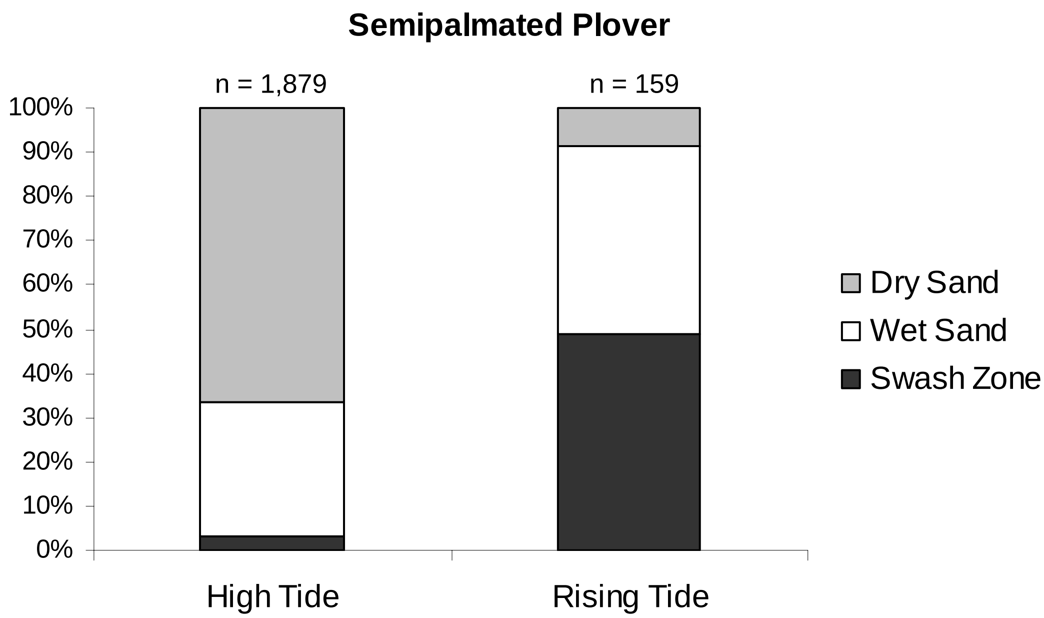

Figure 2.71. The proportions of total Semipalmated Plover detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

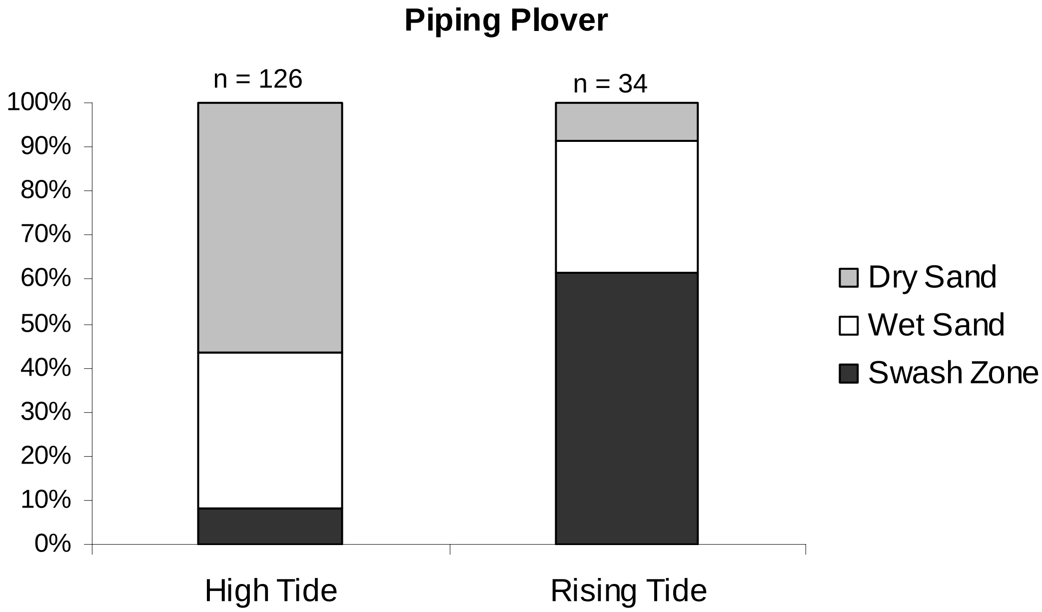

Figure 2.72. The proportions of total Piping Plover detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

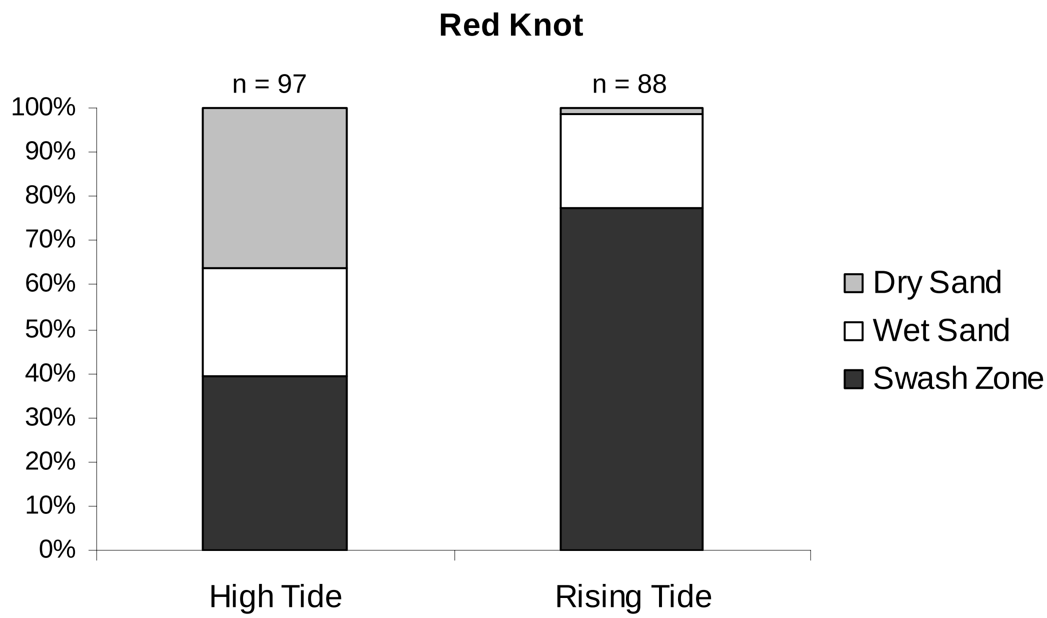

Figure 2.73. The proportions of total Red Knot detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

0076942

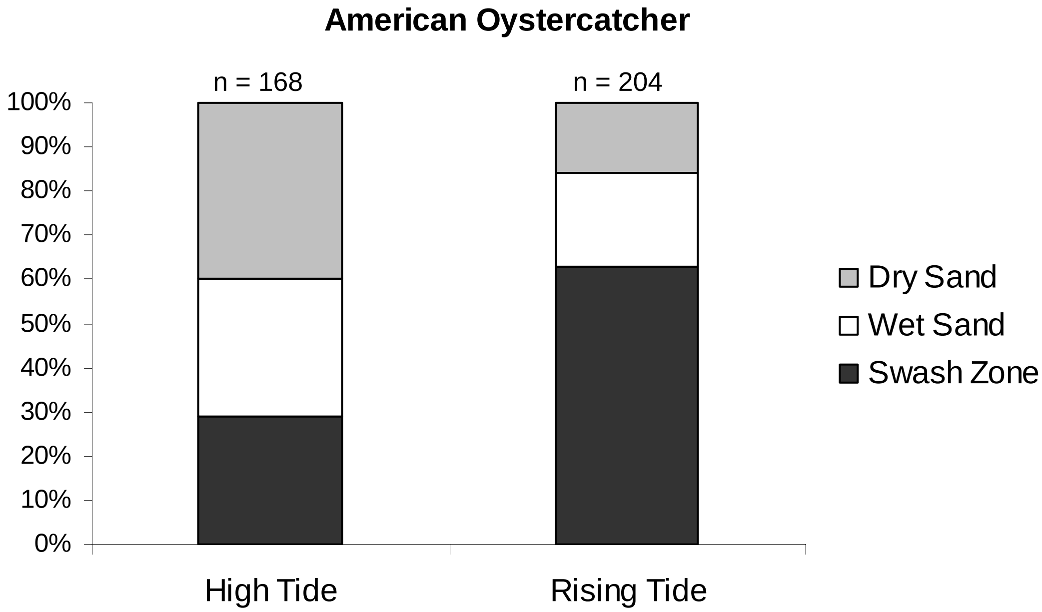

Figure 2.74. The proportions of total American Oystercatcher detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

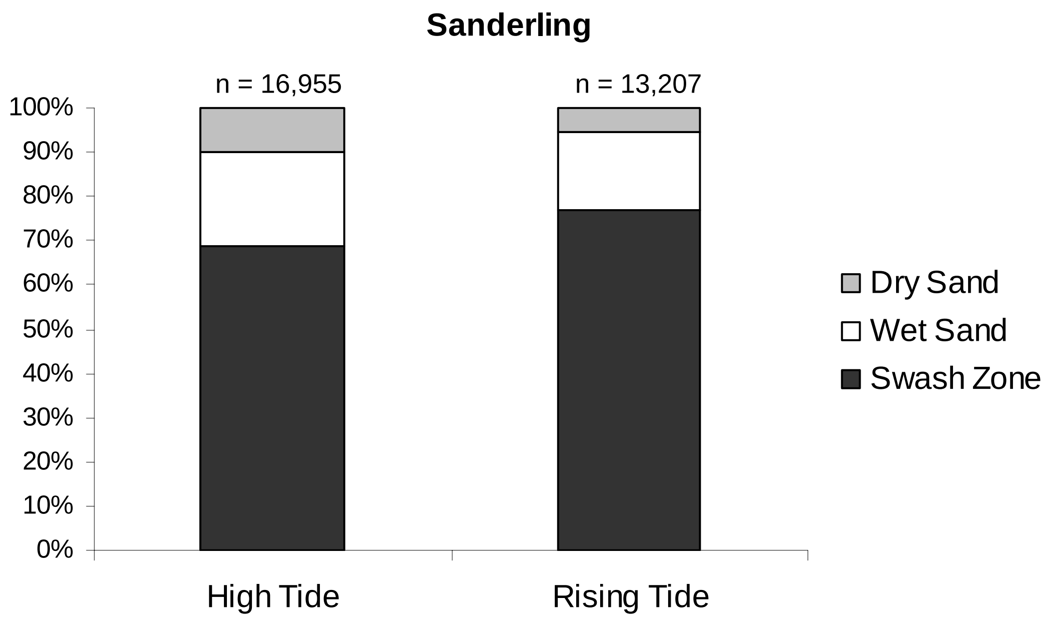

Figure 2.75. The proportions of total Sanderling detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

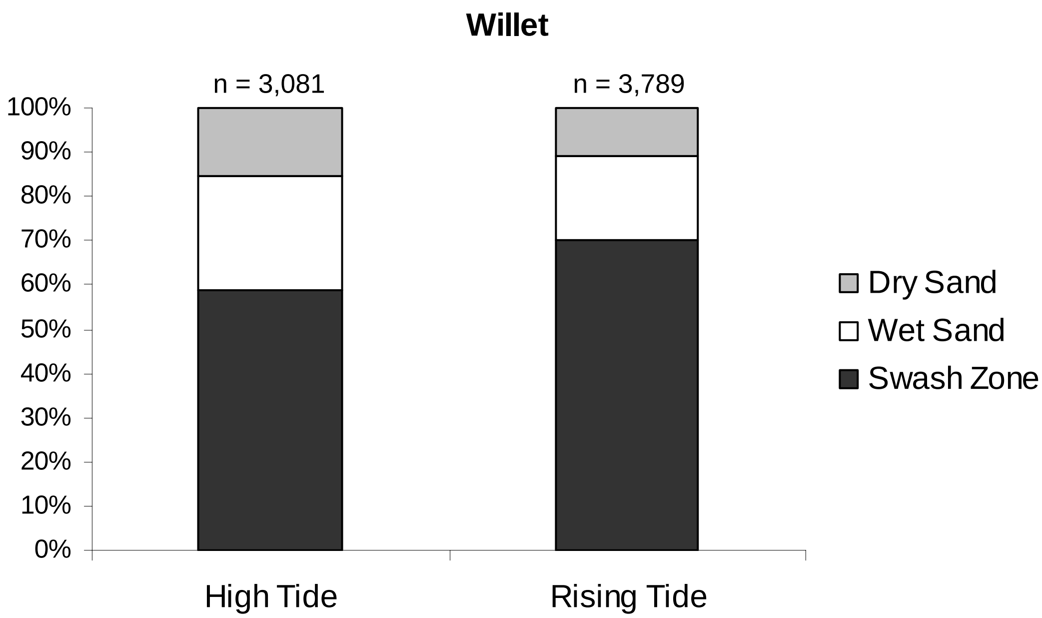

Figure 2.76. The proportions of total Willet detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

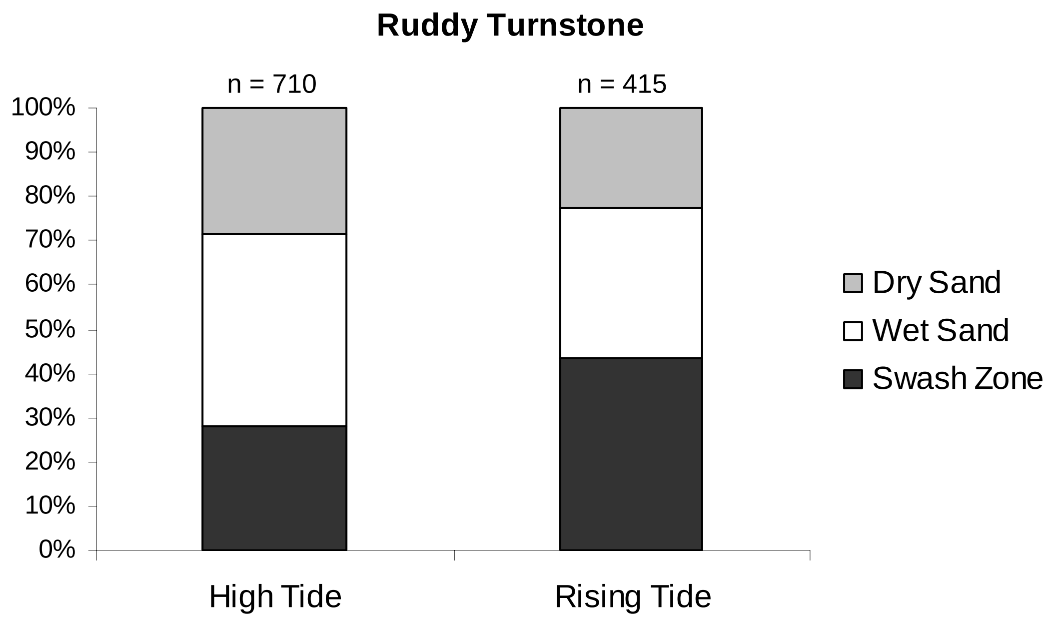

Figure 2.77. The proportions of total Ruddy Turnstone detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

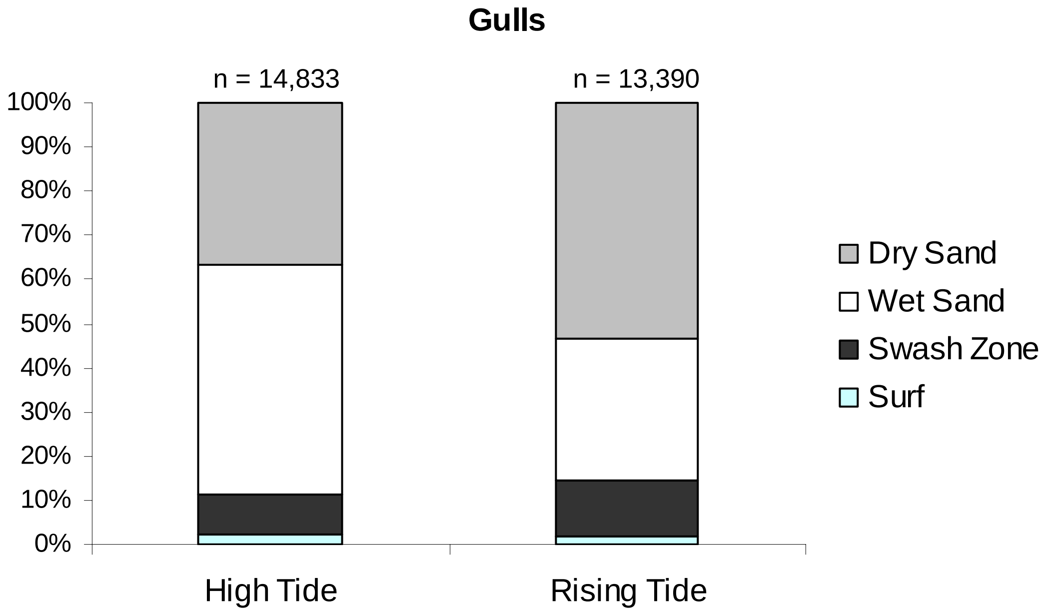

Figure 2.78. The proportions of total gull detections that were from dry sand, wet sand, swash zone, and surf microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

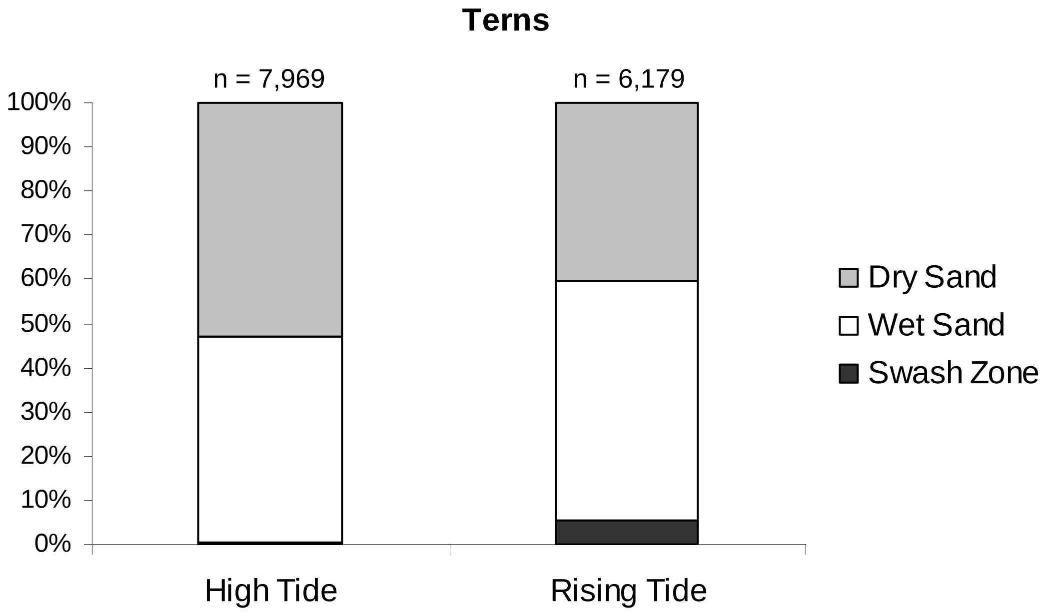

Figure 2.79. The proportions of total tern detections that were from dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

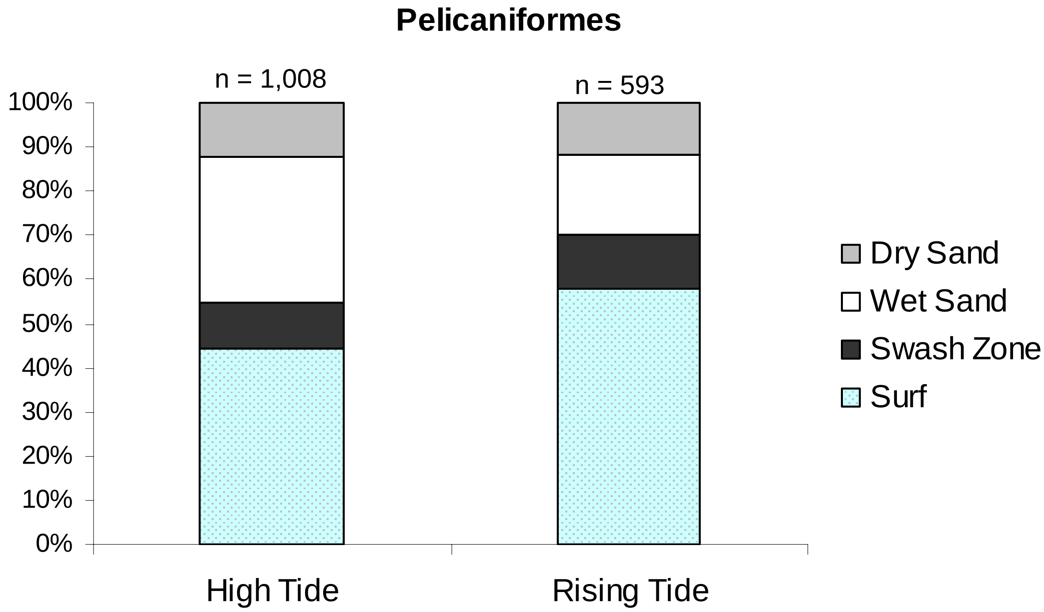

Figure 2.80. The proportions of total Brown Pelican and Double-crested Cormorant (pelicanidae) detections that were from dry sand, wet sand, swash zone, and surf microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

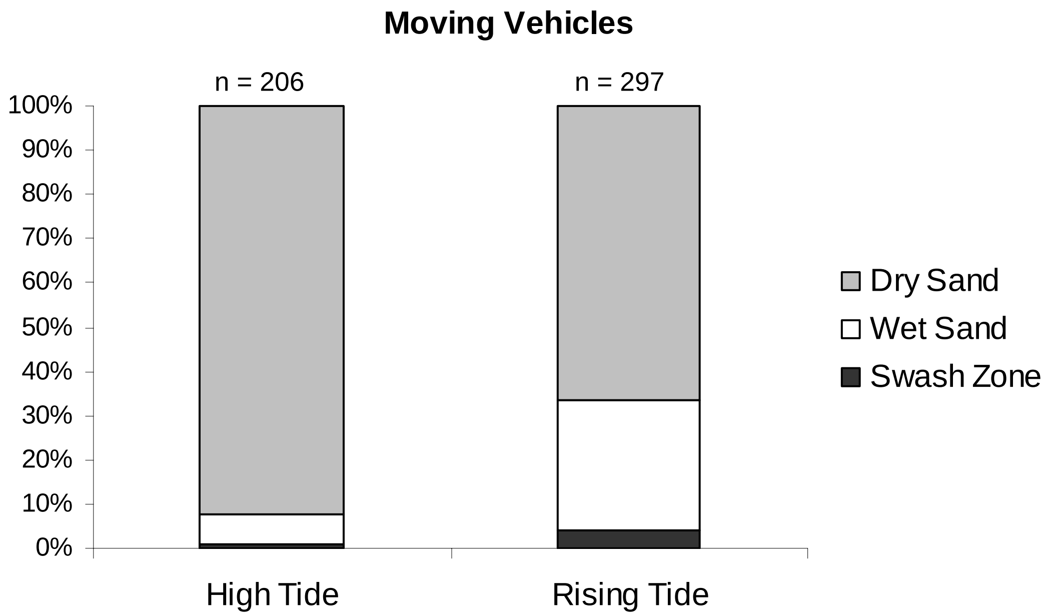

Figure 2.81. The proportions of total moving vehicles (moving ATVs or ORVs) detected that were in dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

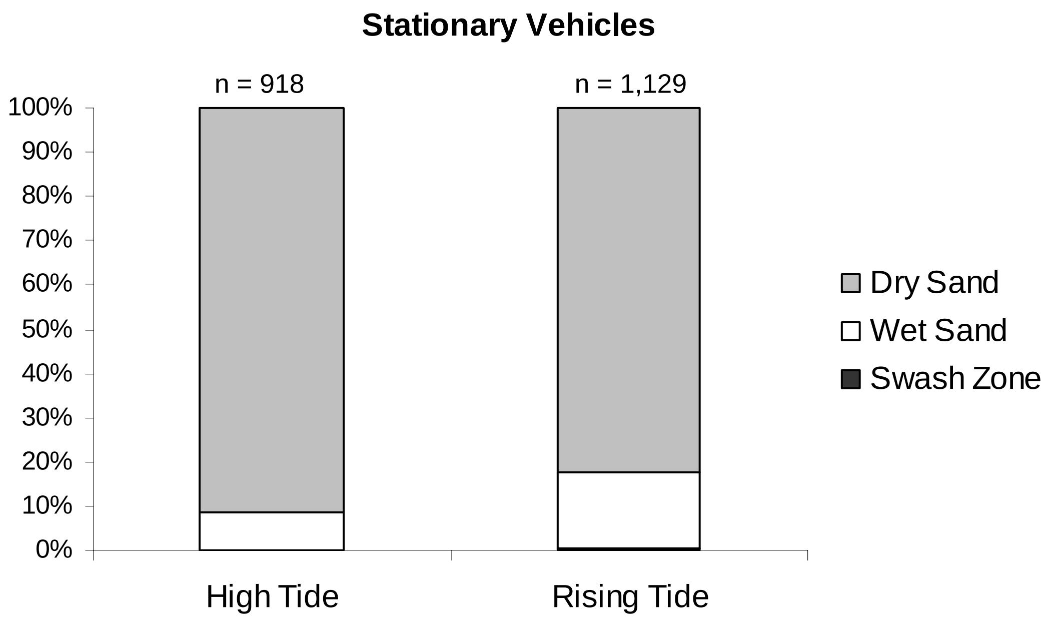

Figure 2.82. The proportions of total stationary vehicles (moving ATVs or ORVs) detected that were in dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

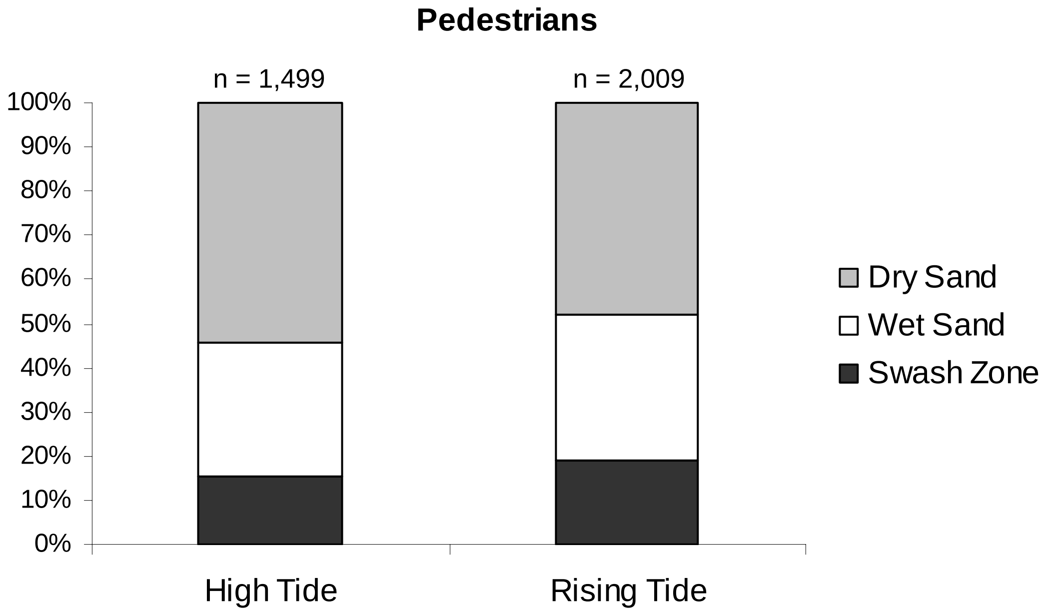

Figure 2.83. The proportions of pedestrians detected that were in dry sand, wet sand, and swash zone microhabitats at high and rising tide levels. Data from 2006 and 2007 were included in this summary.

Table 2.1. A list of species detected during surveys of ocean beach and surf (flyovers were excluded) at South Core Banks, North Carolina during fall 2005, 2006, and 2007. We performed 2,316 surveys at 51 half mile beach segments.

Species	Scientific name	Surveys where present	Total detections
Podicipedidae			
Horned Grebe	*Podiceps auritus*	2	3
Gaviidae			
Common Loon	*Gavia immer*	6	8
Pelecanidae			
Brown Pelican	*Pelecanus occidentalis*	292	2,736
Phalacrocoracidae			
Double-crested Cormorant	*Phalacrocorax auritus*	51	208
Sulidae			
Northern Gannet	*Morus bassanus*	1	1
Ardeidae			
Great Blue Heron	*Ardea herodias*	7	7
Snowy Egret	*Egretta thula*	16	1
Black-crowned Night-Heron*	*Nycticorax nycticorax*	0	0
Threskiornithidae			
White Ibis	*Eudocimus albus*	1	1
Anatidae			
Blue-winged Teal	*Anas discors*	1	1

Table 2.1 Continued

Species	Scientific name	Surveys where present	Total detections
Accipitridae			
Osprey	*Pandion haliaetus*	4	4
Falconidae			
Merlin	*Falco columbarius*	5	6
American Kestrel	*Falco sparverius*	1	1
Peregrine Falcon	*Falco peregrinus*	20	21
Charadriidae			
Black-bellied Plover	*Pluvialis squatarola*	885	3,434
Piping Plover	*Charadrius melodus*	60	204
Semipalmated Plover	*Charadrius semipalmatus*	176	2,329
Wilson's Plover	*Charadrius wilsonia*	9	26
Killdeer	*Charadrius vociferus*	5	8
Haematopodidae			
American Oystercatcher	*Haematopus palliatus*	186	431
Scolopacidae			
Greater Yellowlegs	*Tringa melanoleuca*	1	1
Lesser Yellowlegs	*Tringa flavipes*	1	2
Willet	*Catoptrophorus semipalmatus*	1,104	8,025
Whimbrel	*Numenius phaeopus*	21	34
Marbled Godwit	*Limosa fedoa*	1	1

Table 2.1 Continued

Species	Scientific name	Surveys where present	Total detections
Ruddy Turnstone	*Arenaria interpres*	525	1,438
Red Knot	*Calidris canutus*	91	341
Sanderling	*Calidris alba*	1,937	40,807
Dunlin	*Calidris alpina*	119	567
Pectoral Sandpiper	*Calidris melanotos*	3	16
White-rumped Sandpiper	*Calidris fuscicollis*	1	1
Western Sandpiper	*Calidris mauri*	23	468
Semipalmated Sandpiper	*Calidris pusilla*	6	7
Least Sandpiper	*Calidris minutilla*	9	148
Short-billed Dowitcher**	*Limnodromus griseus*	59	236
Laridae			
Bonaparte's Gull	*Larus philadelphia*	3	3
Laughing Gull	*Larus atricilla*	685	11,237
Ring-billed Gull	*Larus delawarensis*	452	4,381
Herring Gull	*Larus argentatus*	925	10,040
Lesser Black-backed Gull	*Larus fuscus*	107	319
Great Black-backed Gull	*Larus marinus*	959	10,662
Caspian Tern	*Sterna caspia*	89	910
Royal Tern	*Sterna maxima*	128	4,590
Sandwich Tern	*Sterna sandvicensis*	141	3,941
Common Tern	*Sterna hirundo*	69	1,730

Table 2.1 Continued

Species	Scientific name	Surveys where present	Total detections
Forster's Tern	*Sterna forsteri*	117	1,526
Least Tern	*Sterna antillarum*	32	104
Gull-billed Tern*	*Sterna nilotica*	0	0
Black Tern	*Chlidonias niger*	26	210
Black Skimmer	*Rynchops niger*	1	17
Columbidae			
Mourning Dove	*Zenaida macroura*	2	3
Hirundinidae			
Barn Swallow	*Hirundo rustica*	4	81
Icteridae			
Common Grackle	*Quiscalus quiscula*	3	20
Boat-tailed Grackle	*Quiscalus major*	22	38

*Species observed on the beach but not during surveys

**We did not attempt to identify Long-billed Dowitchers (*Limnodromus scolopaceus*).

Table 2.2. Total number of individuals counted at South Core Banks on days when we surveyed all beach segments during low (L), rising (R), or high (H) tide. Flyovers are included in this summary. “Peep” denotes unidentified small sandpipers such as Western Sandpipers, Least Sandpipers, or Semipalmated Sandpipers. Only vehicle counts are reported for 11 October 2006 and 12 October 2007 because extreme high tides blocked vehicle access to some beach segments. On 9 October 2005, the observers did not identify gulls and terns to the species level. Instead, they simply recorded them as “gull species” or “tern species”.

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Pelicaniformes	27		74	77	208	99	169	42	138		138	31
Brown Pelican	27		67	64	201	98	55	42	137		136	28
Double-crested Cormorant	0		7	13	7	1	114	0	1		2	3
Shorebirds	1,284		1,331	145	1,499	1,984	1,340	1,691	1,468		1,431	655
American Oystercatcher	13		4	8	5	5	6	18	8		8	3
Black-bellied Plover	24		79	9	37	27	8	293	99		52	20
Dowitcher species	0		0	0	0	0	1	8	0		3	0

Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Dunlin	0		3	4	43	156	163	0	2		3	0
Killdeer	0		0	0	0	1	0	0	0		0	0
Least Sandpiper	0		0	0	0	0	0	4	7		0	0
Marbled Godwit	0		0	0	0	0	0	0	1		0	0
Pectoral Sandpiper	0		0	0	1	0	0	0	0		0	0
Piping Plover	0		6	0	5	7	0	3	1		5	0
Red Knot	7		6	1	17	8	7	11	2		0	1
Ruddy Turnstone	37		31	5	40	53	12	74	51		47	25
Sanderling	788		1,120	59	1,060	1,475	1,045	800	937		948	573
Semipalmated Plover	4		25	13	33	0	2	84	125		0	3
Semipalmated Sandpiper	0		0	0	2	0	0	0	1		0	0

Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Spotted Sandpiper	0		0	0	0	0	0	1	0		0	0
Western Sandpiper	0		0	0	1	0	2	10	128		0	0
Whimbrel	0		1	0	0	0	0	11	0		0	0
Willet	389		56	46	172	236	87	335	71		365	28
Wilson's Plover	0		0	0	0	0	0	2	7		0	0
"Peep"	0		0	0	0	0	2	24	1		0	2
Semipalmated Plover or "peep"	7		0	0	0	0	0	0	0		0	0
Unidentified shorebird	15		0	0	83	16	5	13	27		0	0
Gulls	752		1,131	692	4,692	3,929	2,110	172	788		812	569
Bonaparte's Gull	0		0	0	0	2	0	0	0		0	0
Great Black-backed Gull	0		320	258	526	629	284	35	304		302	183

Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Herring Gull	0		341	178	1,257	1,395	492	46	278		265	196
Laughing Gull	0		193	86	643	1,125	208	76	157		168	168
Lesser Black-backed Gull	0		14	3	5	62	2	3	16		5	2
Ring-billed Gull	0		79	118	2,181	181	172	5	10		14	10
Unidentified Gull	752		184	49	80	535	952	7	23		58	10
Terns	3		228	34	133	1,226	757	533	262		190	23
Black Tern	0		0	0	0	0	0	19	0		1	0
Caspian Tern	0		8	1	2	41	0	9	95		37	7
Common Tern	0		0	0	0	0	0	30	0		0	0
Forster's Tern	0		54	6	8	416	71	13	10		95	6
Least Tern	0		0	0	0	0	0	5	0		0	0

Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Royal Tern	0		3	3	22	100	52	237	79		6	2
Sandwich Tern	0		23	1	32	500	139	91	61		3	0
Unidentified tern	3		140	23	69	169	495	129	17		48	8
Miscellaneous sp.	5		10	3	4	3	1	10	1		6	6
Barn Swallow	0		0	0	0	0	0	5	0		0	0
Blue-winged Teal	0		0	0	0	0	0	0	0		1	0
Boat-tailed Grackle	0		5	0	2	1	0	0	1		2	1
Common Loon	0		0	0	1	0	0	0	0		1	0
Duck species	0		0	0	0	0	0	3	0		0	0
Great Blue Heron	0		0	1	0	0	0	0	0		1	1
Unidentified heron	0		0	1	0	0	0	0	0		0	0
Horned Grebe	0		0	0	0	2	0	0	0		0	0

Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
Northern Gannet	0		0	0	0	0	1	0	0		0	0
Osprey	1		1	0	0	0	0	1	0		0	0
Peregrine Falcon	3		4	1	0	0	0	0	0		1	4
Snowy Egret	1		0	0	1	0	0	1	0		0	0
All vehicles	82	91	105	129	132	122	127	10	47	69	149	103
ATV	19	10	17	15	22	25	26	4	4	4	30	8
Stationary ATV	15	10	14	9	18	22	20	0	1	3	21	7
Moving ATV	4	0	3	6	4	3	6	4	3	1	9	1
ORV (non-ATV)	63	81	88	114	110	97	101	6	43	65	119	95
Stationary ORV	51	71	83	93	96	80	87	4	35	56	105	71
Moving ORV	12	10	5	21	14	17	14	2	8	9	14	24

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Table 2.2 Continued

Year	2005	2006						2007				
Date	9 Oct	11 Oct	20 Oct		25 Oct	3 Nov		11 Sep	4 Oct	12 Oct		19 Oct
Tide	L	H	H	R	R	H	R	H	H	H	R	R
All boats	0		0	4	11	3	4	0	1		3	49
Stationary boat	0		0	4	4	3	4	0	1		2	2
Moving boat	0		0	0	7	0	0	0	0		1	47
All pedestrians	63		85	140	172	174	178	7	73		240	94
Stationary pedestrian	63		85	138	172	174	178	7	69		228	89
Moving pedestrian	0		0	2	0	0	0	0	4		12	5
All dogs	0		0	0	1	4	0	0	0		2	1
Dog on a leash	0		0	0	1	2	0	0	0		2	1
Unleashed dog	0		0	0	0	2	0	0	0		0	0

Table 2.3. Shorebird densities (birds/km) at six sites on North Carolina's Outer Banks. All data except for South Core Banks are from Dinsmore et al. (1998). We calculated birds/km by dividing the average number of individuals counted during complete surveys by the length of South Core Banks' ocean beaches (41 km).

	Bodie Island	North Beach	South Beach	Ocracoke	North Core Banks	South Core Banks
All shorebirds	88	117	41	36	56	31
Black-bellied Plover	2	4	2	1	3	2
Piping Plover	<l	<l	<l	<l	<l	<1
American Oystercatcher	1	<l	1	<l	1	<1
Willet	6	12	6	9	9	4
Whimbrel	1	2	<1	<1	<1	<1
Ruddy Turnstone	1	2	2	<1	<1	1
Red Knot	1	<l	<l	1	6	<1
Sanderling	76	97	28	22	34	21

CHAPTER 3

A Before-After-Control-Impact Study of Disturbance Effects on Nonbreeding Shorebirds

ABSTRACT

We examined whether the abundance, habitat use, and behavior of migrating shorebirds differed at sites with and without vehicle disturbance. We employed a before-after-control-impact (BACI) experimental study design to isolate treatment effects (vehicle disturbance) from spatial or temporal differences among our study sites. We manipulated disturbance levels within beach closures at South Core Banks, Cape Lookout National Seashore, North Carolina using paired control and impact plots. We measured bird abundance and Sanderling (*Calidris alba*) behavior during before and after periods on both control and impact plots. Control plots were closed to vehicles during both the before and after periods. Treatment plots were closed to vehicles during the before period but subjected to a fixed level of vehicle disturbance during the after period. Differences in shorebird abundance and behavior between paired control and treatment plots provided an estimate of vehicle disturbance effects. We found that vehicle disturbance decreased shorebird abundance and altered shorebird habitat use on treatment plots and decreased the amount of time Sanderlings spent roosting and resting. We believe that experimental BACI study designs provide a practical tool for measuring the effects of disturbance on wildlife without the confounding that affects purely observational approaches.

INTRODUCTION

Many species of shorebirds embark on long, energetically expensive migrations. Stopover sites provide an opportunity for individuals to rest and rebuild the energy stores necessary for migration and survival on their breeding or wintering grounds. North Carolina's Outer Banks include stopover sites that are used by a variety of shorebird species during fall and spring migration (Dinsmore et al. 1998). Many of theses sites are also open to off-road vehicles, which have become popular for human recreational activities, such as camping and fishing. Nonbreeding shorebirds are frequently observed flushing in response to vehicles, a behavior that reflects a tradeoff between avoiding a perceived risk and other requirements such as foraging or roosting (Gill and Sutherland 2000). If flushing in response to human activity increases a bird's overall energy expenditure, then disturbance could have indirect population level consequences via reductions in body condition and other traits associated with fitness (Gill and Sutherland 2000). Declines in the numbers of shorebirds using Atlantic stopover sites (Howe et al. 1989, Bart et al. 2007), coupled with increases in recreational activity have raised concerns about the effects of disturbance on coastal bird populations.

Site-based disturbance studies have provided evidence that the abundance, distribution, and behavior of nonbreeding shorebirds are influenced by human activity. Morton (1996) found that the abundance of wintering Sanderlings (*Calidris alba*) at Assateague Island National Seashore was influenced by human activity. Sanderlings were 14% more likely to occur at beaches without human activity, and Sanderling abundance was 2.4 times higher on plots without human activity. Barbee et al. (1994) found that spring and fall shorebird numbers were larger in areas without disturbance on North Carolina's outer banks. Pfister et al. (1992) found that Short-billed Dowitcher (*Limnodromus griseus*) and Sanderling abundance was negatively correlated with vehicle counts. They also found that roosting site selection by nonbreeding Sanderlings, Semipalmated Sandpipers (*Calidris pusilla*), Black-bellied Plovers (*Pluvialis squatarola*), and Ruddy Turnstones (*Arenaria interpres*) was correlated with disturbance levels. Peters and Otis (2007) found that human activity (boat traffic) influenced roost site selection by Red Knots (*Calidris canutus*). Disturbance has also been correlated with behavioral changes such as increases in vigilance, flying and preening, and decreases in walking, running, and roosting by Sanderlings (Morton 1996). Barbee et al. (1994) found that nonbreeding shorebirds spent less time roosting in areas with human activity than in areas closed to vehicles. Some studies have found a negative correlation between human activity and time spent foraging by nonbreeding Sanderlings (Burger and Gochfeld 1991b, Thomas et al. 2003) while others have found time spent foraging to be unaffected by human activity levels (Barbee et al. 1994, Morton 1996). This difference may reflect different methodologies because Thomas et al. (2003) and Burger and Gochfeld (1991) only sampled foraging birds, while Barbee et al. (1994) and Morton (1996) sampled all birds in their study plots.

Site-based disturbance studies such as these are strictly observational. They identify correlations between disturbance and changes in behavior, distribution, or abundance. Observational studies are often used to study disturbance (Hill et al. 1997) because they are convenient and inexpensive, but results are often difficult to interpret because the effects of disturbance are confounded by variations in environmental or habitat factors that are unrelated to disturbance (Cole and Knight 1991, Gutzwiller 1991, Sutherland 2007, Neuman et al. 2008). This is especially problematic for studies on nonbreeding shorebirds because their behavior is sensitive to many factors that are highly dynamic, such as weather, time of day, and tide levels (Burger et al. 1977, Morton 1996, Beauchamp 2006). For example, Morton (1996) found that Sanderling abundance, human activity, and prey densities covaried temporally, probably in response to temperature. Predation risk is a particularly important factor to consider in disturbance studies because many animals respond similarly to human disturbance and predation-risk (Frid and Dill 2002, Peters and Otis 2005, Yasue 2006). Peters and Otis (2005) found that vigilance behaviors in nonbreeding American Oystercatchers (*Haematopus palliatus*) increased with predator numbers, but that human activity levels covaried with changes in predator numbers. Gutzwiller (1991) and others have advocated the use of experimental studies, especially ones that compare control and treatment areas or before and after impact measures, because of their ability to isolate disturbance effects and demonstrate causal relationships (Walters and Holling 1990, Cole and Knight 1991, Gutzwiller 1991, Knight and Cole 1991, Hill et al. 1997, Sutherland 2007). Experiments are generally only affordable or practical at spatial scales that encompass a small fraction of the populations of interest (Gill et al. 2001b, Sutherland 2007), but they may be feasible for site-based studies in refuges, parks, or other places where human activity or other disturbance factors can be manipulated (Gutzwiller 1991).

We used a before-after-control-impact (BACI) study design to determine how vehicle disturbance affects the abundance, distribution, and activity budgets of nonbreeding shorebirds at a fall migration stopover site; South Core Banks, Cape Lookout National Seashore, North Carolina. The study design allowed us to isolate treatment effects (a controlled level of vehicle disturbance) from spatial or temporal differences among our study sites. This separation would not have been feasible using an observational approach.

METHODS

South Core Banks is one of several barriers islands that comprise Cape Lookout National Seashore, North Carolina (Fig. 3.1). Approximately 41 km in length, the ocean beach faces southeast and is relatively straight with homogeneous structure. The remainder of the island faces west and has two distinctive features.

Cape Lookout Point is a 0.31 km southeast facing sand peninsula that is occasionally inundated on high tides, and the Power Squadron Spit is a flat northeast facing peninsula of sand. South Core Banks is a popular fall surf-fishing location and fisherman are allowed to drive on the ocean beach from mile marker 23 to 46, on a back road that runs behind the dune line from mile marker 24 to 44, and on several access ramps that connect the two areas. Segments of beach between ramps are sometimes closed to public traffic to protect sea turtle nests during the summer and early fall. The Power Squadron Spit and a portion of Cape Lookout Point are closed to public vehicles year round to protect nesting and wintering birds. Beach segments are closed by the establishment of rope fences that run from the high tide line to the dunes, and signs that delineate bird and turtle nesting closures. A variety of shorebird species including Sanderlings, Black-bellied Plovers, Willets (*Catoptrophorus semipalmatus*), Red Knots, Ruddy Turnstones, and Piping Plovers (*Charadrius melodus*) use South Core Banks as a migratory stopover site (Chapter 2). Shorebird numbers on the Outer Banks peak between August and November (Dinsmore et al. 1998), and overnight visitor numbers at South Core Banks peak in October (Chapter 2, National Park Service 2007).

We conducted a BACI study (Stewart-Oaten et al. 1986, Stewart-Oaten and Bence 2001) with replication in areas closed to public vehicles where we could manipulate vehicle disturbance levels and measure responses in shorebird distribution, abundance, and behavior. During the periods 9 September - 5 November 2006 and 29 August - 22 October 2007, we sampled paired control and impact plots (n = 17 pairs) for four days, sampling on consecutive days whenever possible. Both the control and impact plots from each pair remained free of vehicle traffic during the first two days of sampling. We then introduced a vehicle disturbance treatment to the impact plot during the third and fourth days of sampling. Differences in shorebird diversity, abundance, and behavior over time between control and impact plots provided estimates of disturbance effects at each pair of plots. The BACI design is useful because it controls for environmental factors that affect both plots equally (i.e. temperature and wind) as well as controlling for habitat variability, such as beach structure, and associated factors, such as prey abundance, that can vary spatially or temporally among plots. This is possible because BACI studies test for relative differences between paired plots over the pre and post-impact periods, rather than simply measuring the absolute differences between pairs of plots, or the absolute changes at impact plots.

Plot locations were distributed throughout the southeast facing beach and were located in areas with shorebird abundance that was indicative of South Core Banks' southeast facing ocean beach (Figs. 3.1 – 3.5). Plot locations were not randomly selected because placement was restricted by sea turtle nest sites and it was only practical to establish closures adjacent to vehicle access ramps. Early in the season we used closures that were established primarily to protect sea turtle nests, but later in the season, as sea turtle nests hatched or failed, we established closures for the exclusive use of our study. This lack of randomization in our selection of experimental units disqualifies our design as a true experiment (Ott and Longnecker 2001), but it did not preclude our ability to conduct an experimental manipulation and make inferences about the effects of a controlled variable (Hurlbert 1984, Williams et al. 2002). Vehicle exclosures were created by routing vehicle traffic to the back-dune road using closure signs and rope barriers that stretched from the dunes to the high tide line. Closures were established at least 24 h prior to sampling and 48 h or more when possible. We placed plots at least 100 m from closure fences to avoid influences from vehicles outside the closures and at least 200 m from each other to avoid influencing the control plot with the disturbance treatment. Observers were unable to see more than 150 m in either direction, even when standing on top of the primary dunes. Therefore, plots were comprised of 300 m long segments of beach that extended from the dune line 100 m into the surf zone. The distance from the dune line to the water's edge ranged from 23 m to 77 m (mean = 49 m, SD = 12 m).

In an analysis of biweekly survey data from Assateague Island National Seashore, Morton (1996) found that negative correlations between Sanderling and vehicle counts were strongest on his small (161 m) plots. This suggests that our plot size was optimal for capturing disturbance effects on Sanderlings. In most cases we randomly assigned plots as control or impact plots, but in six cases plots containing active sea turtle nests were designated control plots to comply with the park's sea turtle management policy of excluding vehicles in the vicinity of active sea turtle nests.

Vehicles and pedestrians were excluded from our sampling areas with a few exceptions. Park staff drove all-terrain vehicles (ATVs) through six of the plot pairs once per day to monitor sea turtle nests, but this occurred outside of our sampling periods. In at least eight instances, we observed vehicles driving through our plots and one of these was at a time when there were no birds present in either plot. In these situations, the vehicles moved straight through both plots without stopping and were, therefore, unlikely to affect the relationship between the plots or our results.

Our experimental vehicle disturbance treatment involved driving an ATV on a variable, winding route through the impact plot at speeds of 15 to 20 mph every 10 min during the sampling period. Drivers made an effort to approach and flush all birds in the plot, but on a few occasions, high lunar tides created wide swash zones and large puddles on the ocean beach. Under these conditions, we were not able to approach all birds in the plot with the ATV. The disturbance treatment was initiated on the plot immediately following the second sampling period, or 22 h before the third sampling period. We attempted to simulate high levels of beach traffic based on an assessment of traffic levels conducted during a pilot field season.

We observed beach traffic at locations where we expected high traffic over two busy weekends corresponding with the beginning of the fall fishing season (23 September 2006) and a fishing tournament (29 and 30 September 2006) for comparison with our disturbance treatment level. We selected mile markers 28, 32, and 43 as sampling locations because we had previously used these sections of beach as study plots, and because we believed they were located in high traffic areas. However, beach survey data show that these dates were not during the weeks with the largest vehicle numbers and that only one observation location, mile 32, was actually in an area with relatively high vehicle traffic (Chapter 2, Figs. 3.6 and 3.7). We recorded the time, type, and location on the beach of each vehicle during a 1 h period at each location each day, which also provided us with the number of moving vehicles and time intervals between them. We completed nine 1 h sampling periods at mile markers 28 and 32 and four sampling periods at mile marker 43 for a total of 22 h and 17 min of observation.

Plot Surveys

We used scan surveys at 20 min intervals to sample bird abundance and distribution in our plots. Observers recorded all birds and assigned them to one of four habitat types within the plot. Habitat categories were defined as: surf which extended from 100 m offshore to the water's edge; swash zone, the area where waves washed onto the beach; wet sand, areas above the water's edge that were still wet from previous tide levels; and dry sand, the area between the upper reaches of the wet sand and the dune line. Black-bellied Plovers, and shorebirds in general, use dry sand microhabitat more at high tide than at low tide on South Core Banks. This shift in microhabitat use is also true for Sanderlings and Willets, although it is not as well defined (Chapter 2). We sampled plots at high or rising tide when we believed birds were most abundant on the ocean beach. The abundance of several shorebird species is greater during high tide than rising tide (Chapter 2). Burger (1984) identified a time of day effect on shorebird behavior, so we attempted to distribute our sampling effort evenly over the sampling periods. High tide sample periods began 2 h before peak tide and ended 4 h later. Rising tide sample periods began at peak low tide and ended 4 h later. With the exception of one plot that was sampled 12 times, every plot was surveyed 13 times per sampling day. In an attempt to minimize observer influences, surveys were performed from the top of a dune at the center of the plot or at the central point on the beach farthest from the waterline that still allowed a full view of the swash zone. On a few occasions, observers had to stand within 10 m of the swash zone in order to see the entire plot. We assume that the detectability for birds in plots was generally 100 percent because we chose plot dimensions based on the distance an observer could see small birds, beach widths were small, and all detections were visual.

Behavioral Observations

We sampled the behavior of randomly selected Sanderlings during the intervals between complete plot surveys. We chose Sanderlings as our focal species because they are common during fall migration (Dinsmore et al. 1998), and they have served as focal species for numerous investigations of wintering and migrating shorebird behavior (Maron and Myers 1985, Burger and Gochfeld 1991b, Dinsmore and Collazo 2003, Thomas et al. 2003). We recorded a focal bird's behavior every 10 s for 1 to 5 min using a stop watch with a repeat timer. Behavior categories recorded included: foraging, roosting, standing, walking, running, flying, preening, bathing, and pursuing conspecifics. As Sanderlings often change behaviors very quickly, and we recorded their behavior at the instant the timer sounded. This meant that birds recorded as running were, in many cases, feeding in the swash zone, but all birds recorded as feeding were actually feeding (i.e. probing, pecking, stabbing, etc.) and not running from an ATV, wave, or another bird. This definition of foraging differs from those used in some studies on disturbance and foraging Sanderlings (Burger and Gochfeld 1991b, Thomas et al. 2003).

Statistical Analysis

Depending on the normality of data, we used modified paired *t*-tests or signed rank tests to examine whether or not there was a significant treatment effect at the $\alpha = .05$ level using SAS 9.1 (SAS Institute, Cary, North Carolina, USA). This was done by averaging values of the response variable from the pre-impact samples and post-impact samples separately for each plot. We then calculated the difference between the change at the impact plot and control plot, to estimate the treatment effect for each pair of plots. This is represented by

$$D_i = (X_{IAi} - X_{IBi}) - (X_{CAi} - X_{CBi})$$

where D_i is the difference between the *i*th pair control and impact plot (treatment effect), X_{IA} is the average response at the impact plot after the treatment, X_{IB} is the average response at the impact plot before treatment, X_{CA} is the average response at the control plot after the treatment was applied to the impact plot, and X_{CB} is the average response at the control plot before the treatment was added to the impact plot. Calculating the difference in this way eliminates any confounding of treatment with temporal and spatial processes. We used counts from surveys as the response variable when testing for an effect on abundance, the proportion of time sampled individuals spent exhibiting a particular behavior as the response variable for an effect on activity, and the proportion of individuals in a microhabitat as the response variable when testing for an effect on distribution. During the analysis of each behavior, we removed data from pairs of plots that did not have any birds exhibiting a particular behavior during either the before or after period. The paired *t*-tests assume that D_i's are normally distributed and the signed rank tests assume that D_i's are symmetric about the median (Ott and Longnecker 2001). Both tests assume that pairs are independent. All tests on abundance effects were one-tailed, and tests on distribution effects were two-tailed. Tests on behavior effects were one-tailed, except for tests on foraging effects where we used a two-tailed test because of conflicting results from prior studies (Burger and Gochfeld 1991b, Barbee et al. 1994, Morton 1996, Thomas et al. 2003).

RESULTS

We sampled 11 pairs of plots at high tide and 6 pairs during rising tides. Shorebirds were the most abundant group of birds in plots (mean = 9.03, SE = 0.30) followed by gulls (mean = 1.36, SE = 0.23). Terns and waterbirds were present but much less abundant, averaging less than one bird per survey. Sanderlings, Willets, and Black-bellied Plovers were the most abundant shorebirds with Sanderlings (mean = 5.86, SE = 0.25) 3.5 times more abundant than Willets, the next most common shorebird (Fig. 3.8). Other shorebird species observed were American Oystercatcher, Dowitcher sp., Dunlin (*Calidris alpina*), Semipalmated Plover (*Charadrius semipalmatus*), Least Sandpiper (*Calidris minutilla*), Pectoral Sandpiper (*Calidris melanotos*), Piping Plover, Red Knot, Ruddy Turnstone, Semipalmated Sandpiper, Western Sandpiper (*Calidris mauri*), Spotted Sandpiper (*Actitis macularia*), Whimbrel (*Numenius phaeopus*), and Wilson's Plover (*Charadrius wilsonia*). The relative abundance among bird species in our plots was similar to that of the entire ocean beach between miles 23 and 44 (Chapter 2).

Responses to vehicle disturbance varied by species and group. Vehicle disturbance had a significant negative effect on the overall number of birds using experimental plots (one-tailed t = -2.89, df = 16, P = 0.0053). The treatment effect (mean = -7.35, SE = 2.54) due to disturbance was 70% of the average from impact plots before the treatment was introduced (Table 3.1). Pairs with an average abundance of ten or more birds in the impact plot pre-impact showed a negative treatment effect. We removed gulls, terns, and waterbirds from our analyses to measure the response of shorebirds to disturbance. We found a negative effect on abundance (mean = -4.83, SE = 2.14, one-tailed t = -2.26, df = 16, P = 0.019) that was 58% of the average shorebird abundance at impact plots before treatment (Table 3.1). As with our analysis of all birds combined, plot pairs with an average abundance of ten or more shorebirds in the pre-treatment impact plot showed a negative treatment response. The similarity between analyses of all birds and shorebirds was to be expected because 83% of the birds counted in plots were shorebirds. Sanderlings were the most abundant shorebird in plots. We did not detect a significant effect on their numbers (mean = -1.66, SE = 1.66, one-tailed t = -1.50, df = 16, P = 0.077), but all pairs with an average abundance greater than six on impact plots showed a negative treatment response. Willet abundance was not significantly affected by disturbance (mean = -1.00, SE = 0.66, one-tailed t = -1.45, df = 13, P = 0.086). We had zero counts at both the impact and control plots of one pair during the pre-impact period and two pairs during the post-impact period, so we excluded these pairs from analysis. Black-bellied Plover abundance was negatively affected by the disturbance treatment with only four of the 12 pairs included in the analysis showing a positive treatment effect (one-tailed S = -29, df = 11, P = 0.011). This treatment effect (mean = -2.34, SE = 1.20) was approximately two times (193%) the average count from impact plots pre-treatment (Table 3.1). However, Black-bellied Plover numbers were generally low and they were not always present on plots. We excluded five plots from analysis because there were none counted during either the before or after periods.

Birds also shifted their microhabitat associations in response to disturbance (Table 3.2). Disturbance decreased the proportion of Black-bellied Plovers using the dry sand (mean effect = -0.32, SE = 0.11, two-tailed t = -2.94, df = 8, P = 0.02). It shifted the distribution of Sanderlings, shorebirds, and all birds away from wet sand and into the swash zone. Disturbance increased the proportions of Sanderlings using the swash zone (mean effect = 0.13, SE = 0.047, two-tailed t = 2.66, df = 16, P = 0.02) and decreased the proportion using the wet sand (mean effect = -0.10, SE = 0.034, two-tailed t = -2.93, df = 16, P = 0.01). Disturbance increased the proportions of shorebirds and all birds using the swash zone (shorebirds; mean effect = 0.14, SE = 0.048, two-tailed t = 2.97, df = 16, P = 0.009; all birds, mean effect = 0.12, SE = 0.05, two-tailed t = 2.41, df = 16, P = 0.03) and decreased the proportions using the wet sand (shorebirds; mean effect = -0.10, SE = 0.039, two-tailed *t* = -2.55, df = 16, P = 0.02; all birds, mean effect = -0.16, SE = 0.043, two-tailed *t* = -3.79, df = 16, P = 0.002). We did not find significant treatment effects on the distribution of Willets on our plots.

Sanderling behavior was also affected by vehicle disturbance. We performed 1,977 behavioral observations of Sanderlings, with a mean observation length of 3 min. The average number of observations per plot pair was 116, and we performed between two and fifty-six observations per plot per time period (Table 3.3). Vehicle disturbance had a negative effect on the proportion of time Sanderlings spent roosting (mean effect = -0.082, SE = 0.043, one-tailed *t* = -1.88, df = 14, P = 0.04) and resting (mean effect = -0.071, SE = 0.037, one-tailed *t* = -1.89, df = 16, P = 0.04). Resting was defined as roosting or standing. The means of these treatment effects were 85% (roosting) and 34% (resting) of the average proportion of time spent on the behavior on impact plots during the pre-impact period (roosting; mean = 0.096, SE = 0.022, n = 17 resting; mean = 0.28, SE = 0.033, n = 17). Test statistics from an analysis of time spent foraging were not significant (mean effect = 0.022, SE = 0.031, two-tailed S = 34.5, df = 16, P = 0.11). Disturbance did, however, increase the proportion of time birds spent active, which was defined as any behavior other than roosting or standing (mean effect = 0.07, SE = 0.37, df = 16, P = 0.04). We did not find significant effects on any other behaviors (Table 3.4).

We counted 175 vehicles during traffic observations, and the average number of vehicles (average = 7.95, median = 6.50, SD = 5.86) was higher than our treatment level of 6 vehicles per h. No vehicles passed during one 1 h sampling period, and the maximum number of vehicles during one hour was 22. The average length of time between vehicles was less than our treatment interval length of 10 min (average = 5.15 min, SD = 6.37, minimum = 0 min, maximum = 32 min, median = 2 min, and n = 38 intervals). All vehicles were trucks (49%), ATVs (25%), passenger vehicles (17%), or large campers (8%). Fifty eight percent of the vehicles drove on the dry sand and 42% drove on wet sand.

DISCUSSION

Our results indicate that vehicle disturbance influences the distribution, abundance, and behavior of shorebirds on ocean beaches habitats at migratory stopover sites. The introduction of vehicle disturbance to ocean beach segments decreased the numbers of all birds and shorebirds in experimental plots, decreased their relative use of the wet sand microhabitat, and increased their use of the swash zone. These results concur with Barbee et al.'s (1994) comparison of shorebird numbers on open and closed beaches. Black-bellied Plover abundance decreased in response to disturbance and their use of dry sand habitats decreased. This finding is consistent with our observations that most Black-bellied Plovers roosted on upper beach areas and left the plots altogether when disturbed. Some individuals moved toward the water's edge in response to disturbance, but our results did not indicate displacement into wet sand and swash zone habitats. Black-bellied Plover numbers were rarely large in plots, and they were usually absent when the disturbance treatment was applied. We did not detect any disturbance effects on Willets, but we regularly observed them leaving plots in response to our ATV. We believe that our failure to detect a disturbance effect was due to highly variable counts resulting from the tendency of foraging Willets to flock and move quickly through our plots during both before and after treatment periods.

We did not find a significant effect on Sanderling abundance, but their distribution shifted from the wet sand to the swash zone and they spent less time resting and more time in active behaviors. Our results do not support Morton's (1996) findings that Sanderlings were more abundant in areas without human activity, but agree with his finding that Sanderlings roosted less in areas with disturbance.

We found evidence of intraspecific variation in Sanderlings' responses to disturbance. Although we did not mark individuals, unique patterns of molt allowed us to identify and observe individuals over the course of trials at some experimental plots. This mostly occurred during August and the first part of September when we observed individual Sanderlings defending feeding territories within the plot against small roving flocks of foraging Sanderlings (Myers et al. 1979). After we introduced disturbance, the transient individuals seemed to spend less time in the plot while the territorial birds tolerated the disturbance and maintained their feeding territories. If our observations are correct, then it would follow that measuring an overall treatment effect on abundance would be more likely for transient birds than territorial ones.

Our results concur with Morton and Barbee's conclusion that Sanderlings do not spend less time foraging in response to disturbance. We did, however, frequently see Sanderlings leave roosting sites in the dry and wet sand, move to the swash zone, and begin feeding. This behavior is reflected in our finding that their distribution shifted toward the swash zone and leads us to agree with Morton's (1996) suggestion that foraging is a manifestation of agitation. It is possible that disturbance decreases the time foraging birds spend probing, pecking, and eating (foraging as we defined it), supporting Burger and Gochfeld (1991b) and Thomas et al.'s (2003) work, while increasing the time birds spend in the swash zone foraging.

Although we demonstrated responses of shorebirds to moderate levels of disturbance, it is important to recognize that we are unable to assess the effects of these responses on individuals and populations. The connection between behavior and population level responses has rarely been demonstrated (Hill et al. 1997). Interpreting behavioral responses in terms of the costs to individuals or populations is problematic because an individual's decisions about how to respond to disturbance stimuli and their consequences depend on the context of current resources, body condition, and risks (Gill et al. 2001b, Gill 2007). Behavioral responses are not good indicators of impacts on fitness for this reason. For example, in a food supplementation experiment, Beale and Monaghan (2004) showed that Ruddy Turnstones' responses to disturbance were influenced by their body condition and birds in better condition responded more to disturbance than birds in poor condition. Bouton et al. (2005) found that Wood Storks' (*Mycteria americana*) reproductive success was negatively influenced by boat disturbance despite the lack of a noticeable behavioral response.

Changes in abundance and distribution are not reliable measures of fitness consequences either. Disturbance may influence the distribution of birds among or within habitats but not affect the numbers of individuals that a site can support because birds may compensate for habitat deterioration in one area by using other areas more heavily or returning when disturbance declines, for example by foraging at night (Burger and Gochfeld 1991b, Morton 1996, Gill et al. 2001a, Smart and Gill 2003). Similarly, interspecific variation in responses to disturbance may merely be a result of different spatial and temporal patterns of habitat use. Species that use ocean beach as well as sound-side habitat may be more likely to leave in response to disturbance than species that exist exclusively in the disturbed habitat. Our results support such a relationship because we observed gulls, terns, and Black-bellied Plovers in large numbers on sound-side beaches and sand flats but Willets and Sanderlings appeared most abundant on the ocean beach. Studies that use measures of resource use, refueling rates, body condition, or physiological stress, rather than behavior would be better for assessing disturbance impacts on individual fitness (Beale and Monaghan 2004, Lyons et al. 2008).

Assessment of the BACI study design

We believe that our study illustrates the practicality and value of BACI study designs to measure the response of wildlife to disturbance or other treatment effects when simultaneously sampling or applying a treatment to numerous replicate study sites is not feasible. One particularly useful feature of the BACI design for studies involving shorebirds is its ability to handle the dynamic environmental conditions characteristic of coastal habitats. Using control and impact plots with before and after periods allowed us to measure disturbance effects over days with different weather conditions and at sites that were similar but not identical. This design can also handle environmental conditions that affect sampling, as long as they affect both plots identically. For example, strong winds and changes in local beach topography occasionally limited visibility at some of our paired plots, but we were able to include data from these plots because the conditions were similar at both plots and we do not think they affected the relationship between them.

A common challenge when designing field experiments is to choose a treatment level that can be standardized and is heavy enough to test hypotheses while still being similar to actual levels in the system of interest (Gutzwiller 1991). Researchers could, therefore, benefit greatly from pilot studies that measure the natural patterns and levels of treatment factors and from careful selection of a treatment level. We were unable to simulate vehicle traffic patterns from unrestricted areas because they are irregular, and it was important that our treatment be standardized among treatment plots. Actual traffic levels on the National Seashore consist of a variety of vehicle types (ATV, recreational vehicle, pickup truck etc.) driven at variable frequencies and speeds, primarily in the dry sand. Our treatment was consistent, frequent, spanned all beach microhabitats, and almost always resulted in birds flushing. Our findings identify a disturbance level at which we know disturbance influences shorebirds' utilization of ocean beach habitat but it is not an assessment of the effects of actual traffic levels.

Selecting an appropriate distance between paired control and impact plots is a critical issue to consider when designing a BACI study, because plots need to be close enough together that they are similar in terms of environmental conditions and habitat characteristics (e.g. wind, prey density, predator levels) but far enough apart that they are independent in terms of the treatment effect. Plots that are too close together will violate the central assumption that the change in the relationship between the plots is a result of the treatment, and plots that are too far apart will compromise the study's ability to separate the treatment effect from responses to changes in environmental conditions. Pilot studies that assess how far treatment effects persist in space and time should be used to identify an appropriate distance between plots. We chose a between-pair distance of 200 - 300 m based on informal observations of how far birds flew when flushed and Thomas et al.'s (2003) description of minimal approach distances for nonbreeding Sanderlings (30 m), but we were often constrained by the length of beach closures. Morton reported mean flush distances in nonbreeding Sanderlings of 17.8 m and 10.8 m for pedestrians and vehicles, respectively. Despite the seemingly large distance between our plots, we observed occasional interactions between birds on treatment and control plots. On a few occasions, large flocks of Willets or Sanderlings were observed occupying both treatment and control plots simultaneously. This meant that when birds were disturbed part of the flock on the impact plot, a chain reaction occurred that eventually caused birds to leave both treatment and control plots. On several other occasions foraging birds were flushed from the impact plot into the control plot. While these cases violated the assumption that paired plots were independent, we do not believe they compromised our results because they were infrequent, and they could have resulted in increases or decreases in the number of birds on control plots.

BACI studies that are designed to measure the effects of disturbance on abundance should distribute sampling units in a way that maximizes the initial abundance of animals. In our study, plots with low abundance showed greater variation and smaller treatment effects than plots with high abundance, and all plots with high abundance showed a negative treatment effect. We believe that this is a result of greater opportunities to measure treatment effects when there are more individuals on plots. Another benefit of using plots with high before-treatment abundance is that statistical tests could be used that test hypotheses about the percent change in response to disturbance rather than just the response itself, which would address biological significance more directly than comparing treatment effects to before-treatment abundance as we have done. Such an approach would be accomplished by adding X_{IBi} to the denominator when calculating D_i's to give a new variable

$$D_i^* = \frac{(X_{IAi} - X_{IBi}) - (X_{CAi} - X_{CBi})}{X_{IBi}}$$

Using this method with small or variable before-treatment abundance would result in extreme and excessively variable D_i values and that is why it was not used here.

Finally, we recommend the use of blinds in disturbance studies because we observed that most birds avoided areas in the immediate proximity (approximately <10 m) of observers. The distance maintained by most individuals was shorter than the distance to the plot edge, so we don't think it influenced our abundance estimates. However, many American Oystercatchers, Brown Pelicans (*Pelecanus occidentalis*), and Double-crested Cormorants (*Phalacrocorax auritus*) were seen roosting on the beach outside of our plots and they often flushed at distances greater than 150 m, effectively excluding them from our study.

The BACI design allowed us to identify disturbance effects on nonbreeding shorebirds at a migration stopover site, which is a highly variable system with many environmental and habitat factors that often covary. These effects were short-term and difficult to relate to population level consequences, but the BACI design may also be useful for studies that seek to identify disturbance effects on breeding birds, which are more directly related to population sizes and individual fitness. We believe that it could be especially useful for studies of disturbance effects on parental and chick behaviors because disturbance effects would likely be measurable immediately, and other experimental designs would be difficult to use because of logistical difficulties associated with measuring behavior and applying a disturbance treatment to multiple sites at once.

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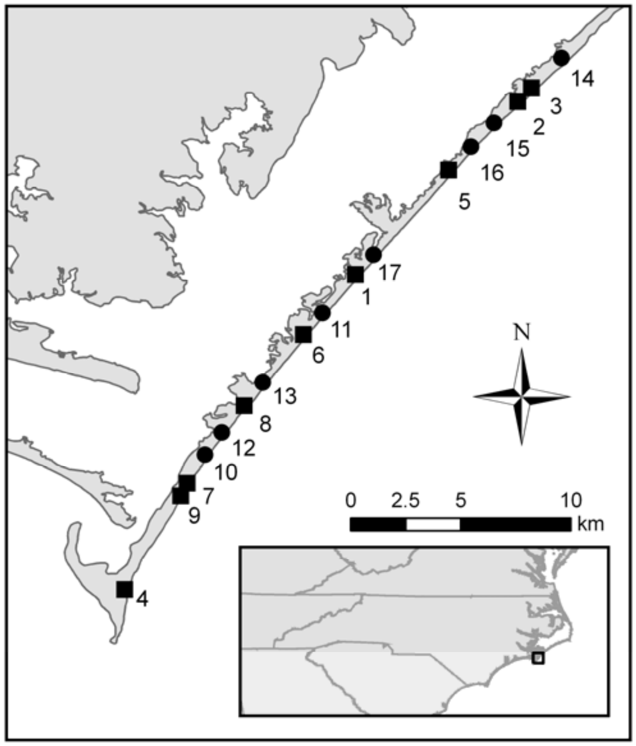

Figure 3.1. Study sites at South Core Banks, Cape Lookout National Seashore, on North Carolina's Outer Banks. Each square represents a pair of plots used in fall 2006 (n = 9) and each circle represents a pair used in fall 2007 (n = 8). Pairs are numbered in the order they were used.

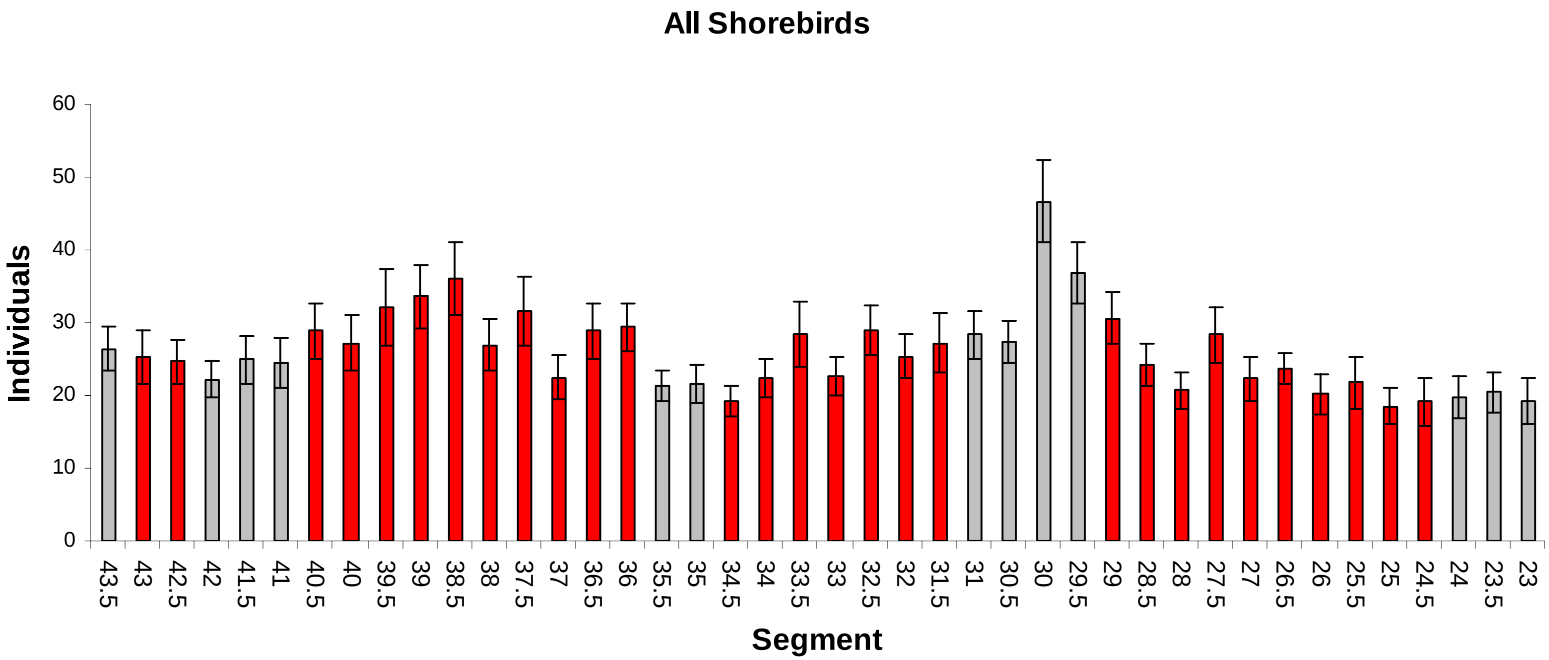

Figure 3.2. Average shorebird abundance at beach segments where we placed study plots. Segments that were used in our study are red and those that were not used, but that had beach structure similar to that of our plots, are grey. Segment numbers correspond with their position in the CALO mile marker system, in which mile numbers increase from north to south.

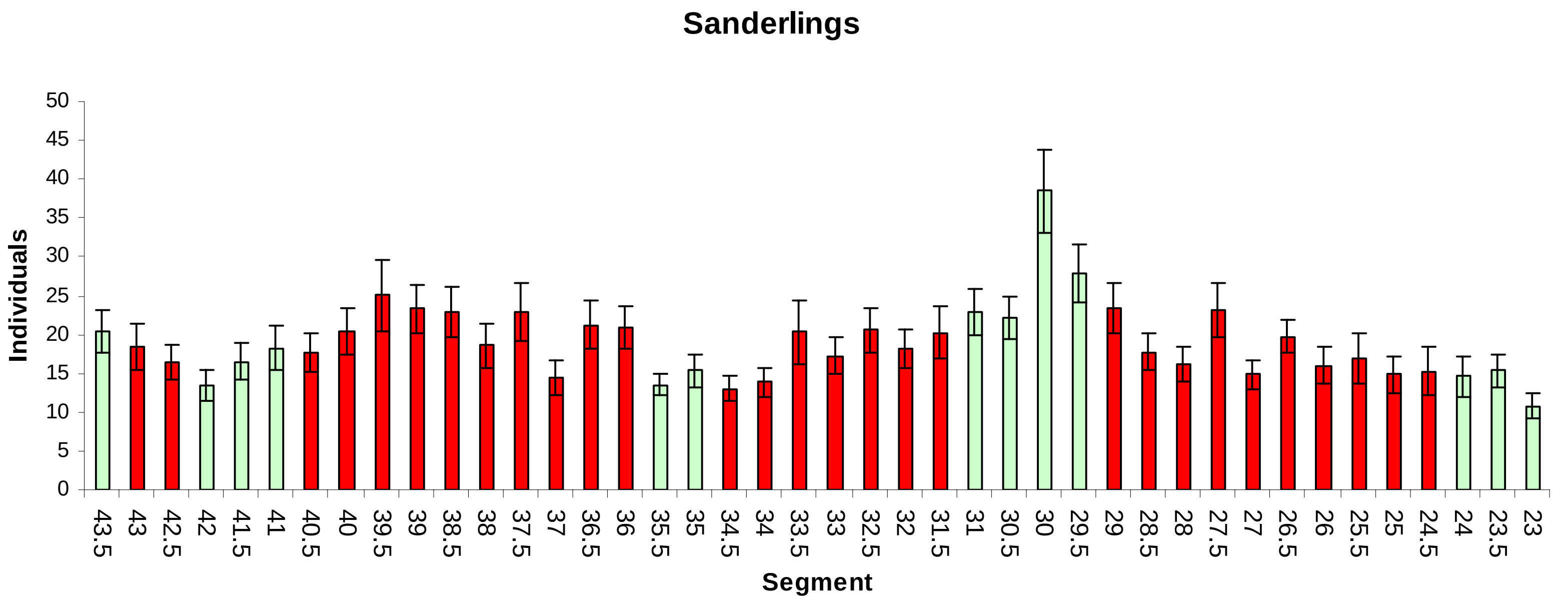

Figure 3.3. Average Sanderling abundance at beach segments where we placed study plots. Segments that were used in our study are red and those that were not used, but that had beach structure similar to that of our plots, are blue-green. Segment numbers correspond with their position in the CALO mile marker system, in which mile numbers increase from north to south.

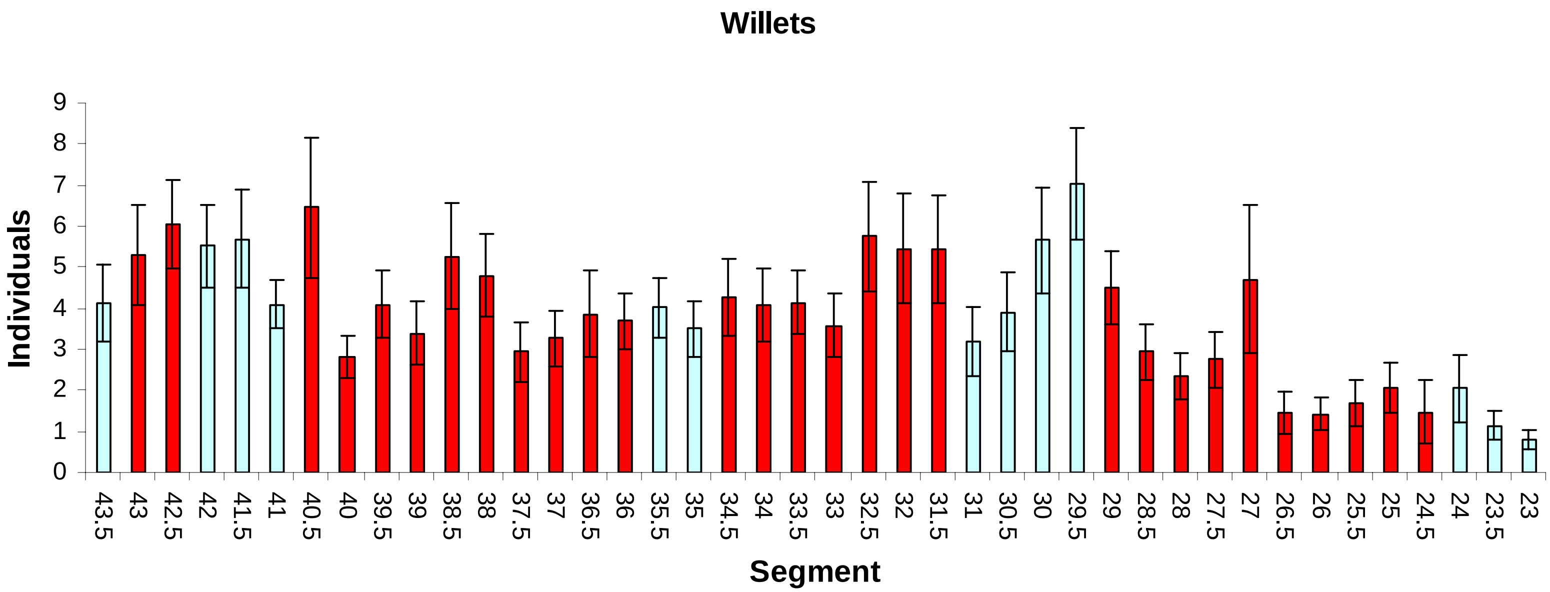

Figure 3.4. Average Willet abundance at beach segments where we placed study plots. Segments that were used in our study are red and those that were not used, but that had beach structure similar to that of our plots, are blue. Segment numbers correspond with their position in the CALO mile marker system, in which mile numbers increase from north to south.

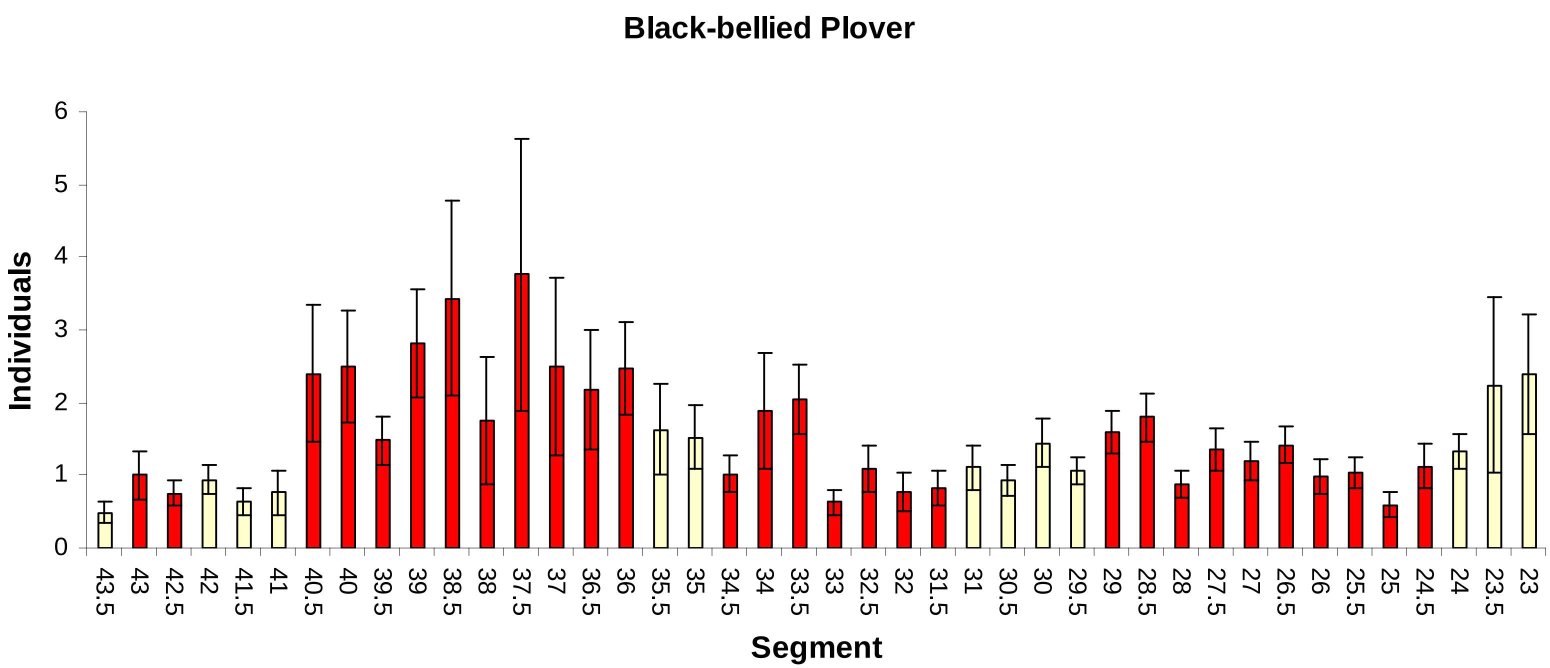

Figure 3.5. Average Black-bellied Plover abundance at beach segments where we placed study plots. Segments that were used in our study are red and those that were not used, but that had beach structure similar to that of our plots, are light yellow. Segment numbers correspond with their position in the CALO mile marker system, in which mile numbers increase from north to south.

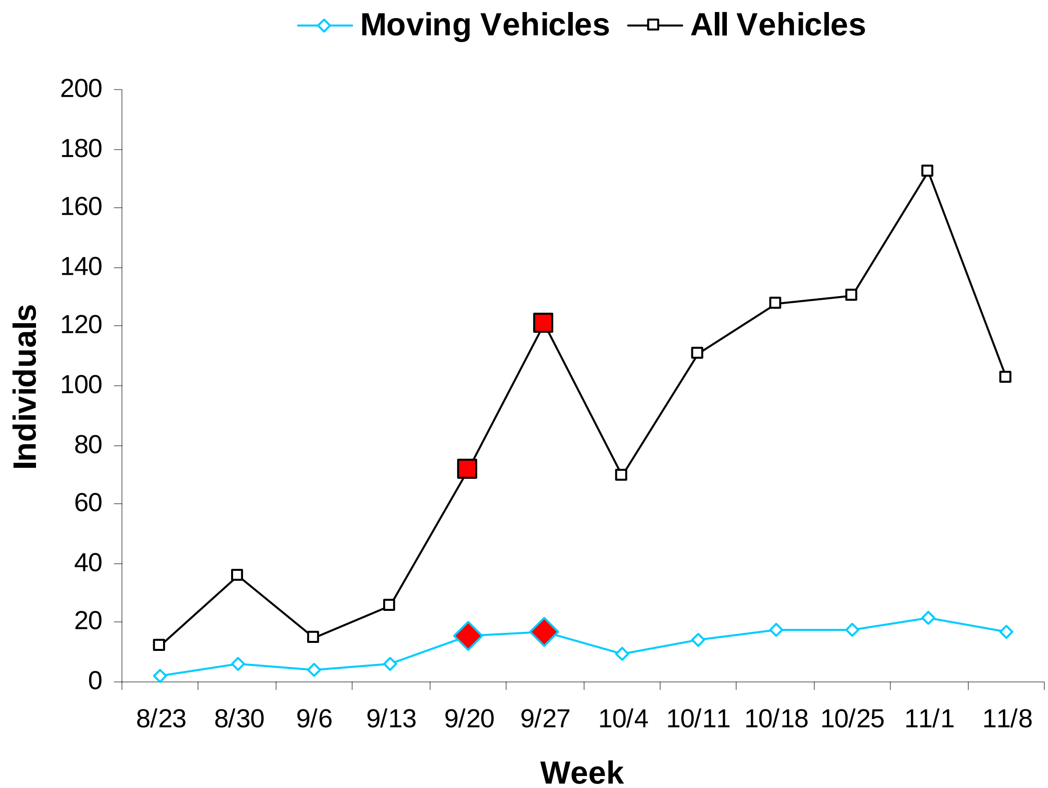

Figure 3.6. Indices of total vehicle and moving vehicle abundance on the ocean beach of South Core Banks for 12 weeks during the fall. Weeks when we performed traffic observations are highlighted with large, red marks. We calculated abundance indices by summing the means of surveys from all beach segments for each week (Chapter 2). We named weeks after their first day (month/day).

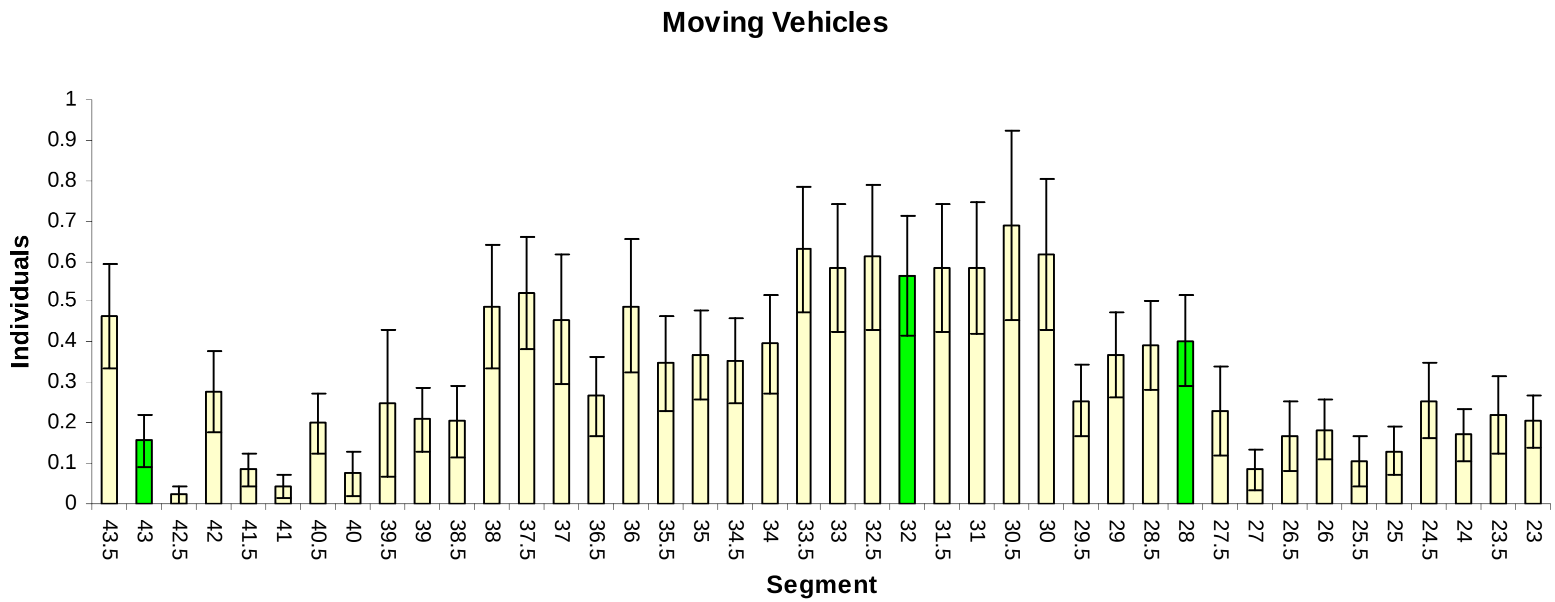

Figure 3.7. Average moving vehicle numbers at beach segments on the southeast facing ocean beach of South Core Banks. We recorded moving vehicle abundance at every segment during surveys (Chapter 2) and recorded the frequency of vehicle passes during traffic observations at three locations. Segments where we performed traffic observations are green and all other segments are beige. Error bars show one standard error, and segment numbers correspond with their position in the CALO mile marker system, in which mile numbers increase from north to south.

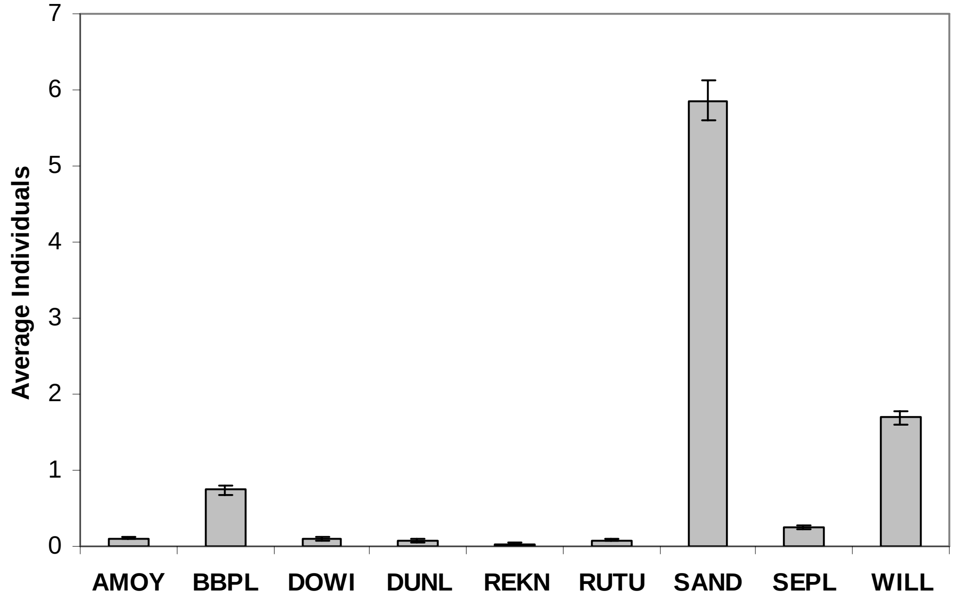

Figure 3.8. Average count of American Oystercatcher (AMOY), Black-bellied Plover (BBPL), Dowitcher species (DOWI), Dunlin (DUNL), Red Knot (REKN), Ruddy Turnstone (RUTU), Sanderling (SAND), Semipalmated Plover (SEPL), and Willet (WILL) during plot surveys (n = 1760). Error bars represent one standard error.

Table 3.1. Average disturbance effect on the numbers of all birds, shorebirds, Sanderlings, Willets, and Black-bellied Plovers with the average abundance at impact plots in the before-treatment period for comparison. All tests for significance were one-tailed.

	Disturbance Effect					Impact, Before	
	mean	SE	Test statistic	df	P	mean	SE
All birds	-7.35	2.54	*t* = -2.89	16	0.01*	10.50	2.04
Shorebirds	-4.83	2.14	*t* = -2.26	16	0.02*	8.38	1.92
Sanderlings	-1.66	1.11	*t* = -1.50	16	0.08	4.52	0.55
Willets	-1.00	0.66	*t* = -1.45	13	0.09	2.35	0.94
Black-bellied Plovers	-2.34	1.20	S = -29	11	0.01*	1.21	0.19

*P<0.05

Table 3.2. Average effects of ATV disturbance treatment on the proportion of all birds, shorebirds, Sanderlings, and Black-bellied Plovers in beach microhabitats. Averages from impact plots during the before-treatment period are shown for comparison. All tests for significance were two-tailed.

	Disturbance Effect					Impact, Before	
	Mean	SE	Test statistic	df	P	mean	SE
All birds							
Swash zone	0.12	0.05	*t* = 2.41	16	0.03*	0.52	0.04
Wet sand	-0.16	0.04	*t* = -3.79	16	<0.01*	0.27	0.03
Dry sand	-0.03	0.04	*t* = -.70	16	0.49	0.13	0.04
Surf	0.07	0.04	S = 31	16	0.12	0.08	0.03
Shorebirds							
Swash zone	0.14	0.05	*t* = 2.97	16	0.01*	0.61	0.05
Wet sand	-0.10	0.04	*t* = -2.55	16	0.02*	0.26	0.03
Dry sand	-0.04	0.05	*t* = -0.86	16	0.40	0.13	0.04
Sanderlings							
Swash zone	0.13	0.05	*t* = 2.66	16	0.02*	0.70	0.05
Wet sand	-0.10	0.03	*t* = -2.93	16	0.01*	0.23	0.04
Dry sand	-0.02	0.03	*t* = -0.68	16	0.51	0.07	0.02
Black-bellied Plovers							
Swash zone	0.02	0.12	*t* = 0.15	8	0.88	0.20	0.10
Wet sand	0.30	0.17	*t* = 1.77	8	0.12	0.42	0.11
Dry Sand	-0.32	0.11	*t* = -2.94	8	0.02*	0.37	0.11

*P<0.05

Table 3.3. Number of Sanderling behavioral observations at each plot during before and after-treatment time periods.

	Before Treatment		After Treatment		
Pair	Control Plot	Impact Plot	Control Plot	Impact Plot	Total
A	30	31	31	25	117
B	10	25	26	31	92
C	18	15	13	7	53
D	18	19	20	13	70
E	32	18	10	16	76
F	2	2	15	33	52
G	13	18	44	54	129
H	27	33	35	30	125
I	24	14	48	50	136
J	47	44	51	21	163
K	33	35	38	53	159
L	56	27	54	38	175
M	51	24	24	22	121
N	26	18	48	33	125
O	18	23	17	19	77
P	33	30	45	31	139
Q	35	41	52	40	168
Mean	28	25	34	30	116

Table 3.4. The average effect of the ATV disturbance treatment on the proportion of time Sanderlings spent on each behavior and tests for significance. One-tailed, paired *t* or signed-rank tests were used for all analyses except for foraging. We defined resting as the proportion of time spent roosting or standing and defined active as the proportion of time spent foraging, walking, running, flying, bathing, preening, or pursuing.

	Disturbance Effect					Impact, Before	
	mean	SE	Test statistic	df	P	mean	SE
Resting	-0.07	0.04	*t* = -1.89	16	0.04*	0.21	0.03
Roosting	-0.08	0.04	*t* = -1.88	14	0.04*	0.10	0.02
Standing	0.00	0.03	*t* = 0.19	16	0.43	0.13	0.01
Active	0.07	0.04	*t* = 1.87	16	0.04*	0.79	0.03
Foraging	0.02	0.03	S = 34.5	16	0.11	0.38	0.04
Walking	0.00	0.03	*t* = 0.14	16	0.45	0.15	0.02
Running	0.01	0.02	*t* = 0.41	16	0.34	0.17	0.02
Flying	0.02	0.01	*t* = 1.52	15	0.07	0.02	0.00
Bathing	-0.00	0.00	S = -7.5	9	0.25	0.00	0.00
Preening	0.02	0.03	S = 5.5	16	0.41	0.07	0.01
Pursuing	-0.00	0.00	S = -1	5	0.48	0.01	0.00

*P<0.05