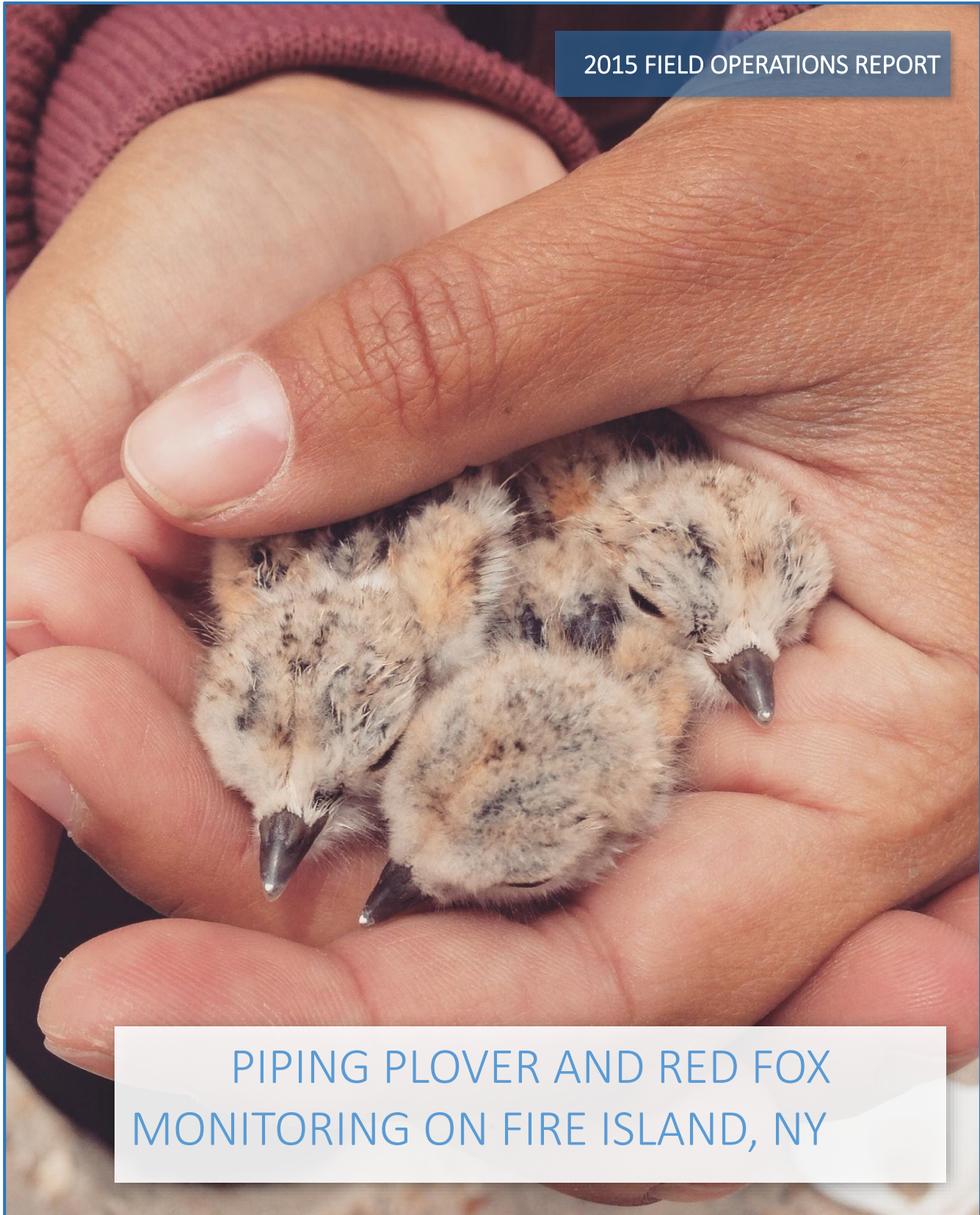




2015 FIELD OPERATIONS REPORT

PIPING PLOVER AND RED FOX MONITORING ON FIRE ISLAND, NY

JULIA D. MONK, KAT MILES, AUDREY DEROSE-WILSON, JAMES D. FRASER, DANIEL H. CATLIN, SHANNON RITTER, KATIE M. WALKER AND SARAH M. KARPANTY



DEPARTMENT OF FISH AND WILDLIFE CONSERVATION

VIRGINIA TECH
BLACKSBURG, VA 24061

Cite this report as: Monk, J. D., K. Miles, A. DeRose-Wilson, J. D. Fraser, D. H. Catlin, S. Ritter, K. M. Walker, and S. M. Karpanty. 2015. Piping plover and red fox monitoring on Fire Island, NY. Annual report prepared by the Virginia Tech Shorebird Project. Virginia Tech, Blacksburg, VA.

Table of Contents

EXECUTIVE SUMMARY	5
BACKGROUND INFORMATION	6
PART I: PIPING PLOVER MONITORING ON FIRE ISLAND AND WESTHAMPTON ISLAND, NEW YORK	8
INTRODUCTION	8
<i>USACE BCP and FIMI Project Descriptions</i>	<i>8</i>
<i>Joint Project Goals</i>	<i>8</i>
FIELD METHODS.....	9
<i>Study area</i>	<i>9</i>
<i>Habitat classification</i>	<i>14</i>
<i>Adult survey</i>	<i>14</i>
<i>Nest Location</i>	<i>15</i>
<i>Egg masses</i>	<i>16</i>
<i>Nest checks</i>	<i>16</i>
<i>Brood observations and chick behavior</i>	<i>16</i>
<i>Trapping and banding</i>	<i>16</i>
<i>Banding schemes</i>	<i>17</i>
<i>Terrestrial invertebrates</i>	<i>18</i>
<i>Substrate invertebrates</i>	<i>19</i>
<i>Human use</i>	<i>19</i>
ANALYTICAL METHODS	19
<i>Nesting habitat use</i>	<i>19</i>
<i>Adult movements</i>	<i>19</i>
<i>Nest survival</i>	<i>20</i>
<i>Egg mass</i>	<i>20</i>
<i>Chick behavior</i>	<i>20</i>
<i>Brood home range</i>	<i>20</i>
<i>Chick mass</i>	<i>21</i>
<i>Terrestrial invertebrates</i>	<i>21</i>
<i>Human use</i>	<i>21</i>
PRELIMINARY RESULTS	21
<i>Banding</i>	<i>21</i>
<i>Nesting habitat use</i>	<i>22</i>
<i>Adult movements</i>	<i>24</i>
<i>Nest survival</i>	<i>25</i>

<i>Egg mass</i>	25
<i>Chick behavior</i>	25
<i>Chick survival</i>	26
<i>Brood home range</i>	27
ACKNOWLEDGMENTS	34
APPENDICES	35
<i>Appendix A: Nest predation incident reports</i>	35
LITERATURE CITED	41
PART II: RED FOX MOVEMENTS, HABITAT SELECTION, AND DEMOGRAPHY ON FIRE ISLAND, NEW YORK	42
INTRODUCTION	42
FIELD METHODS	43
<i>Study site</i>	43
<i>Sign, scat, and den surveys</i>	43
<i>Trapping, ear-tagging, and collaring</i>	45
<i>GPS tracking</i>	48
<i>Remote camera surveys</i>	48
PRELIMINARY RESULTS	51
<i>Sign, scat, and den surveys</i>	51
<i>Trapping, ear-tagging, and collaring</i>	51
<i>GPS tracking</i>	52
<i>Remote camera surveys</i>	58
LITERATURE CITED	58
ACKNOWLEDGMENTS	58

EXECUTIVE SUMMARY

This project was developed to provide a broader ecological understanding of the ways in which storm-created habitats and beach stabilization projects affect piping plover populations and their invertebrate prey communities and red fox predators on Fire Island and Westhampton Island, NY. We compared the dynamics of bird use, reproductive output, and invertebrate densities in natural and artificially stabilized areas. We monitored piping plover (*Charadrius melodus*; hereafter plover) and red fox (*Vulpes vulpes*) population movements, habitat selection, and demography on Fire Island.

During the 2015 breeding season, we banded 27 adult plovers and 47 plover chicks. Of the 48 nests established over the course of the season, 16 hatched, representing a 47.66% probability of hatching for nests that were exclosed, a 24.51% probability of hatching for nests that were never exclosed, and a 0% probability of hatching for nests that were exclosed and then exclosures were removed. Of the 47 chicks that hatched, 13 survived to fledging (25 days of age). This survival rate reflected a productivity of 0.45 fledges/female for the entire study area. Broken down by management units, productivity was 0.43 fledges/female at Robert Moses State Park, 0.14 fledges/female at Cupsogue County Park, 0.31 fledges/female at Smith Point County Park, and 2.50 fledges/female in the Otis Pike Wilderness of the National Seashore.

We conducted systematic transects to locate red fox denning sites, scat and sign; we captured 21 red foxes and attached GPS collars and ear-tags to 16 individuals; and we deployed camera-trapping grids to quantify red fox, and co-occurring predator, occupancy and abundance. Initial exploratory analyses of red fox data indicate differences in abundance and occupancy across management units, overlapping patterns of home range use for both sexes of foxes within and across management units, and wide ranging movements by male red foxes in October-November.

BACKGROUND INFORMATION

This report presents the results of field efforts and analyses undertaken in support of Cooperative Agreement Numbers F15AC00393 and F13AC00194 entered into with the U.S. Fish and Wildlife Service (USFWS) through the Southern Appalachian Cooperative Ecosystem Studies Unit regarding federally-listed species within two U.S. Army Corps of Engineers (USACE) project areas on Fire Island and Westhampton Barrier Island, Suffolk County, New York. Funding originated from the USACE as part of the requirements under the Biological Opinion.

The two project areas include Breach Contingency Plan (BCP; USACE 1996) and Fire Island Inlet to Moriches Inlet Stabilization Coastal Storm Risk Reduction Project (FIMI; USACE 2013). In October 2012, the USACE in concert with the State of New York closed two breaches at Smith Point County Park on Fire Island and Cupsogue Beach County Park on Westhampton Island, both of which were formed by Hurricane Sandy. Under the Disaster Relief Appropriations Act of 2013 (Public Law 113-2), the USACE designed and constructed the FIMI project. The project entails beach and dune construction along 19 miles of Fire Island, and was initiated by USACE in winter 2014.

The USACE formally consulted with the USFWS pursuant to the Endangered Species Act of 1973, as amended due to the potential direct and indirect adverse impacts of these projects on the federally-listed species. The USFWS's Biological Opinion for the BCP covered the piping plover (*Charadrius melodus*; threatened) and seabeach amaranth (*Amaranthus pumilus*; threatened); the Biological Opinion for the FIMI included these species in addition to the red knot (*Calidris canutus rufa*; threatened; USFWS 1995 and 2014).

The adverse effects of the FIMI on piping plovers included habitat loss and degradation, exacerbation of predation, and increased human disturbance. As a result, the FIMI Biological Opinion includes a number of conservation measures to address these effects and reduce the effect of the anticipated level of incidental take authorized by the USFWS, including inlet to inlet monitoring, habitat maintenance and restoration, predator management, and reduction in human disturbance.

A program of targeted field studies, developed by the USFWS with the assistance of Virginia Tech, are the subject of this report. Both Virginia Tech and the USFWS worked closely with an interagency team consisting of the National Park Service (NPS), New York State Office of Parks, Recreation, and Historic Preservation (NYSOPRHP), the County of Suffolk, and the USACE to obtain the necessary permits to undertake this work.

The Scope of Work of piping plover monitoring includes the following objectives:

[Key methods to inform these objectives are in brackets following each objective.]

- *Objective 1: Compare changes in numbers, density, and distribution of piping plovers in various habitats on Fire Island. [Trapping and banding (pg. 17), Nest location (pg. 16)]*

- *Objective 2:* Estimate the “effect distance” of artificially created habitat at New Made Island and Great Gun Beach. [*Adult surveys (pg. 15)*]
- *Objective 3:* Compare egg weights of birds with access to natural and man-made foraging habitat, such as bay side intertidal flats, with egg weights of birds without such access. [*Egg mass (pg. 17)*]
- *Objective 4:* Compare piping plover nest and chick survival rates in various habitats across Fire Island. [*Nest checks (pg. 17), Brood observations and chick behavior (pg. 17)*]
- *Objective 5:* Compare the relative contribution of local growth (recruitment) vs. immigration in population growth associated with new habitats. [*Trapping and banding (pg. 17), Adult surveys (pg. 15)*]
- *Objective 6:* Collect and compare habitat characteristics (e.g. location, elevation, and vegetation density data in breeding areas). [*Habitat classification (pg. 15), Nest location (pg. 16), Invertebrate sampling (pg. 19 & 20)*]
- *Objective 7:* Evaluate the effectiveness of recreational and predator management measures on Fire Island. [*Human use (pg. 20)*]

The Scope of Work of red fox monitoring includes the following objectives:

- *Objective 1:* Quantify the abundance and occupancy of red foxes and relate changes in these parameters to changes in habitat and predator management activities.
- *Objective 2:* Assess habitat use versus availability by red foxes and any variation in habitat selection related to changing habitat composition and predator management.
- *Objective 3:* Quantify home range size, long-range movements, and variation in movement ecology of red foxes and relate to changing habitat composition and predator management.
- *Objective 4:* Estimate red fox reproductive success and adult survival, and variation in these population parameters, relative to habitat composition and predator management.
- *Objective 5:* Quantify the interactions of red fox with shorebird nests and chicks.
- *Objective 6:* Utilize information collected in objectives 1-5 to make recommendations on the utility of, and recommended methodologies for, management of red fox populations in the study area and in other coastal habitats.

PART I: PIPING PLOVER MONITORING ON FIRE ISLAND AND WESTHAMPTON ISLAND, NEW YORK

INTRODUCTION

A major unanswered question in the management of breaches and overwashes is how long a breach needs to remain open to provide benefits to piping plovers, or whether the currently used engineered breach fill and beach stabilization designs are suitable for piping plovers. Piping plover responses to changes in habitat suitability have been reported throughout the species' range. For example, at Westhampton Dunes, the barrier island was breached in December of 1992, and the breach was closed by the United States Army Corps of Engineers (USACE) the following fall. In the approximately 9 months the breach was open, natural processes created about 16 ha of bay side intertidal habitat. This habitat, along with the expansive backshore habitat created as a result of natural processes and the USACE emergency breach fill project, initially attracted a piping plover population that grew to 39 pairs over the next 7 years (Cohen et al. 2009). Although the population declined as the connectivity between nesting and foraging habitat was broken by construction and vegetation of the dune of the USACE Westhampton Storm Damage Protection Project as well as housing and roads, even now, some 20 years after the breach, approximately 6 pairs of plovers still use the area (Steve Papa, USFWS, personal communication, 2016). In October 2012, Hurricane Sandy created several new breaches, including one breach at Old Inlet which remains open, and overwashes on Fire Island and Westhampton Island.

USACE BCP and FIMI Project Descriptions

Following Hurricane Sandy, the USACE closed two breaches at Smith Point County Park and Cupsogue Beach County Park. Detailed project descriptions are provided in USACE (1996) and (2014). The BCP project description includes special provisions to reduce the adverse effects to piping plovers including maintaining the breach fill profile at a maximum 9.5 ft National Geodetic Vertical Datum and removing sand fences during the piping plover season.

The Fire Island Inlet to Moriches Inlet, Fire Island Stabilization Project (FIMI) was designed to address ocean shoreline erosion and protect mainland communities from future storm damage due to breaches and overwashes. The scope of the project extends the entire length of Fire Island from Fire Island Inlet at Robert Moses State Park east to Moriches Inlet at Smith Point State Park.

To avoid or minimize adverse effects of dune and beach construction, USACE cleared vegetation and modified the topography in approximately 33.7 ha (83.2 ac) of ocean side habitat at Great Gun Beach (Smith Point East), so as to mimic early successional habitat. Additionally, USACE cleared vegetation and modified topography of an additional 6 ha (15.8 ac) of bay side habitat south of New Made Island, so as to mimic nesting and foraging plover habitat.

Joint Project Goals

This study is consistent with the USACE's responsibilities under the Endangered Species Act (16 USC 1531 et. Seq.), viz. Section 2. C. (All Federal departments and agencies shall seek to conserve endangered species and

threatened species and shall utilize their authorities in furtherance of the purposes of this act), Section 7 a. 1. (...Federal agencies shall, in consultation with and with the assistance of the secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species...) and Section 7. A. 2. (Each Federal agency shall...ensure that any action authorized, funded, or carried out by such agency...is not likely to jeopardize the continued existence of any endangered species or threatened species...).

The goal of this project is to provide a broader ecological understanding of the ways in which the breaches and USACE breach-fill projects affect piping plover populations and their invertebrate prey communities by comparing the dynamics of bird use and invertebrate densities in a breach area, two filled breach areas, two restoration areas, overwash areas, and other areas. Ultimately our results will help refine our understanding of the time frame and manner in which piping plover habitat develops and persists.

In addition to monitoring breeding piping plovers, a key goal of our study is to band piping plover adults and chicks to allow us to compare the relative contribution of local recruitment versus immigration to population growth in the storm-created habitat and artificially closed breaches in subsequent years of the study. Here we present the results of our banding efforts, data on piping plover reproductive output in various habitats, information on the quality of clutches, chick behavior and responses to disturbance in different management units, and information on invertebrate prey abundance in different habitats for April through August 2015.

FIELD METHODS

Study area

We focused monitoring efforts on a 27.1-km stretch of barrier islands within the administrative boundaries of the NPS (5.8 km of Otis Pike Wilderness Area and 1.5 km of the Fire Island Lighthouse Tract), Suffolk County (Cupsogue County Park and Smith Point County Park), and NYSOPRHP (Robert Moses State Park), on Fire Island and Westhampton Island. We divided the study site into two units: Democrat Point (9.8 km, comprising the Robert Moses State Park and Fire Island Lighthouse Tract management units) and the Eastern Barrier Islands (17.3 km, comprising the Otis Pike Wilderness Area, Smith Point County Park, and Cupsogue County Park). Potential plover nesting habitat at our study site consisted of sandy beaches backed by dunes and habitat created by Hurricane Sandy in October 2012, including overwashes, a new breach at Old Inlet, and breaches or near breaches created by Sandy and subsequently filled by the USACE. The breach at Cupsogue County Park was filled with a berm 9+ ft. NGVD in elevation, 150 ft. wide and 2000 ft. long (presentation on Coastal Breach Closures, Bocamazo 2013). The breach at Narrow Bay was filled with a berm about 12 ft. NGVD in elevation (based on a completion drawing of Smith Point breach fill, 2013). Potential plover nesting habitat also included two restoration areas built by the USACE: 33.7 ha of flat sand oceanside habitat at Great Gun Beach/Smith Point East, and 6 ha of flat sand bayside habitat at New Made.

All beaches were open to pedestrians throughout the season. Recreational vehicles are typically permitted to drive on the beach at Smith Point County Park and Robert Moses State Park, however, according to the Biological Opinion, closures may be necessary during the chick-rearing season if certain conditions are not met. In 2015, Smith Point was closed to recreational off-road-vehicle traffic from 9 July – 13 August. The

closure did not include law enforcement, park staff, and researchers, who continued to drive All-Terrain Vehicles (ATVs) or Utility-Terrain Vehicles (UTVs) throughout the season at Cupsogue Beach County Park and the Otis Pike Wilderness, but recreational driving was not allowed in these areas.

We divided the study area into subsites of habitat small enough that monitoring activities could be completed throughout the entire subsite on each visit. In some cases, subsites were more or less consistent with one or more beach stabilization management activities, such as breach filling or dune building by sand fence. In 2015, we expanded our study area to include resighting surveys on one new subsite at the western portion of our study area (in addition to the 16 monitored in 2014) and seven new subsites at the new Robert Moses State Park study site (Figures 1 and 2, Table 1). Each subsite consisted primarily of vegetated dunes, beach, storm-created habitats (natural breach and overwashes), or engineered beaches. Engineered beaches, consisting of artificially filled breaches and stabilized overwashes, were initially storm-created habitat, but efforts were made to restore dune elevation and width using sand fence and discarded Christmas trees to trap sand. Additionally, new upland sandy flat habitat was created by the USACE at the New Made and Smith Point East subsites in an attempt to provide nesting areas for piping plovers as part of the FIMI project.

Table 1. Subsite names, relative locations, and general habitat descriptions at Fire Island and Westhampton Island, 2015

Name	Subsite Code	Description	Habitat Type
Cupsogue Mud Flats	CMF	Mud flats north of the Cupsogue Beach County Park parking lot, and south of the high bare island in Moriches Bay.	Mud flat
Cupsogue Sand Bar	CSB	Large low energy sandbar/shoal north of Cupsogue West	Sand bar
Cupsogue East	CSE	Beach and narrow strip of bayside intertidal zone at east end of Cupsogue Beach County Park. Begins at the east edge of the breach-fill and extends east to the west end of the parking lot.	Beach
Cupsogue West	CSW	Breach-fill and Moriches Inlet area of Cupsogue Beach County Park. Begins at Moriches Inlet and extends east to the west edge of the breach-fill.	Filled breach
Smith Point East	SPTE	Begins on west side of Moriches Inlet and extends west to Cut 3 on Burma Road.	Beach
Smith Point West	SPTW	Begins at Cut 3 on Burma Road and extends to Cut 2 of Burma Road.	Beach
Narrow Bay East	NBE	Begins at Cut 2 on Burma Road and extends west to the east end of the filled dredge spoil.	Overwash
New Made	MWPF	Begins at the east end of the filled dredge spoil and extends west to the east edge of the small breach-fill.	Filled dredge spoil

Narrow Bay West	NBW	Includes the overwash and small breach-fill west of the New Made dredge spoil-fill.	Overwash and filled breach
Pattersquash East	PSE	Stretch of beach with primary duneline between Narrow Bay West and Pattersquash overwashes.	Beach
Pattersquash Overwash	PSO	Overwash west of Pattersquash East.	Overwash
Bridge East	BRE	Begins where the primary duneline begins at west end of Pattersquash Overwash and extends to the Otis Pike Wilderness Area at the NPS Visitor Center.	Beach
Bridge Overwash	BRO	Overwash in the Otis Pike Wilderness Area just west of the NPS Visitor Center.	Overwash
Bridge West	BRW	Stretch of beach with primary duneline between Bridge Overwash and Old Inlet East.	Beach
Old Inlet East	OIE	Begins where the primary duneline ends and extends west to Old Inlet.	Overwash and inlet
Old Inlet West	OIW	Begins at west side of Old Inlet and extends to the point where large primary dunes begin.	Overwash and inlet
Old Inlet West Reference	OIWR	Stretch of beach between the east end of Old Inlet West and Bellport Beach.	Beach and overwash
Flood Shoals	FS	Flood shoals associated with Old Inlet.	Flood shoals
Fire Island Lighthouse	FIL	Fire Island Lighthouse Tract of NPS; begins at eastern edge of sand ORV track running inland before housing begins and extends west to signage indicating the boundary with Robert Moses State Park.	Mature dunes
Field 5	FLD5	Begins at signage at west end of Fire Island Lighthouse and extends west to the blue hut at the boundary of Field 4.	Beach
Field 4	FLD4	Begins at blue hut at the west end of Field 5 and extends west to the next blue hut in front of the Field 3 parking lot.	Beach
Field 3	FLD3	Begins at blue hut at the west end of Field 4 and extends west to the next blue hut in front of the Field 2 parking lot.	Beach
The Golf Course	GOLF	Begins at the west side of the Field 2 parking lot behind the primary dune line and extends west to the beginning of the sand stock pile area and north to the major roadway. Not plover habitat.	Golf course
Ocean South Side	OSS	Begins at blue hut at the west end of Field 3 and extends west to the western stone jetty on the ocean side.	Beach

Stockpile	STP	Sand stock pile area on bay side of island; begins at west end of golf course and extends west to the northernmost rock jetty.	Sand stock pile
Demo Point	DMP	Begins at stone jetties on bay and ocean side at the east ends of OSS and STP, and extends west to the inlet.	Mature dunes and inlet

Figure 1. The study area at Robert Moses State Park and the Fire Island National Seashore Lighthouse Tract, depicted from west to east, with subsites delineated in yellow. Background imagery is from April 2015.

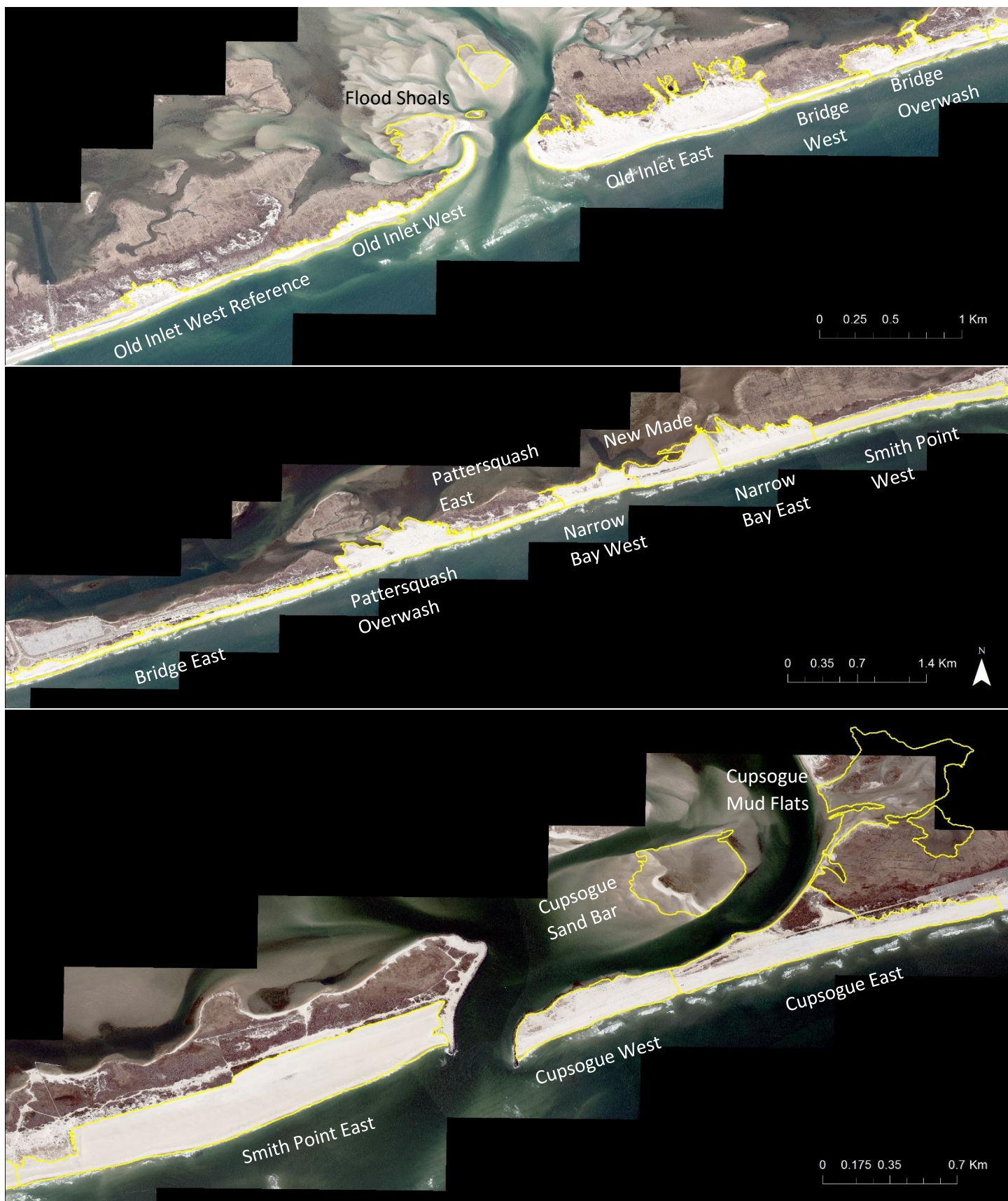


Figure 2. The study area at the Eastern Barrier Islands, including Fire Island and Westhampton Island, depicted from west to east, with subsites delineated in yellow. Background imagery is from April 2015.

Habitat sampling and mapping

We used a Trimble Geo7X and Trimble GeoExplorer 6000 (Trimble Navigation, Ltd., Sunnyvale, California, USA) to map bay and inlet high and low tide lines, bay and ocean spring tide lines, and wrack lines. Spring tide mapping occurred during spring tides in mid-May and early June. Other shoreline and wrack line mapping was completed in late July and early August.

Habitat classification

We used 6inx6in ultra-high resolution color and infrared imagery collected in April 2015 to determine the total available nesting habitat for each subsite. The imagery was in New York State Plane coordinate system, Long Island Zone, NAD 83, US Survey Feet 6-inch resolution, 4 band. We used ArcGIS (Release 10.2.1 Environmental Systems Research Institute, Redlands, CA) to mosaic the grids into two rasters: Democrat Point and Eastern Barrier Islands. The Eastern Barrier Islands raster was clipped to a spring high tide line we mapped in the field. Democrat Point was not mapped during the spring tide, so the imagery was clipped to subsite boundary lines digitized by hand in ArcMap. We used an unsupervised classification to classify each raster into four classes (dry sand, wet sand, vegetation, and water) by comparing pixels in each class to substrates visible in the original aerial imagery.

Any pixel classified as “dry sand” was considered available nesting habitat, since piping plovers avoid nesting near large patches of dense vegetation and moist intertidal areas (Espie et al. 1996, Haig and Elliot-Smith 2004, Cohen et al. 2008). We clipped the raster by subsite boundary polygons to yield a pixel count for each habitat class within each subsite. For each subsite raster, we divided the count of dry sand pixels by 430,556 (the number of pixels in a hectare). This yielded the final total area in hectares for each subsite. This method probably substantially overestimates the amount of open sand that is available to piping plovers, because in many places the sand habitat is highly fragmented by vegetation and piping plovers tend not to nest near large dense patches of vegetation. We are currently working on a classification that accounts for fragmentation in order to more accurately estimate the amount of habitat available to piping plovers.

Adult survey

We surveyed the entire study area for adult piping plovers every 1 – 3 days, April-September, 2015. We surveyed subsites on foot and by UTV. Subsites that did not have bay side habitat and consisted only of narrow ocean beach were surveyed by driving a UTV slowly along the ocean intertidal zone and then back along the upper beach. UTVs were only driven outside of areas protected by symbolic fencing established by land managers. At least twice per week during the nesting season (April-July) we surveyed these subsites on foot to check for plover tracks and scrapes. Subsites with interior overwash habitat or bay shorelines were always surveyed on foot. When conducting foot surveys, observers walked regularly spaced transects through each subsite along the east-west axis, using spotting scopes to observe plovers (Figure 3). Transect width varied depending on topography, vegetation, weather conditions, and other factors affecting visibility, and the width was generally adjusted to allow the entire area between transects to be in view of at least one of the observers. If the entire width of the subsite could not be surveyed in one pass, observers conducted multiple passes of the subsite walking parallel transects. Between one and four observers made each pass walking parallel 50-100m apart, depending on the size of the subsite. We attempted to avoid double-counting plovers

by keeping track of all previously seen birds. If we were unable to keep track of plovers throughout the duration of the survey we recounted both banded and unbanded plovers. Upon sighting a plover, we recorded its band combination (if banded), sex, behavior, and habitat. We also recorded a location within 30 m of each plover with a GPS unit (Garmin International, Olathe, KS).



Figure 3. Surveying for piping plovers at Smith Point East, Smith Point County Park. View facing west away from Moriches Inlet.

Nest Location

We searched all beaches, flood shoals, overwashes, and other sparsely vegetated habitat for piping plover nests and recorded nest locations with a Garmin GPS unit. We floated all eggs from nests found with four eggs to estimate incubation stage and hatch dates (Alberico 1995).

Egg masses

We weighed all four eggs from recently completed known-age clutches using a digital pocket scale (American Weigh, Norcross, GA, Figure 4).

Nest checks

We checked nests every 1-3 days throughout the incubation period and once per day as the hatch date approached to monitor hatching progress.

Brood observations and chick behavior

After hatching, we searched the nest area to locate and count chicks. We attempted to locate and band all piping plover chicks on the initial nest visit post-hatching, and to resight them on all subsequent visits, until they fledged (Figure 5). If weather permitted, we visited broods once per day and observed them for at least 30 minutes per visit. We collected a behavioral sample on at least one randomly selected chick in each brood at each visit, using a random number generator to determine the start time of the behavioral sample after locating a brood. We recorded peck rate continuously, and behavioral state (forage, sit, run, walk, chase, flee, preen, encounter with another individual) and habitat (moist sand, moist vegetation, dry sand, dry vegetation, and wrack) every ten seconds (Altmann 1974). We also conducted a disturbance point count during each brood visit. We recorded the number and type of disturbances (humans, vehicles, predators, competing piping plovers, etc.) within 100 m of the observer during a five minute period, noting their location relative to the brood. If more than one observer was present, we conducted the behavioral sample and the disturbance point count simultaneously; if only one observer was present during the brood observation, we conducted the disturbance point count immediately after the behavioral sample. If the brood moved more than 100 m during the first 30 minutes of observations we randomly selected a chick and conducted another behavioral sample at the new location.

Trapping and banding

We captured incubating piping plover adults on nests with complete clutches using a drop-box nest trap or shoo-in funnel trap. Once captured, the plover was removed from the trap, weighed, measured, and banded. If the second adult had not yet been trapped in 2015, we reset the trap while banding the first adult. We attempted to capture both unbanded plovers and plovers banded in previous years of the study to check bands and flags for fading and/or warping. If no adults entered the trap within 20 minutes of its deployment, we removed the trap and did not return to the nest that day. We recaptured all chicks using butterfly nets once they reached 22 days old to weigh and measure them a second time and to check their bands (Figure 5).



Figure 4. Weighing a complete clutch of piping plover eggs.



Figure 5. Piping plover chicks captured at a) 0 days old (on day of hatch) and b) 22 days old.

Banding schemes

Plover adults and chicks banded in 2015 received a green flag with a field-readable three-digit alphanumeric ID etched in white on the upper left leg, and an orange band on the upper right leg (Figure 6).



Figure 6. a) A piping plover adult banded with an alphanumeric flag and color band and b) releasing a newly banded piping plover adult.

Terrestrial invertebrates

During June and July, we sampled terrestrial invertebrates across a range of available habitat types (beach, overwash, breach fill, sand flat, and mature dune). Each sample set contained four sample stations. The first two stations followed a transect along the shoreline (we defaulted to the bay shoreline if the subsite had bay access; otherwise, the transect followed the ocean shoreline), with the stations placed at the upper edge of the intertidal zone. At each visit, we navigated to the previous sample location (or east edge of the subsite on the initial visit) and paced a randomly selected number of meters westward to establish a new sample station. If we reached the west end of a subsite, we began moving back eastward in the same way. The second station was placed 50 m further along the shoreline transect. The locations of the third and fourth stations of the sample set were selected from a larger set of randomly generated points; after placing the shoreline stations, we navigated to the waypoints with the lowest ID numbers within 100 m. This process randomly placed the stations in upper beach, backshore, dune, or interior island habitat. At each station, we sampled arthropods on two paint stirrers coated with Tanglefoot Insect Trap Coating (Tanglefoot Company, Grand Rapids, Michigan). We placed 1 stick horizontally on the ground and the other vertically, approximately 10 cm from the horizontal stick (Figure 7). The sticky area on the horizontal stick was 64.5 cm² and was 129 cm² on the vertical stick. We placed a wire mesh cage over each trapping station to prevent birds from becoming stuck to the trap. After allowing insects to collect for 30 minutes we counted and identified captured arthropods to taxonomic order, grouping them by size class.



Figure 7. A terrestrial arthropod trapping station.

Substrate invertebrates

In April, we sampled marine invertebrates on transects in all flood shoal, mud flat, and ocean to bay overwash intertidal habitats. We established 33 sampling stations in the intertidal zone at every subsite with such habitats (Flood Shoals, Cupsogue Sand Bar, Cupsogue Mud Flats, Cupsogue West, Narrow Bay West, and Pattersquash Overwash). We determined the location of the first sampling station by pacing a random number of steps from the east end of the subsite, and set each subsequent station at 10 m intervals. At each station we collected a substrate prey core (7.6 cm diameter, 10 cm deep) and sediment core (2.6 cm diameter, 10 cm deep). All samples were collected within an hour of low tide. We sieved samples with a 0.5 mm mesh sieve to remove fine grain sand, and preserved the remainder of the sample in 10% formalin with Rose Bengal. We transported samples to a lab at the Marine Resources Institute at the Department of Natural resources in South Carolina to identify and count organisms.

Human use

To generate an index of human activity, we recorded the number of people present each time we entered a subsite. We recorded the number of people categorically as 0, 1-50, 51-100, or >100. Whenever possible, we also recorded the number of on- and off-leash dogs.

Four times per month we conducted disturbance point counts at six subsites (one subsite per management unit, with two subsites sampled within Smith Point County Park and Fire Island National Seashore to account for different levels of human use). We conducted counts on one weekday (Monday-Thursday) and one weekend day (Friday-Sunday) during the first two weeks and last two weeks of each month, timing surveys between 13:30 and 16:30 to coincide with peak human use. The disturbance point counts were conducted at fixed points on high ground at each subsite to allow for maximum visibility. We recorded the number and type of disturbances (humans, vehicles, predators, etc.) within 100 m of the survey point during a five minute period.

ANALYTICAL METHODS

Nesting habitat use

We compared nesting habitat use versus availability in two ways. First, we calculated the area of four types of potential nesting habitat (beach, restoration area, unfilled breach/overwash, and filled breach/stabilized overwash) and used a chi-square test of equal proportions and Bonferroni-corrected confidence intervals to test observed use against expected use (chi-square) and determine selection for or against each type of habitat (Neu et al. 1974, Byers and Steinhorst 1984). We then performed the same test using length of beach frontage for the four habitat types as the measure of habitat availability. Because predator exclosures were not used equally within all parts of the study area, pairs in some areas were more likely to lose nests and re-nest, thus we used the peak number of territorial pairs that concurrently used each overwash or beach subsite, instead of total number of nests as a measure of use.

Adult movements

We used a Wilcoxon rank sum test to compare the average distance moved by adults with active nests in overwashes with direct bay side access (a plover could walk to bay intertidal habitat without encountering

dense vegetation, hereafter overwash-nesting plovers) and no direct access to bay side intertidal habitat (hereafter beach-nesting plovers).

Nest survival

We used a logistic exposure model (Rotella et al. 2004, Shaffer 2004) to estimate daily survival rates. For the logistic exposure model, we considered a nest to be exclosed only during the intervals when exclosures were present. Midway through the nesting season, Suffolk County Parks removed exclosures from all nests with exclosures in Smith Point County Park after a fox at Smith Point West managed to tear through the netting at the top of two exclosures and eat the eggs at those nests. We thus had three nest categories: nests that were exclosed and remained exclosed for their entire term, nests that were never exclosed, and nests that were exclosed but had those exclosures removed on May 24th. We then calculated the average survival rate by raising the daily survival rate for each nest state (exclosed, unexclosed, and previously exclosed) to the power of the number of days nests in each category were in that state, and multiplying the results for each state. Under this model, hatch date was set at 34 days (Heisey et al. 2007).

Egg mass

We used a Wilcoxon rank sum test to determine whether clutch mass differed between nests in overwashes with direct bay side access (Cupsogue West, Narrow Bay West, Pattersquash Overwash, Mount Plove, and parts of New Made and the Holy Land) and nests in subsites with no direct access to bay side intertidal habitat (Cupsogue East, Smith Point East, Smith Point West, Narrow Bay East, Old Inlet East, and parts of New Made and the Holy Land).

Chick behavior

We classified brood behavioral observations into three groups based on the level of human use at the location where we observed. See below for methods and the results section for a description of human use classes. The groups were, 1) high pedestrian use, 2) moderate pedestrian use, and 3) low pedestrian use. We used a Multi-response permutation procedure (MRPP) in the software package Blossom (Blossom Version W2008.04.02, www.fort.usgs.gov, accessed 1 November 2014) to compare the time chicks in each group spent foraging, mobile (running, walking, fleeing, chasing), inactive, sitting, standing, preening, and brooding during a five minute sample period. We also used MRPP to compare the peck rate of chicks from broods in these four groups.

Brood home range

We used a Wilcoxon rank sum test to determine whether the length of brood home ranges differed for broods that foraged on ocean beaches to those that foraged on the bay side of the overwash (whether or not the open habitat extended to bay shoreline or was backed by marsh)

Chick survival

We estimated chick daily survival rates using a Lukacs Young Survival (Lukacs et al. 2004) model with 31 encounter periods in Program MARK. Each encounter interval was one day long, and thus corresponded to chick age. We ran all possible subsets of models where survival rate and resight rate were held constant, varied with time, or varied with time in a linear trend. We multiplied the daily survival estimates for the first 25 intervals to predict the probability of surviving to fledging. We calculated productivity as the number of

fledglings produced per female. We chose to present fledges/female rather than fledges/pair because we observed that pairs divorced, and individuals partnered with new mates within the breeding season. Therefore, that the number of unique pairings of individuals or distinct pairs was more than the total number of males or females using the area. When calculating productivity by management unit, we used the highest count of females concurrently nesting within each subsite summed by management unit as the count. This method may have double counted females that moved between subsites and may have missed counted females that were not breeding in the study area when peak counts occurred.

Chick mass

We used an ANOVA to compare the mass of 22-day-old chicks in areas of high, moderate and low human use.

Terrestrial invertebrates

We used an ANOVA test to test for a difference between the mean numbers of arthropods captured on the bay shoreline, ocean shoreline, and island interior.

Human use

We graphically summarized the frequency of various levels of human use by subsite based on subsite visits and point counts.

PRELIMINARY RESULTS

Banding

We banded 29 adults and 47 chicks (Table 2). We recaptured 12 additional adult plovers that were banded in previous years (9 were banded as adults and 3 were banded as chicks). We banded all of the chicks that we found as hatchlings.

Table 2. Piping plover adults and chicks banded on Fire Island and Westhampton Island during April-August 2015. Subsite abbreviations are included in parentheses for each management unit. See Table 1 for a detailed description of subsites.

Management Unit	Adults		Chicks
	Females	Males	
Cupsogue Beach County Park (CSE, CSW, CMF, CSB)	3	1	19
Smith Point County Park (BRE, PSO, PSE, NBW, MWPF, NBE, SPTW, SPTE)	4	4	7
Fire Island National Seashore – east of breach (OIE, BRW, BRO)	0	1	6
Fire Island National Seashore – west of breach (OIW, OIWR)	0	0	0
Fire Island National Seashore – Lighthouse Tract (FIL)	0	0	0
Robert Moses State Park (FLD5, FLD4, FLD3, OSS, GOLF, STP, DMP)	10	6	15
Total	17	12	47

Nest location

We located 48 nests during the 2015 breeding season, 38 in the Eastern Barrier Islands, and 10 in Robert Moses State Park (Table 3).

Table 3. Piping plover nest distribution and nest fates at Fire Island and Westhampton Island, April-July 2015.

Management Unit	Habitat	Nests			
		Found	Hatched	Failed	Reason for loss
Cupsogue Beach County Park	Filled breach/stabilized overwash	8	5	3	Predated (1), Abandoned/Flooded (1), Unknown (1)
Cupsogue Beach County Park	Beach	3	2	1	Predated
Smith Point County Park	Filled breach/stabilized overwash	13	2	11	Predated
Smith Point County Park	Beach	2	0	2	Predated
Smith Point County Park	Great Gunn restoration area	2	0	2	Predated
Smith Point County Park	New Made restoration area	6	0	6	Predated (4), Abandoned (1), Unknown (1)
Fire Island National Seashore – east of breach	Natural breach/overwash	4	2	2	Predated
Fire Island National Seashore – west of breach	Natural breach/overwash	0	0	0	N/A
Fire Island National Seashore – Lighthouse Tract	Beach	0	0	0	N/A
Robert Moses State Park	Mature dune/sand flat	10	5	5	Abandoned
Total		48	16	32	

Nesting habitat use

The area-based use vs. availability analysis showed that nesting piping plovers used habitats (beach, restoration area, unfilled breach/overwash, and filled breach/stabilized overwash) as expected based on area available (the chi-square test was not significant and the Bonferroni adjusted confidence intervals on proportion of use overlapped the proportion available; Table 4). With four habitat categories, and length of beach frontage as a measure of availability, plovers used habitats as expected based on beach-frontage available (the chi-square test was not significant and the Bonferroni adjusted confidence intervals on proportion of use overlapped the proportion available; Table 5)

Table 4. Proportion of availability (P_a , area of each habitat type) versus use (P_u , proportion of breeding pairs in each habitat, N=22) and Bonferroni-corrected confidence intervals on proportion of use from a chi-square test of equal proportions for four different habitat types used by nesting piping plovers at Fire Island and Westhampton Island, April-July 2015. Restoration areas were dune or dredge spoil habitats artificially levelled and filled with sand to create piping plover nesting habitat. Artificially filled breaches and stabilized overwashes were initially storm-created habitat, but efforts were made to restore dune elevation and width using sand fence and discarded Christmas trees to trap sand. No efforts to raise the beach elevation had occurred at natural breaches and overwashes at the time of analysis.

Habitat Type	Area (ha)	P_a	P_u	CI (95%)		Select ^a
Beach	53	0.28	0.23	0.01	0.44	=
Restoration area	45	0.24	0.23	0.01	0.44	=
Unfilled breach/overwash	35	0.19	0.09	-0.06	0.24	=
Filled breach/stabilized overwash	54	0.29	0.45	0.20	0.71	=

^aSelection (Select) = for (+), against (-), and no selection (=).

^bOverall chi-square test $\chi^2 = 1.72$, df=3, $P=0.6326$

Test was not significant at $P=0.05$.

Table 5. Proportion of availability (P_a , length of each habitat type) versus use (P_u , proportion of breeding pairs in each habitat, N=22) and Bonferroni-corrected confidence intervals on proportion of use from a chi-square test of equal proportions for four different habitat types used by nesting piping plovers at Fire Island and Westhampton Island, April-July 2015. Restoration areas were dune or dredge spoil habitats artificially levelled and filled with sand to create piping plover nesting habitat. Artificially filled breaches and stabilized overwashes were initially storm-created habitat, but efforts were made to restore dune elevation and width using sand fence and discarded Christmas trees to trap sand. No efforts to raise the beach elevation have occurred at natural breaches and overwashes.

Habitat Type	Length (m)	P_a	P_u	CI (95%)		Select ^a
Beach	8704	0.38	0.23	0.01	0.44	=
Restoration area	2509	0.11	0.23	0.01	0.44	=
Unfilled breach/overwash	3232	0.14	0.09	-0.06	0.24	=
Filled breach/stabilized overwash	8282	0.36	0.45	0.20	0.71	=

^aSelection (Select) = for (+), against (-), and no selection (=).

^bOverall chi-square test $\chi^2 = 5.4$, df 3, $P=0.139$

Test was not significant at $P=0.05$.

Adult movements

The median distance adult plovers with active nests were observed from their nest was significantly lower for plovers that had direct access to bay side intertidal habitat (direct access was defined as nesting in, or on the beach in front of, an overwash with a bay side intertidal zone, $N=153$ observations on 40 individuals) than for those that did not ($N=102$ observations on 32 individuals, $W=15343$, $P<0.0001$, Figure 8).

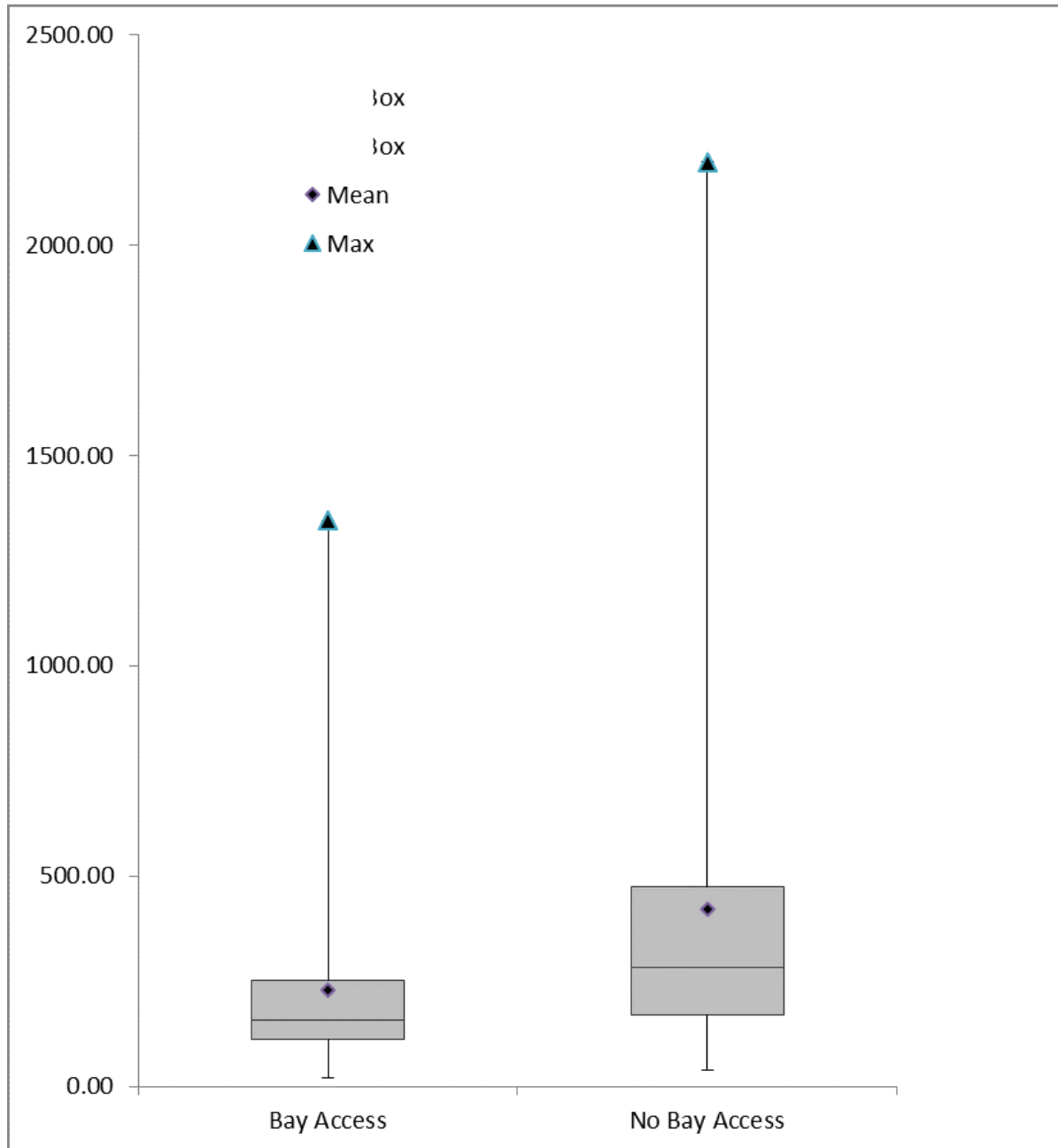


Figure 8. The median distance marked adult plovers with active nests were observed from their nest was greater for plovers that nested at locations without direct access to the bay at Fire Island and Westhampton Island, May-August 2015. Direct access was defined by habitat that a plover could walk through to access bay intertidal habitat without encountering dense vegetation. Box plots include the mean (diamond), median (solid line in the box), the 25th and 75th quartile range (solid boxes), and the maximum and minimum (the error bars).

Nest survival

The daily survival rate for nests with exclosures was 0.9825, and 0.9595 for nests without exclosures. The daily survival rate for nests that had their exclosures removed was 0.3807. Nests that were exclosed when the clutch was complete (and remained exclosed throughout their term) had a 47.66% predicted probability of surviving to hatching, while nests that were never exclosed had a 24.51% predicted probability of surviving to hatching. Nests that were exclosed when the clutch was complete but later had their exclosures removed at approximately 15 days after clutch completion had a 0% predicted probability of surviving to hatch.

Egg mass

There was no difference in egg mass between the clutches of piping plovers with direct bay side access and those without ($Z=-1.57$, $df=9$, $P=0.116$).

Chick behavior

The mean number of pecks per 5 minute observation period was higher for chicks that foraged in areas with low pedestrian use compared to high or moderate pedestrian use, however this difference was not significantly different for chicks 10 days old and younger (MRPP, $S=-1.67$, $P=0.07$; Figure 9) or chicks 11-30 days of age (MRPP, $S=0.42$, $P=0.58$; Figure 9). There was no difference in time spent in each activity (foraging, active [running, walking, fleeing, chasing], inactive [sitting, standing, preening], or brooding) in areas with different levels of human use for chicks 10 days old and younger (MRPP, $S=-1.61$, $P=0.07$; Figure 10) or chicks 11-30 days of age (MRPP, $S=-1.14$, $P=0.13$; Figure 10).

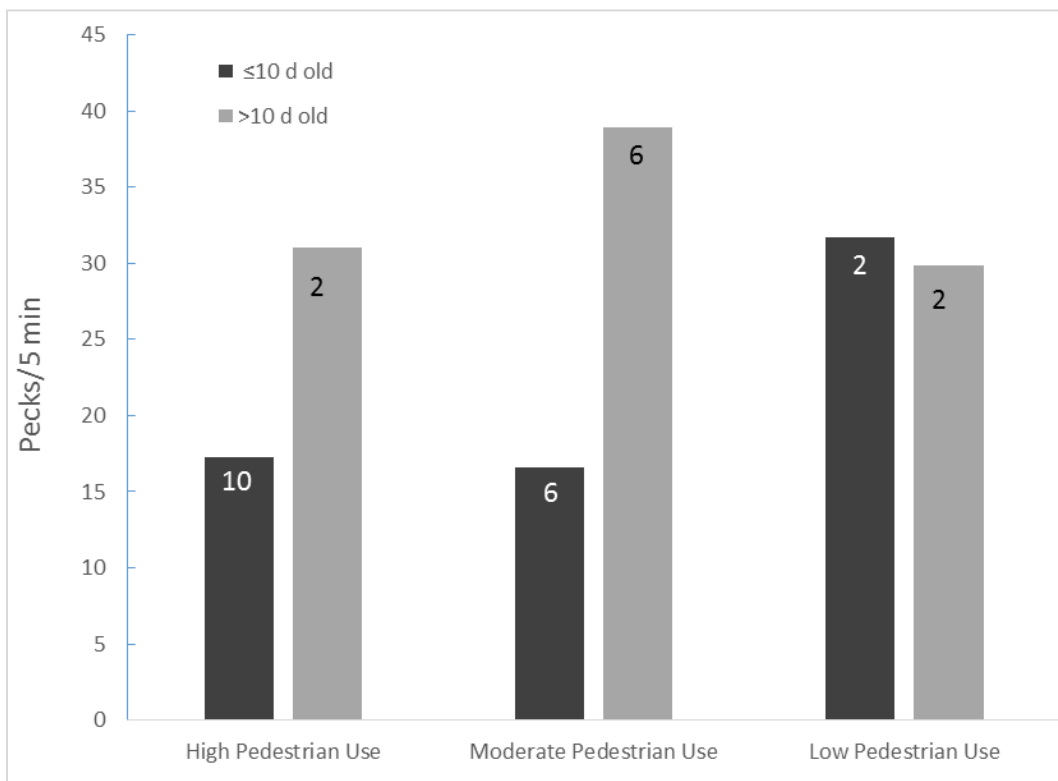


Figure 9. There was no difference in peck rates in areas with different levels of human activity for chicks ≤ 10 days old (MRPP, $S=-1.67$, $P=0.07$), or chicks > 10 days (MRPP, $S=0.42$, $P=0.58$). Numbers in bars are sample sizes (number of broods).

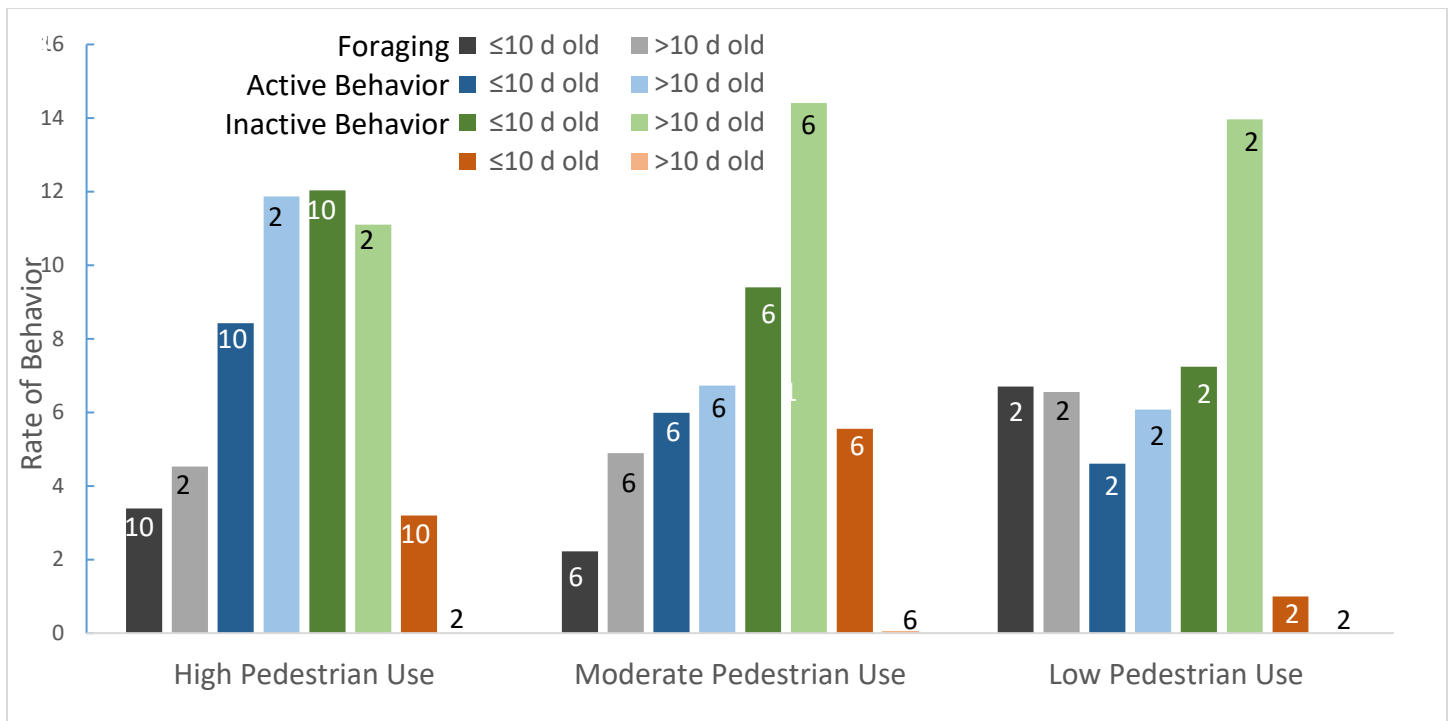


Figure 10. There was no difference in time spent in various activities in areas with different levels of human activity chicks ≤ 10 days old (MRPP, $S=-1.61$, $P=0.07$), or chicks > 10 days (MRPP, $S=-1.14$, $P=0.13$). Numbers in bars are sample sizes (number of broods).

Chick survival

Across the study area, predicted probability of chicks surviving to fledging was 30.15%, which was slightly higher than the observed fledging rate of 27.66%. Productivity (fledges/female) was 0.45 for the entire study area. Productivity was highest on Fire Island National Seashore and lowest at Cupsogue County Park (Table 6).

Table 6. Piping plover productivity (fledges/female) in four different management units at Fire Island and Westhampton Island, June-August 2015.

Management Unit	# Hatched	# Fledged	# of Territories	Fledges/female ^a
Robert Moses State Park	15	3	7	0.43
Fire Island National Seashore (Otis Pike High Dunes Wilderness)	6	5	2	2.5
Smith Point County Park	7	4	13	0.31
Cupsogue County Park	19	1	7	0.14
Total	47	13	29	0.45 ^b

^a Number of females in each management unit is the sum of the max number of females observed nesting concurrently in each subsite. Peak counts occurred at different dates in each subsite, thus females may have been counted twice if they moved between subsites, or missed if they were not breeding in the study area during peak counts

^b Productivity for the entire study area cannot be computed from productivity by management unit.

Brood home range

Brood home range size did not differ between broods that foraged on ocean beaches and broods that foraged on the bay side of overwashes (Wilcoxon rank sum, $Z=1.30$, $df=4$, $P=0.193$; Figures 11 – 13). Results may have been skewed by high mortality rates among beach-foraging broods and by the fact that two bay-foraging broods made one-time movements of >1km to reach bay intertidal habitat.

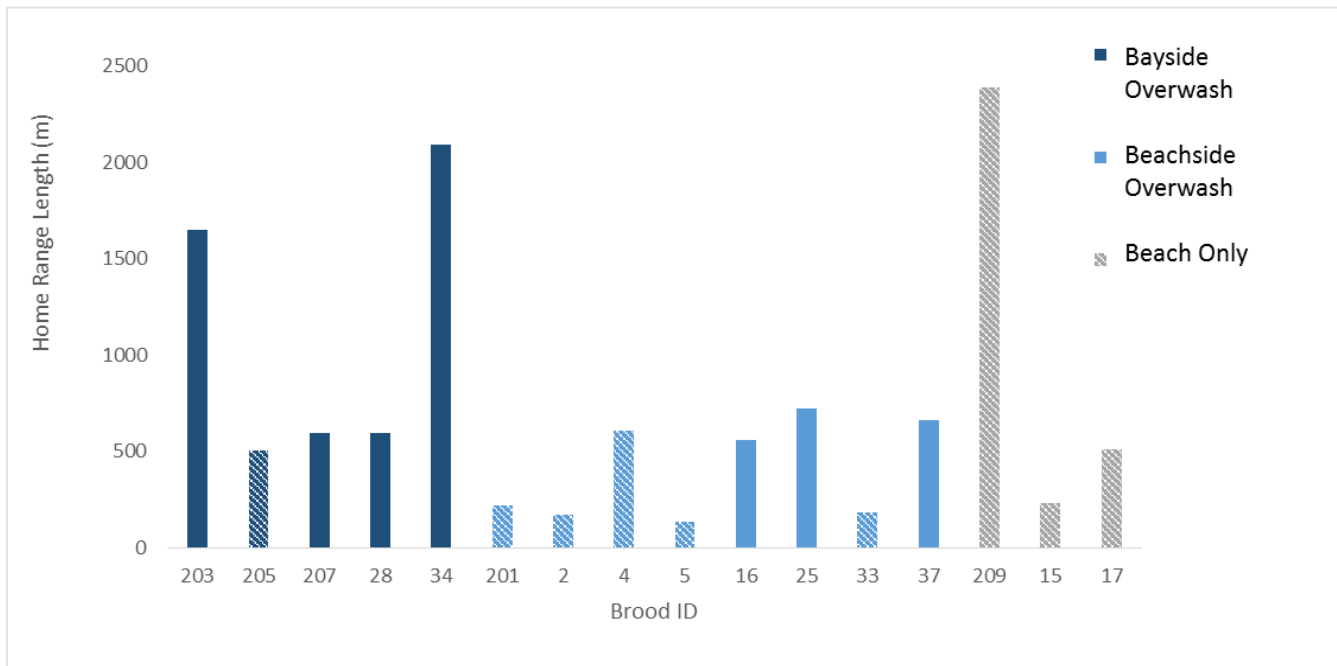


Figure 11. Brood home range lengths for piping plovers that foraged on ocean beaches, on beaches adjacent to overwashes, or on the bay side of an overwash. Striped bars represent broods from which no chicks survived to fledging, which probably affected home range size. Light blue and grey bars represent broods that only had access to ocean beach foraging, or were adjacent to an overwash but foraged on the ocean beach, presumably because the interior and bay side of the overwash were too vegetated to be suitable habitat (16 and 25) or experience high rates of human disturbance (Broods 2, 5, 17, and 34).

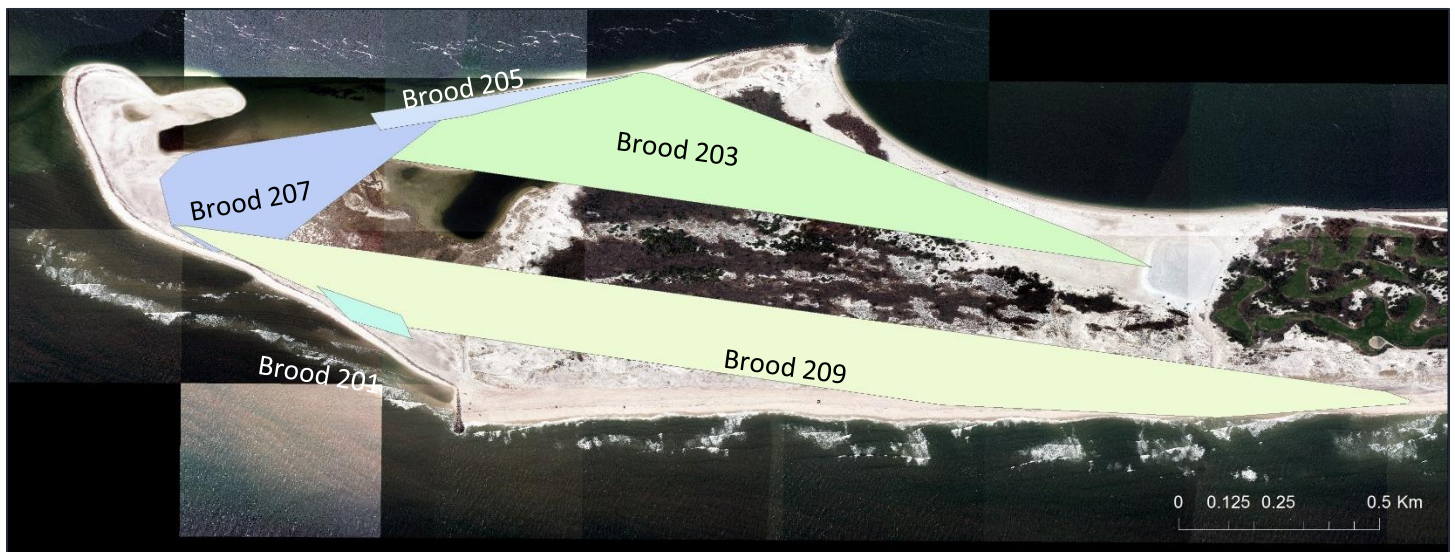


Figure 12. Brood home ranges of piping plovers at Robert Moses State Park, NY, June – August 2015. Background imagery is from April 2015.

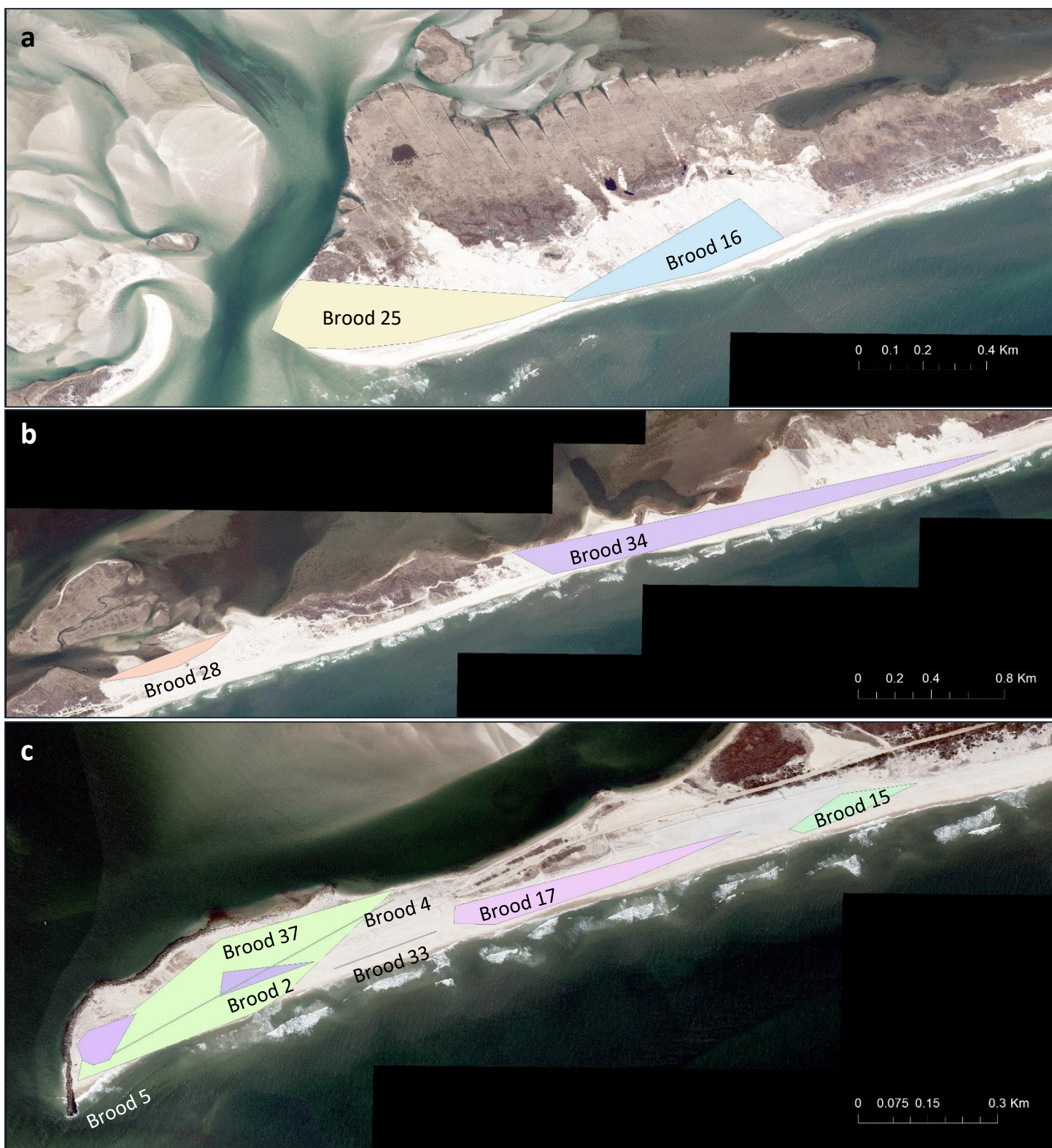


Figure 13. Brood home ranges of piping plovers at a) the Otis Pike Wilderness, b) Smith Point County Park, and c) Cupsogue County Park, NY, June - August 2015. Background imagery is from April 2015.

Terrestrial invertebrates

More arthropods were captured in the bay intertidal habitat than in the island interior in non-shoreline habitats (ANOVA, $F=4.07$, $df=2$, $P=0.0177$, Table 7). A post-hoc Tukey test showed that the apparent differences between arthropods catch rate in bay and ocean shoreline habitats or between catch rate in ocean shoreline and island interior habitats, were not statistically significant at $p<.05$.

Table 7. Mean numbers of arthropods captured during a 30-minute period at bay shoreline, ocean shoreline, and interior habitats on Fire Island and Westhampton Island, June-August 2015. Capital letters shared among groups indicate no significant difference between those groups.

Geologic Location	Mean insects/30 min	Std Error	N
Bay shoreline	22.75 ^A	14.25	82
Interior	1.19 ^B	0.10	343
Ocean shoreline	14.91 ^{AB}	9.72	114

Human use

Cupsogue East, Bridge East, Bridge Overwash, and Ocean South Side, the four subsites adjacent to large parking lots and thus most easily accessible to pedestrians, had the highest numbers of visitors, with multiple visits with >100 people present (Figures 14-16). Recreational driving was not allowed at Smith Point County Park from 9 July – 13 August, and sites that were not easy to walk to experienced little recreational activity. Recreational driving was not allowed in the Otis Pike Wilderness, and the area west of the breach was particularly inaccessible to pedestrians. The people counts based on subsite visits are less robust for some time periods because we began our work day at 06:00 (24-hr time format) and were usually off the beach in some areas before many beachgoers arrived, whereas because of travel time we rarely reached our most inaccessible subsites before 08:00. For the disturbance point counts, we standardized sampling to occur between 14:30 and 16:30. We are in the process of evaluating which method best quantifies human activity in areas used by piping plovers.

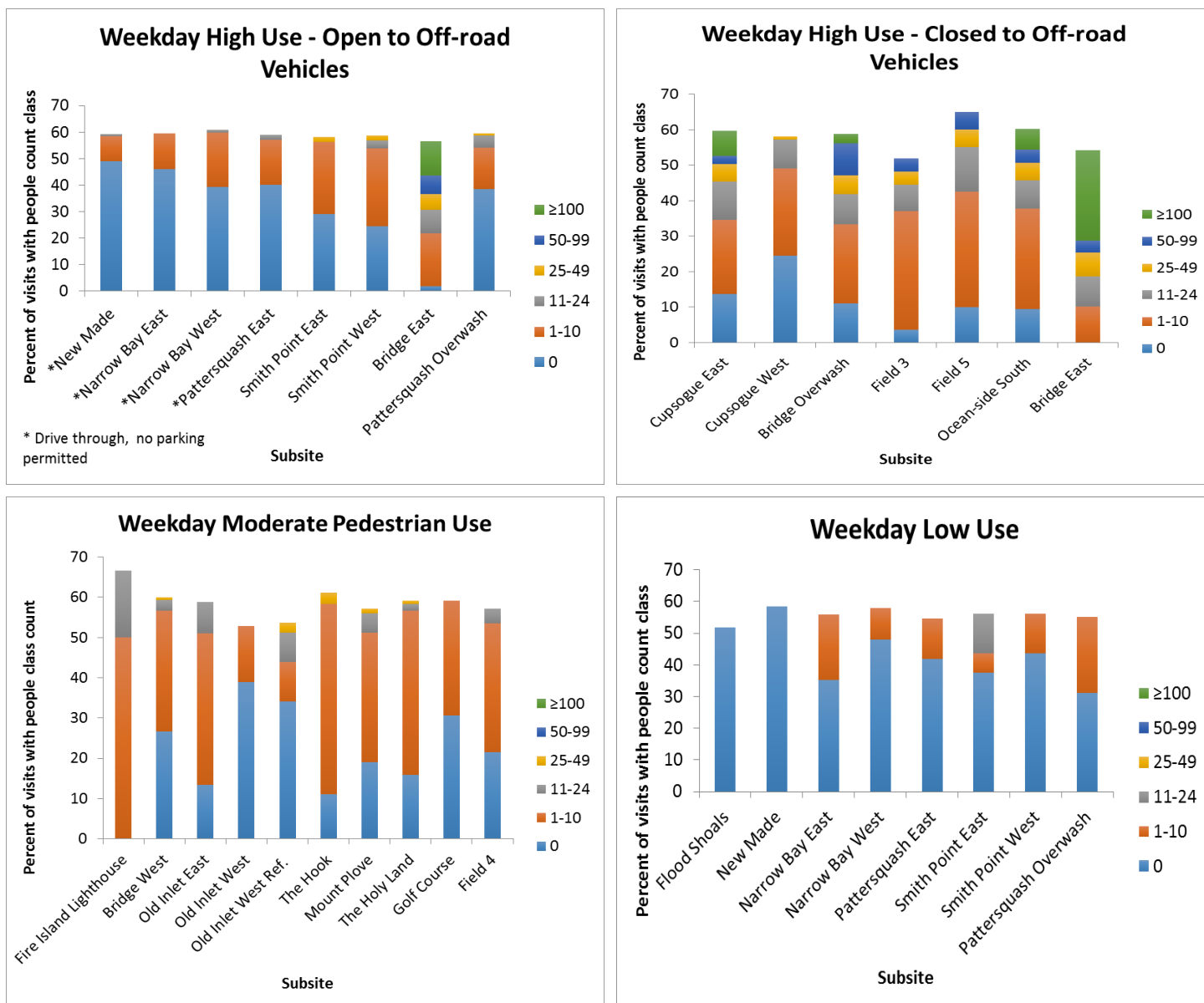


Figure 14. Weekday human activity on Fire Island and Westhampton Island, NY, April-September 2015. Human activity was divided into people count size classes (0, 1-10, 11-24, 25-49, 50-99, ≥ 100), and the proportion of visits with each of those people count classes is given for each subsite in the study area that was accessible to humans. The four graphs are divided into a priori categories based on ease and type of human access (ORV access, pedestrian access near parking, pedestrian access far from parking, ferry or boat access only, etc.). Some subsites appear twice because their access type changed (i.e. all of the Smith Point sites were classified as High Use – Open to ORVs when the beach was open for driving, but were counted during beach closure as either High Use – Closed to ORVs or Low Use depending on their proximity to pedestrian access points such as parking lots).

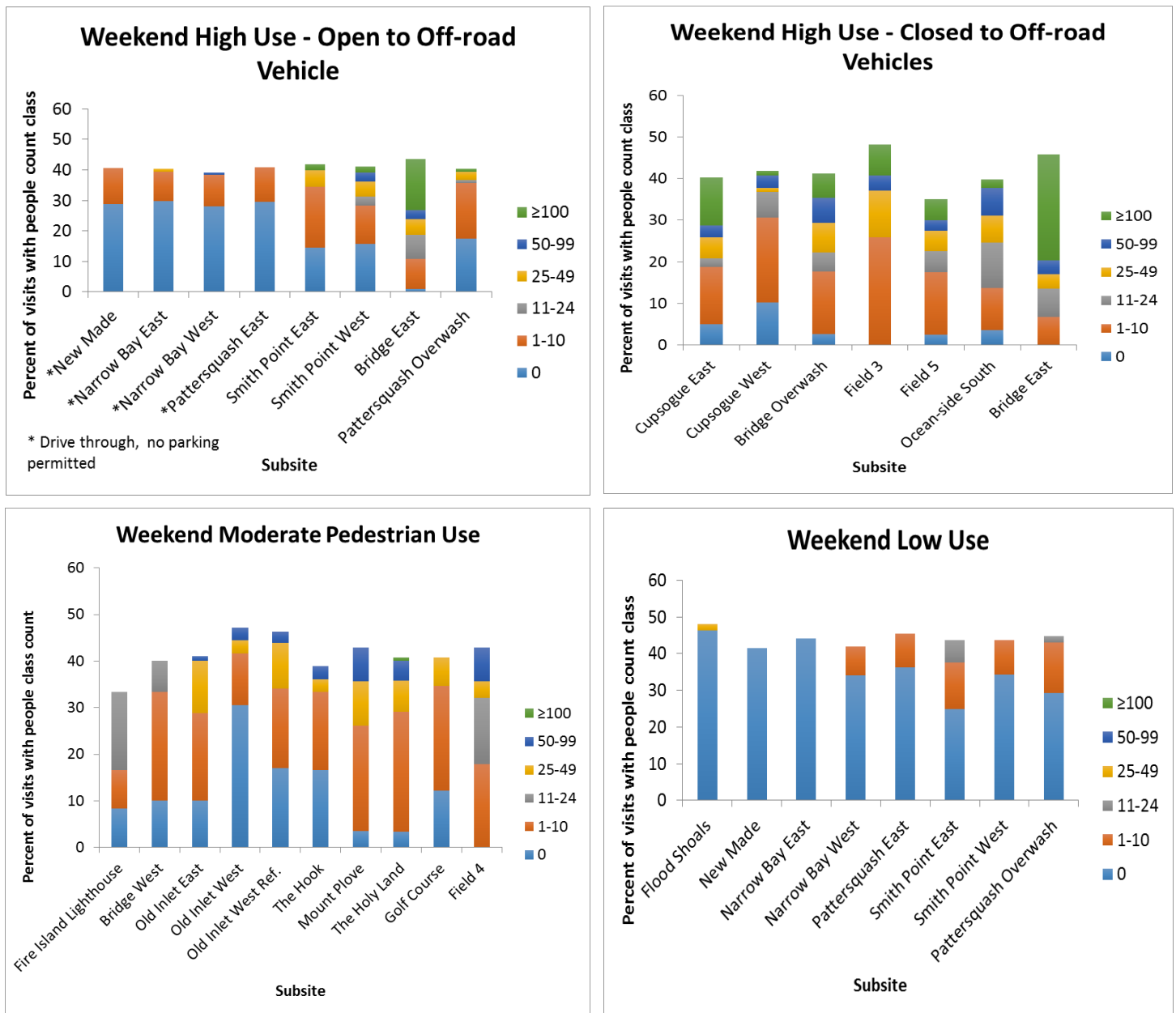


Figure 15. Weekend human activity on Fire Island and Westhampton Island, NY, April-September 2015. Human activity was divided into people count size classes (0, 1-10, 11-24, 25-49, 50-99, ≥ 100), and the proportion of visits with each of those people count classes is given for each subsite in the study area that was accessible to humans. The four graphs are divided into a priori categories based on ease and type of human access (ORV access, pedestrian access near parking, pedestrian access far from parking, ferry or boat access only, etc.). Some subsites appear twice because their access type changed (i.e. all of the Smith Point sites were classified as High Use – Open to ORVs when the beach was open for driving, but were counted during beach closure as either High Use – Closed to ORVs or Low Use depending on their proximity to pedestrian access points such as parking lots).

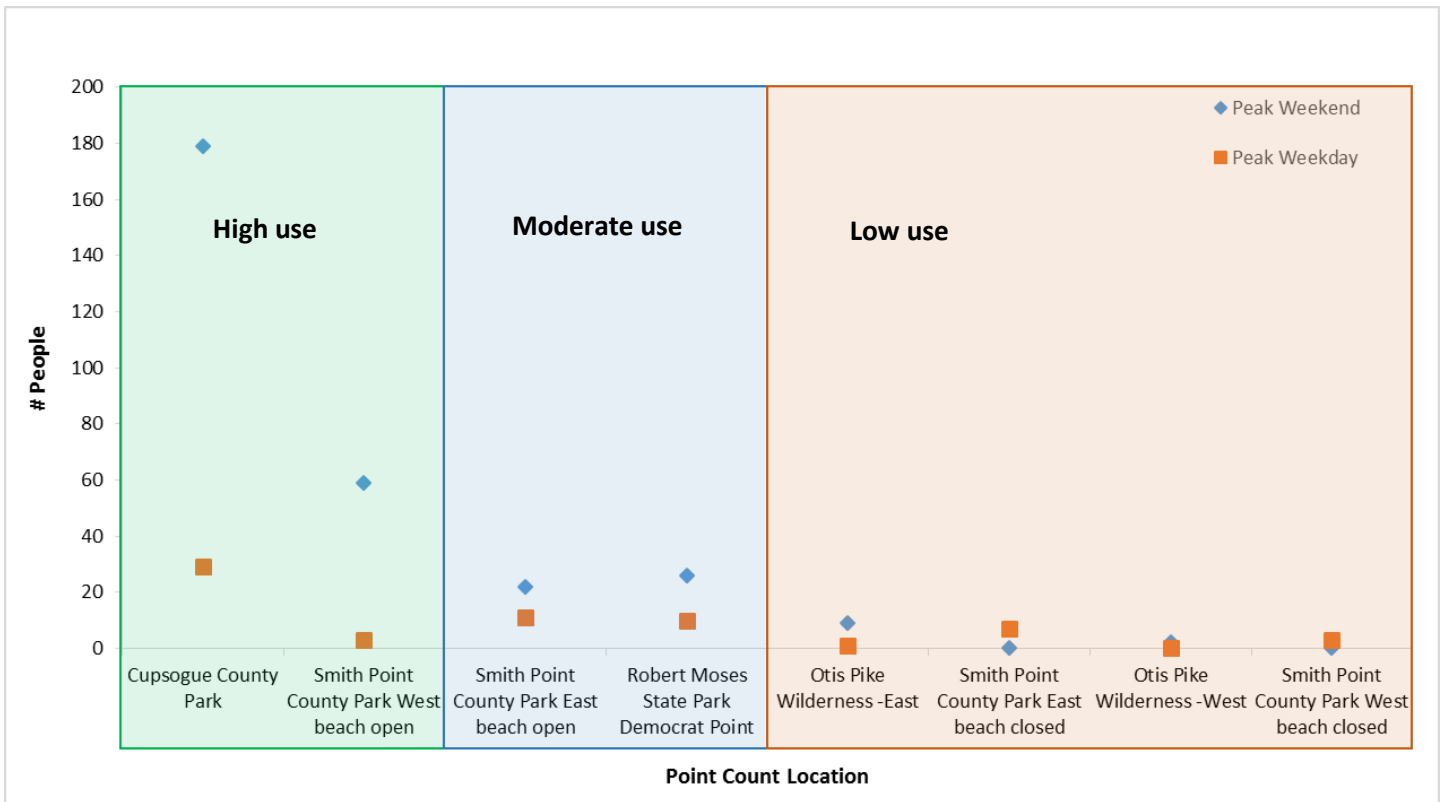


Figure 16. Peak weekday and weekend people counts during disturbance point count samples on Fire Island and Westhampton Island, NY, April-August 2015. Colored boxes delineate a priori human activity categories (green = high use, blue = moderate use, orange = low use). Smith Point County Park point count locations appear twice, once representing the peak people counts when the beach was open to ORV traffic and once when the beach was closed to ORV traffic.

Chick mass

Mass at 22 days of age was lower in areas of high human use compared to moderate and low human use (ANOVA, $F=4.69$, $df=2$, $P=0.0312$, Figure 17).

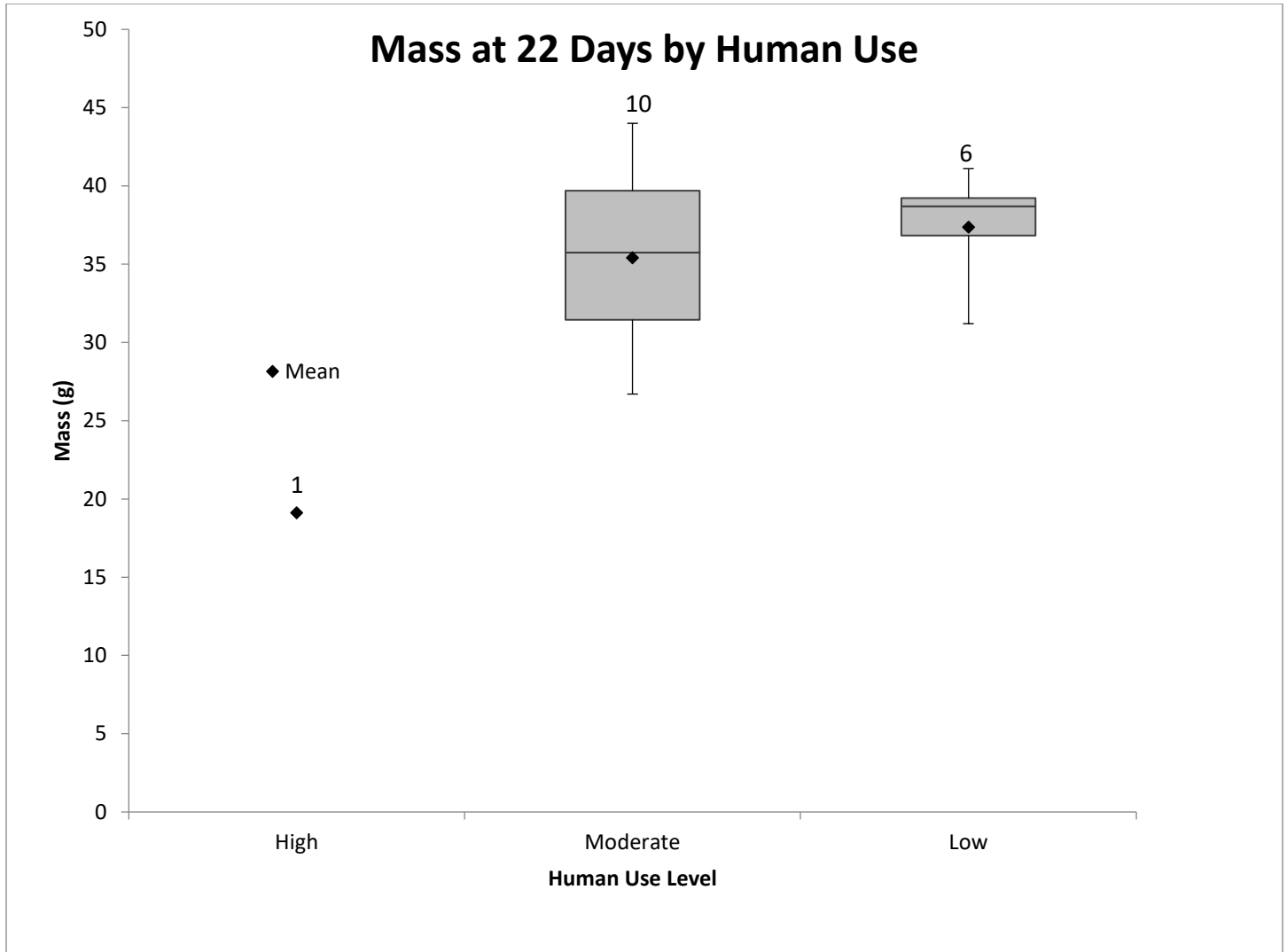


Figure 17. Mass at 22 days of age was lower in areas of high human use compared to moderate and low human use (ANOVA, $F=4.69$, $df=2$, $P=0.0312$). Human were classified based on people count size classes (0, 1-10, 11-24, 25-49, 50-99, ≥ 100), and the proportion of visits with each of those people count classes. Human use was primarily a function of ease and type of human access (ORV access, pedestrian access near parking, pedestrian access far from parking, ferry or boat access only, etc.). Box plots include the mean (diamond), median (solid line in the box, the 25th and 75th quartile range (solid boxes), and the maximum and minimum (the error bars). Numbers above the error bars are sample size.

ACKNOWLEDGMENTS

Funding for this study was provided by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, and conducted in cooperation with the National Park Service, Suffolk County Parks, and New York State Parks. We thank Robert Smith (USACE) and Steve Papa (FWS) for funding and support. We thank NPS staff, especially Mike Bilecki, Lindsay Ries, Jordan Raphael, and seasonal plover technicians for their extensive logistical support and collaboration. We thank Nick Gibbons, Diana Sanford, and all of the Suffolk County plover stewards for their assistance, support, and efforts to protect piping plovers and their habitat. We are especially grateful to H. Bellman, A. Carey, L. Granger, J. Ialeggio, R. Moylan, E. Peyton, M. Kynoch, and C. Kupferman for their enthusiastic and tireless work during the 2015 field season. Support from the Virginia Tech Department of Fish and Wildlife Conservation and our colleagues in the Virginia Tech Shorebird Program was essential to the success of this monitoring effort.

APPENDICES

Appendix A: Nest predation incident reports

The following are two incident reports following dog predation of nests at Cupsogue County Park on May 14, 2015 and June 14, 2015.

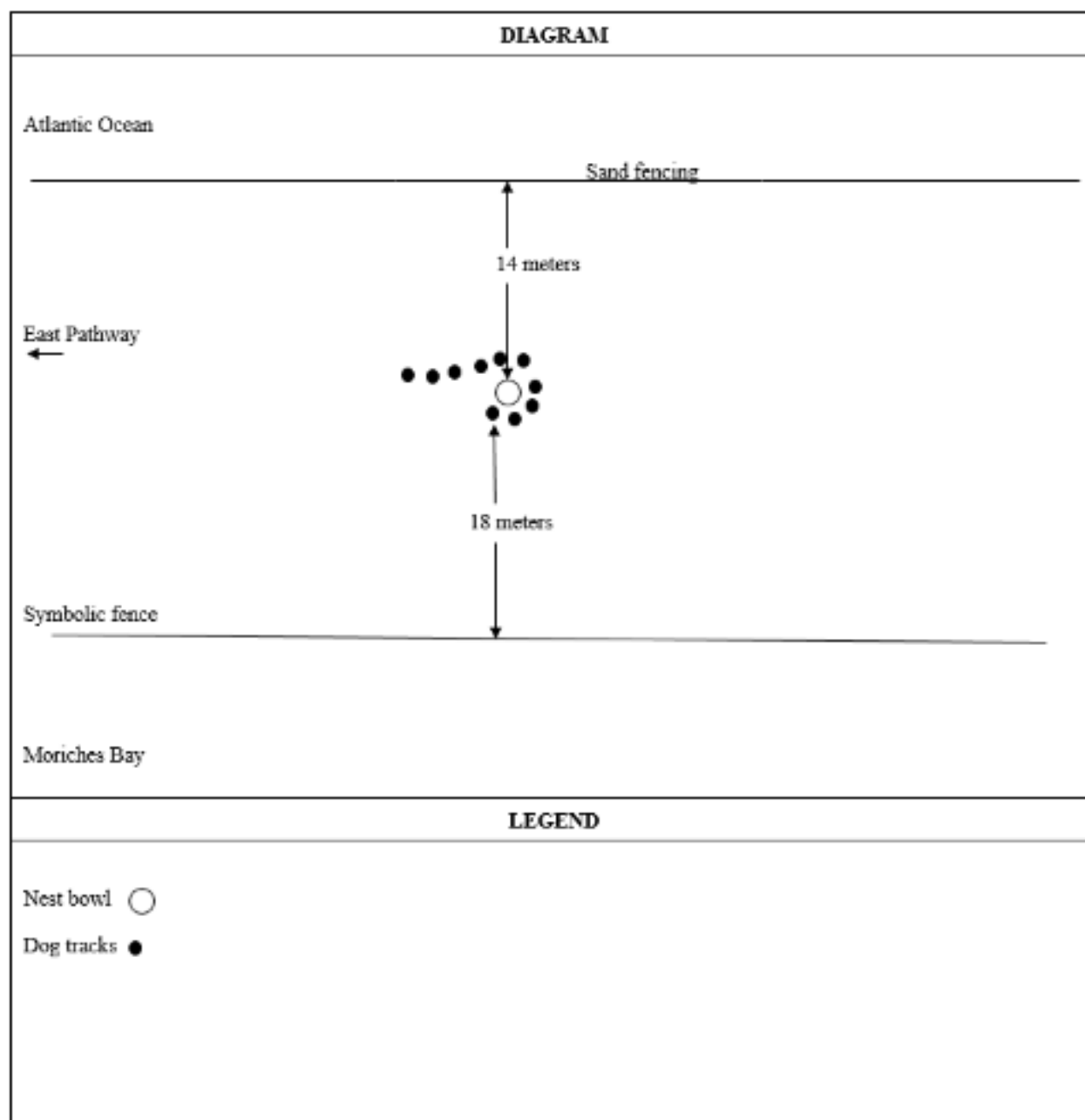
Incident Observation Report			
DO NOT DISTURB THE SITE. DO NOT TOUCH OR REMOVE THE BIRD OR EGG UNLESS OTHERWISE AUTHORIZED TO DO SO BY U.S. FISH AND WILDLIFE LAW ENFORCEMENT STAFF.			
Observer's Name: <u>Audrey DeRose-Wilson</u>		Date: <u>5/14/2015</u>	
Affiliation: <u>Virginia Tech</u>		Time: <u>10:00</u>	
Site Name: <u>Cupsogue County Park</u>		Town: _____	
Time of Incident (if known): <u>n/a</u>			
Witness? (Name) <u>n/a</u>		Witness? (Name) <u>n/a</u>	
Tel. Number (include area code): <u>631 365-3856</u>		Tel. Number (include area code): _____	
Bird / Nest Conditions			
	# of Eggs	# of Chicks	# of Adults
Plovers Observed Today	0	0	0
# and Date Last Sighted	5/11/2015 (1 egg)	0	5/11/2015 (1)
Nest Condition: Undisturbed _____ Disturbed (describe) Eggs gone, yolk in nest bowl.			
Condition of Eggs/Bird: Shell Broken _____ Bird: Plump <u>n/a</u> Flat <u>n/a</u> Missing Parts?			
Tracks present?: Tire <u>none</u> Animal (type) <u>dog</u> Footprints: <u>YES</u>			
Number & location relative to bird or egg(s): _____			
Dog tracks up to and around nest bowl. Large amount of yolk in nest bowl.			
Incident Setting (where and how found): <u>Found during routine nest check.</u>			
Site / Environmental Conditions			
Current Weather Conditions:			
Date of Last Rainfall (if known): _____ Tide: High _____ Low _____ Rising _____ Falling _____			
Condition of Sand: Loose <u>X</u> Packed _____ Wet _____ Dry <u>X</u> Other (describe) _____			
Symbolic Fencing: <u>Yes</u> Predator <u>Exclosures</u> : <u>No</u> Damage? (describe) _____			
Efforts to secure the scene: _____			
Photos taken? YES Notification: USFWS/LE <u>notified</u> Town _____ Trustees _____ Local LE _____			
____NYSDEC/LE _____ TNC _____ Landowner _____ Other _____			

Threats / Disturbances

Unleashed Pets X ORVs _____ Crows _____ Gulls _____ Fox _____ Other _____

Other Comments:

PLEASE DRAW A SITE DIAGRAM (on the reverse). **Include:** legend, take location (distance to permanent landmark), nest location, fencing and predator enclosure (if present), tire ruts, roads, & other significant landmarks, water bodies, all wrack lines, AHWL, etc.



Incident Observation Report

DO NOT DISTURB THE SITE. DO NOT TOUCH OR REMOVE THE BIRD OR EGG UNLESS OTHERWISE AUTHORIZED TO DO SO BY U.S. FISH AND WILDLIFE LAW ENFORCEMENT STAFF.

Observer's Name: Julia Monk Date: 6/14/2015
 Affiliation: Virginia Tech Time: 10:44
 Site Name: Cupsogue County Park Town: _____
 Time of Incident (if known): n/a
 Witness? (Name) n/a Witness? (Name) n/a
 Tel. Number (include area code): 631 559-7497 Tel. Number (include area code): _____

Bird / Nest Conditions

	# of Eggs	# of Chicks	# of Adults
Plovers Observed Today	0	0	1
# and Date Last Sighted	6/12/2015 (2 eggs)	0	6/12/2015 (1)

Nest Condition: Undisturbed _____ Disturbed (describe) Eggs gone, yolk in nest bowl.
 Condition of Eggs/Bird: Shell Broken _____ Bird: Plump n/a Flat n/a Missing Parts?
 Tracks present?: Tire none Animal (type) dog Footprints: YES
 Number & location relative to bird or egg(s):

Dog tracks up to and around nest bowl. Large amount of yolk in nest bowl.

Incident Setting (where and how found): Found during routine nest check.

Site / Environmental Conditions

Current Weather Conditions:
 Date of Last Rainfall (if known): _____ Tide: High _____ Low _____ Rising _____ Falling _____
 Condition of Sand: Loose X Packed _____ Wet _____ Dry X Other (describe) _____
 Symbolic Fencing: Yes Predator Enclosures: No Damage? (describe) _____

Efforts to secure the scene:

Photos taken? YES Notification: USFWS/LE notified Town _____ Trustees _____ Local LE _____

 _____NYSDEC/LE _____ TNC _____ Landowner _____ Other _____

Threats / Disturbances

Unleashed Pets X ORVs Crows Gulls Fox Other

Other Comments:

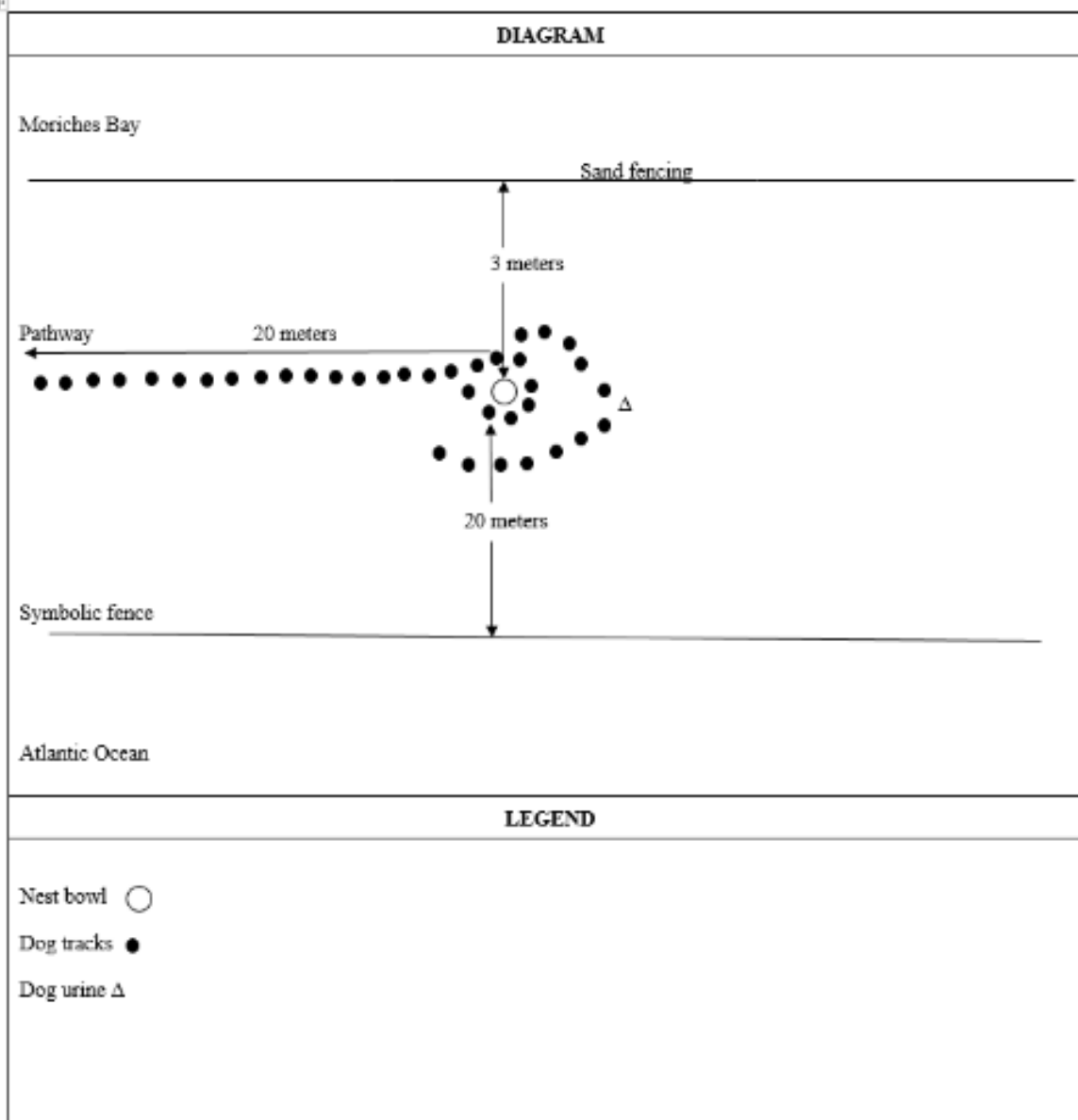
Dog tracks led from the path between the bay and the ocean directly to the nest and then circled around the nest area before being obscured.

We found a partially predated egg near Moriches Inlet, approximately 550 meters west of the predated nest. We have no way of knowing whether the egg was from this nest, but it was the only active non-excused nest in the area so it seems likely. There was a significant amount of yolk left in the opened egg. One of the adult plovers may have flown it out of the nest once it was damaged.



PLEASE DRAW A SITE DIAGRAM (on the reverse). **Include:** legend, take location (distance to permanent landmark), nest location, fencing and predator enclosure (if present), tire ruts, roads, & other significant landmarks, water bodies, all wrack lines, AHWL, etc.

40



LITERATURE CITED

- ALTMANN, J. 1974. Observational study of behavior: sampling methods. *Behaviour* 49:227-267.
- ALBERICO, J. A. R. 1995. Floating eggs to estimate incubation stage does not affect hatchability. *Wildlife Society Bulletin* 23:212-216.
- BYERS, C. R., AND R. K. STEINHORST. 1984. Clarification of a technique for analysis of utilization-availability data. *Journal of Wildlife Management* 48:1050-1053.
- COHEN, J. B., L. M. HOUGHTON, AND J. D. FRASER. 2009. Piping plover nesting density and reproductive success in response to storm and human-created habitat changes. *Wildlife Monographs* 173.
- COHEN, J. B., E.H. WUNKER, AND J. D. FRASER. 2008. Substrate and Vegetation Selection by Nesting Piping Plovers. *The Wilson Journal of Ornithology* 120:404-407
- ESPIE, R. H. M., R. M. BRIGHAM, P. C. JAMES. 1996. Habitat selection and clutch fate of Piping Plovers (*Charadrius melodus*) breeding at Lake Diefenbaker, Saskatchewan. *Canadian Journal of Zoology* 74:1069-1075.
- HAIG, S. M. AND E. ELLIOTT-SMITH. 2004. Piping Plover (*Charadrius melodus*). *The birds of North America*. Number 2.
- HEISEY, D. M., T. L. SHAFFER, AND G. C. WHITE. 2007. The ABC's of nest survival: theory and application from a biostatistical perspective. *Studies in Avian Biology* 34:1-21.
- LUKACS, P. M., V. J. DREITZ, K. P. BURNHAM, AND F. L. KNOPF. 2004. Estimating Survival Probabilities of Unmarked Dependent Young When Detection Is Imperfect. *Wildlife Biology Faculty Publications*. Paper 60. http://scholarworks.umt.edu/wildbio_p
- NEU, C. W., C. R. BYERS, AND J. M. PEEK. 1974. A technique for analysis of utilization-availability data. *Journal of Wildlife Management* 38:541-545.
- ROTELLA, J. J., S. J. DINSMORE, AND T. L. SHAFFER. 2004. Modeling nest-survival data: a comparison of recently developed methods that can be implemented in MARK and SAS. *Animal Biodiversity and Conservation* 27:187-205.
- SHAFFER, T. L. 2004. A unified approach to analyzing nest success. *Auk* 121:526-540.
- U.S. FISH AND WILDLIFE SERVICE (USFWS). 2014. Biological opinion and conference opinion, Fire Island to Moriches Inlet, Fire Island Stabilization Project. USFWS, Suffolk County, NY, USA.
- U.S. ARMY CORPS OF ENGINEERS. 1996. Breach Contingency Plan, Fire Island to Montauk Point, Long Island, New York. New York District, August 1995, revised January 1996.
- _____. 2014. Fire Island Inlet to Moriches Inlet to Fire Island Stabilization Project Hurricane Sandy Limited Reevaluation Report Draft. Evaluation of a Stabilization Plan for Coastal Storm Risk Management In Response to Hurricane Sandy & Public Law 113-2. Main Report. NY District.

PART II: RED FOX MOVEMENTS, HABITAT SELECTION, AND DEMOGRAPHY ON FIRE ISLAND, NEW YORK

INTRODUCTION

Many studies have shown that predation is a key determinant of piping plover reproductive output, and predator management often is used to improve piping plover breeding success. The red fox (*Vulpes vulpes*) is a key piping plover predator in a number of areas on the U.S. Atlantic Coast. On Long Island, Cohen et al. (2009), showed that plover reproductive output in West Hampton Dunes was improved when foxes and cats were removed. Our ongoing piping plover monitoring work at Robert Moses State Park, Fire Island National Seashore and Smith Point County Park on Long Island (see Part I of report) showed that foxes were common in all areas, and an important predator of piping plovers on Fire Island. Despite the recognition that predator management is an important part of piping plover management along the entire U.S. coast, and that management of red foxes at these sites on Long Island, whether through lethal removal of adults, destruction of active den sites, or simple nest exclosure, may be important for piping plover populations, there still are many gaps in our knowledge of the foxes, fox responses to management, and the effects of foxes and fox management on piping plover habitat use and reproductive output.

As part of the monitoring actions of the Fire Island Inlet to Moriches Inlet, Fire Island Stabilization Project (FIMI), we are collecting data needed to best design and implement predator monitoring and management activities, in particular for the red fox. Specifically, we are working to accomplish the following 6 objectives.

Objective 1: Quantify the abundance and occupancy of red foxes and relate changes in these parameters to changes in habitat and predator management activities. (*Methods: Camera-trapping, den surveys, habitat assessment, collaboration with predator management partners*)

Objective 2: Assess habitat use versus availability by red foxes and any variation in habitat selection related to changing habitat composition and predator management. (*Methods: GPS collars, habitat assessment, collaboration with predator management partners*)

Objective 3: Quantify home range size, long-range movements, and variation in movement ecology of red foxes and relate to changing habitat composition and predator management. (*Methods: GPS collars, habitat assessment, collaboration with predator management partners*)

Objective 4: Estimate red fox reproductive success and adult survival, and variation in these population parameters, related to habitat composition and predator management. (*Methods: GPS collars, den surveys, habitat assessment, collaboration with predator management partners*)

Objective 5: Quantify the interactions of red foxes with shorebird nests and chicks. (*Methods: GPS collars, camera traps on shorebird nests, opportunistic scat collection, collaboration with shorebird management partners*)

Objective 6: Utilize information collected in objectives 1-5 to make recommendations on the utility of, and recommended methodologies for, management of red fox populations in the study area and in other coastal habitats.

We report here on activities related to these objectives that have occurred in 2015.

FIELD METHODS

Study site

We focused red fox monitoring efforts from Fire Island Inlet to Moriches Inlet on Fire Island, within the administrative boundaries of the National Park Service, the County of Suffolk (Smith Point County Park), and the State of New York (Robert Moses State Park). When conducting red fox monitoring activities during the piping plover nesting and brood-rearing seasons, the red fox research team recorded all activities as they pertained to the sub-sites as described in part I of this report (See Part I-Figures 1 and 2, Table 1). However, the red fox research efforts were conducted across the entirety of Fire Island as GPS-collared foxes utilized the entire area. Details on placements of camera trap grids and den/scat/sign surveys within the larger study area are described below.

Sign, scat, and den surveys

We used ArcMap 10.3 GIS software to create and overlay a grid onto each of the 3 study sub-sites (Robert Moses State Park, Fire Island National Seashore, and Smith Point County Park), subdividing them into 300 m by 300 m cells, and identified the center point of each cell. We used a 300 m grid cell size, as our work with red foxes at Assateague Island National Seashore (Gieder 2015) showed that foxes rarely moved between camera stations spaced 300 m from each other, except for occasional long distance movements (> 6km), for example to potentially occupy territory available after lethal control efforts. Thus, the goal was to focus survey efforts (for sign, scat, den, abundance, occupancy—see camera trapping design below) such that each potential core range of a fox was sampled with equal probability. Given that foxes rarely moved between camera stations separated by 300 m in the Gieder (2015) study, we used a 300 m spacing of all transects and cameras to approximate equal sampling across potential home ranges.

We walked 96 transects (24 in Robert Moses State Park, Part II, Figure 1a; 40 in Fire Island National Seashore, Figure 1b; and 32 in Smith Point County Park, Figure 1c) from the ocean beach high tide line to the bayside high tide in June-July 2015; the transects connected the center points across the island of the 300 m grid described above. Specifically, we walked game trails, or in as close to a straight line as possible if no game trails present, between the grid cell center points from ocean beach to bayside as possible on each transect. All fresh red fox scats located on the transects were collected, labeled by transect and GPS coordinates, and frozen for later analysis of prey items. All observed red foxes were recorded and GPS locations noted. All inactive and active red fox den sites were also recorded and GPS locations noted, as well as all tracks. We defined active dens as dens with fresh tracks leading in and out of entrance holes and/or foxes seen in close proximity. We defined tracks as areas where a clear trail used by fox (i.e., fresh red fox tracks) intersected the transect.

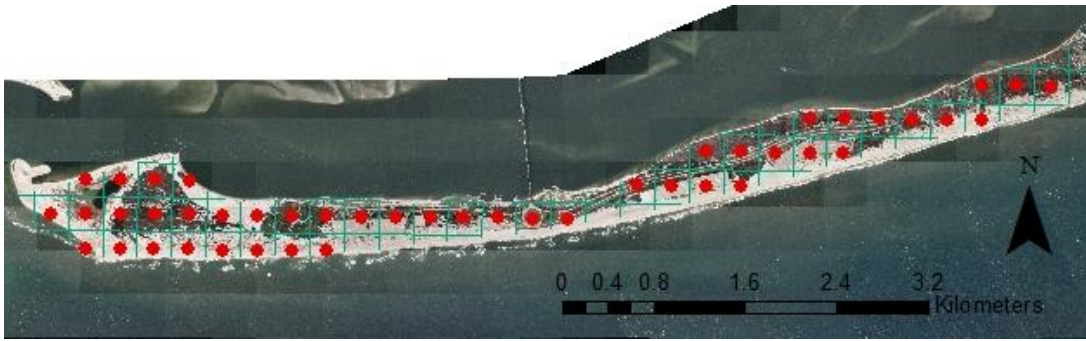


Figure 1a. Transect locations in Robert Moses State Park and Fire Island National Seashore Lighthouse Tract.

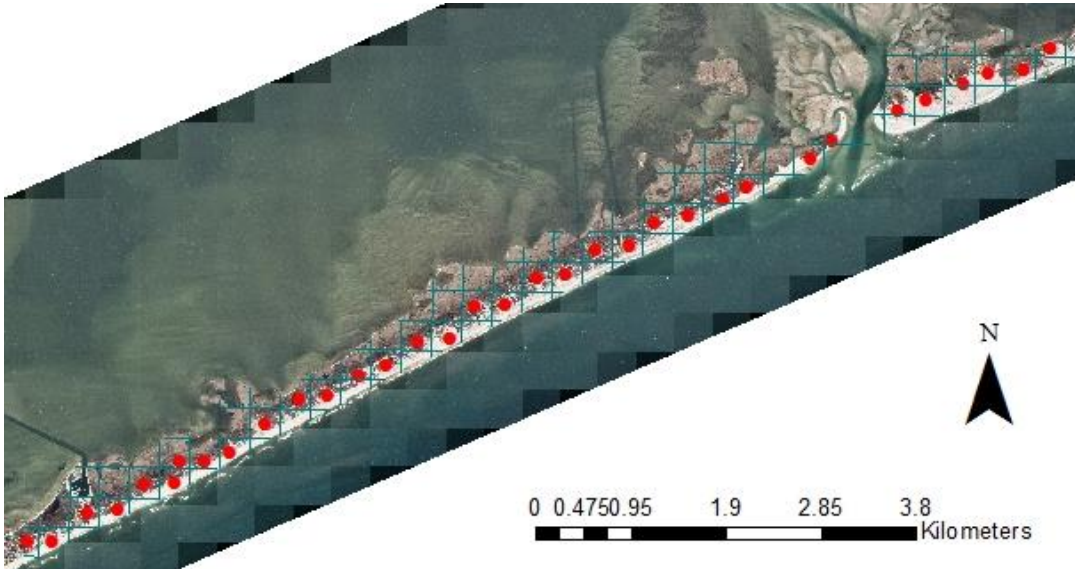


Figure 1b. Transect locations in Fire Island National Seashore.

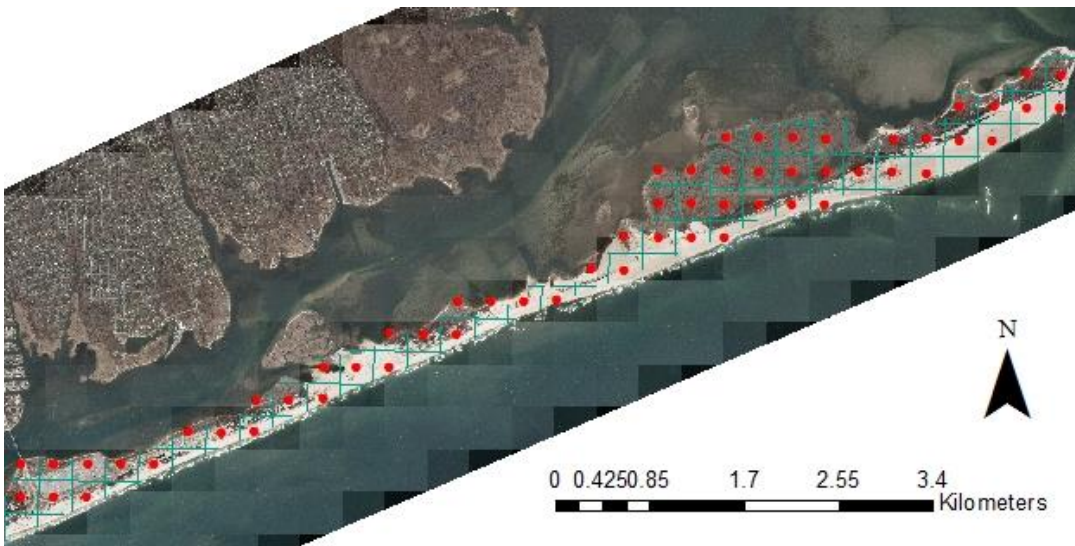


Figure 1c. Transect locations in Smith Point County Park.

Figures 1a-c: Research technicians walked as close to straight-line transects as possible between grid cell center points shown here, from ocean beach high tide line to bayside high tide line to identify fox sign, collect fox scat, and locate fox dens in June-July 2015.

Trapping, ear-tagging, and collaring

We attempted to capture up to 5 foxes in each management unit to attach GPS collars (Telemetry Solutions, Quantum 4000E, Figure 2a), from August-present. In future years of effort, all captures will be completed in February-March of the year so that collars are active during piping plover nesting season. However, the timing of arrival of funding, and timing needed to obtain permits and arrange logistics, prevented collaring during the core of plover nesting season in 2015.

We also were permitted to catch additional foxes to attach ear-tags (Premier 1 Mini-tags, Figure 2b) in both Robert Moses State Park and Smith Point County Park in order to assess whether ear-tagged individuals could be better identified than non-ear-tagged individuals on camera traps. We used serially-numbered/lettered white ear tags at Robert Moses State Park and blue ear tags at Smith Point County Park.

We used capture techniques as recommended by the Association of Fish and Wildlife Agencies Best Management Practices for Trapping Red Foxes in the United States (Updated 2014); specifically, we used Victor 1 1/2 Soft Catch padded foothold traps (set to 2-lb pressure to avoid capture of lighter animals), Bridger #2 Offset coil spring traps, and Tomahawk 2-door fox-size box traps (Figure 2c,d).

Upon capture, we manually restrained the foxes using a catch-pole and attached a muzzle, leg-ties and a blind-fold. No sedatives were used (Figure 3). We attached the Quantum 4000E collar, the ear-tag (when permitted) in the right ear, and conducted morphometric measurements.



Figure 2a.



Figure 2b.



Figure 2c.



Figure 2d.

Fig. 2a-d: We used Telemetry Solutions Quantum 4000E GPS collars (on fox in 2a) and Premier 1-ear tags (when permitted, on fox in 2a and 2b) to identify individual red foxes. We used foot-hold traps successfully to catch foxes (sprung trap set in 2c), and while we attempted box traps (trap set in 2d), no captures have yet been made using box traps. Photos: Matt Kynoch.



Figure 3: Captured fox being processed. We manually restrained foxes, and took morphometric measurements before releasing them. Photo: Caitlin Kupferman.

GPS tracking

We programmed the Quantum 4000E collars to record GPS locations once per hour, every day for 30 days from their deployment date, and then once per hour, every other day from day 31 through the loss of the collar (anticipated in Jan-Feb 2016 for most currently deployed collars). We used Collar SW v 2.09 software (Telemetry Solutions) to remotely download data from each collar every 10-14 days since deployment. In order to download the data remotely, we relocated the collared fox using the VHF signal on the collar, approached to between 10-50m, connected wirelessly to the fox using the Quantum Base Station, and downloaded the data.

We mapped GPS locations for each individual collared red fox in ArcMap for exploratory analyses in the early phases of this project. We overlaid these points onto 6- inch orthophotograph imagery taken in April 2015, and visually separated locations into “home range” and “foray” categories. We used the “Minimum Bounding Geometry (MBG)” tool in ArcMap to create minimum convex polygons (MCP) using each individual’s locations, for a basic estimate of home ranges and area used. As the project progresses, we will use a variety of home range estimation techniques, from MCP to kernel estimation to Brownian bridge estimation, to better assess home range movements and interactions with piping plover nests and broods. We also are in the process of designing habitat sampling techniques, using both remote-sensing sources and field-based data, for 2016.

Remote camera surveys

We used the same 300 m grid cells and center points created in ArcMap to guide camera placement in each of the 3 study sites, as described above for the transect surveys for sign, scat, and dens. Within 50 m of the center point of each grid cell containing suitable sites (i.e., we excluded hard surface developed areas and inundated marsh from survey grids), we established an un-baited camera station. Each station consisted of 2 different models of Moultrie game cameras (Pradco Incorporated, Moultrie M880c and M880 Gen2 cameras), each mounted on a plastic t-post and facing towards a game trail, clearing, or other potential wildlife trail (Figure 4a). We set each camera on opposite sides of the game trail, in order to photograph both sides of passing animals (Figure 4b), and angled them to be offset from each other.

We programmed the cameras to take 3 pictures per trigger, with 5 seconds delay after each trigger. We returned every 10-14 days to switch memory cards, replace batteries as needed, and check each station. We established 34 stations at Smith Point County Park starting in late October, and 34 stations at Fire Island National Seashore starting in early November (Figures 5a,b). Our surveys in these areas are currently ongoing. We plan to begin setting up camera stations to survey Robert Moses State Park starting in mid-December. Each grid will be operational for approximately 1200 trap nights, defined as the number of camera stations * number of nights the cameras are in operation.

Upon completion of each survey, we will work to identify all animals captured on the cameras, identify individual red foxes using ear tags and variation in pelage, and conduct analyses of occupancy, and abundance and density if enough individual foxes are detected and can be identified in each management area.



Figure 4a.



Figure 4b.

Figures 4a,b. Sample camera station set-up (a). Cameras were mounted on plastic t-posts along game trails and wildlife travelways. We set one camera on each side of the travel-way (b), in order to photograph both sides of passing animals. Red fox and other captured animal photos will be identified to individual when possible for analyses of abundance, density and occupancy.

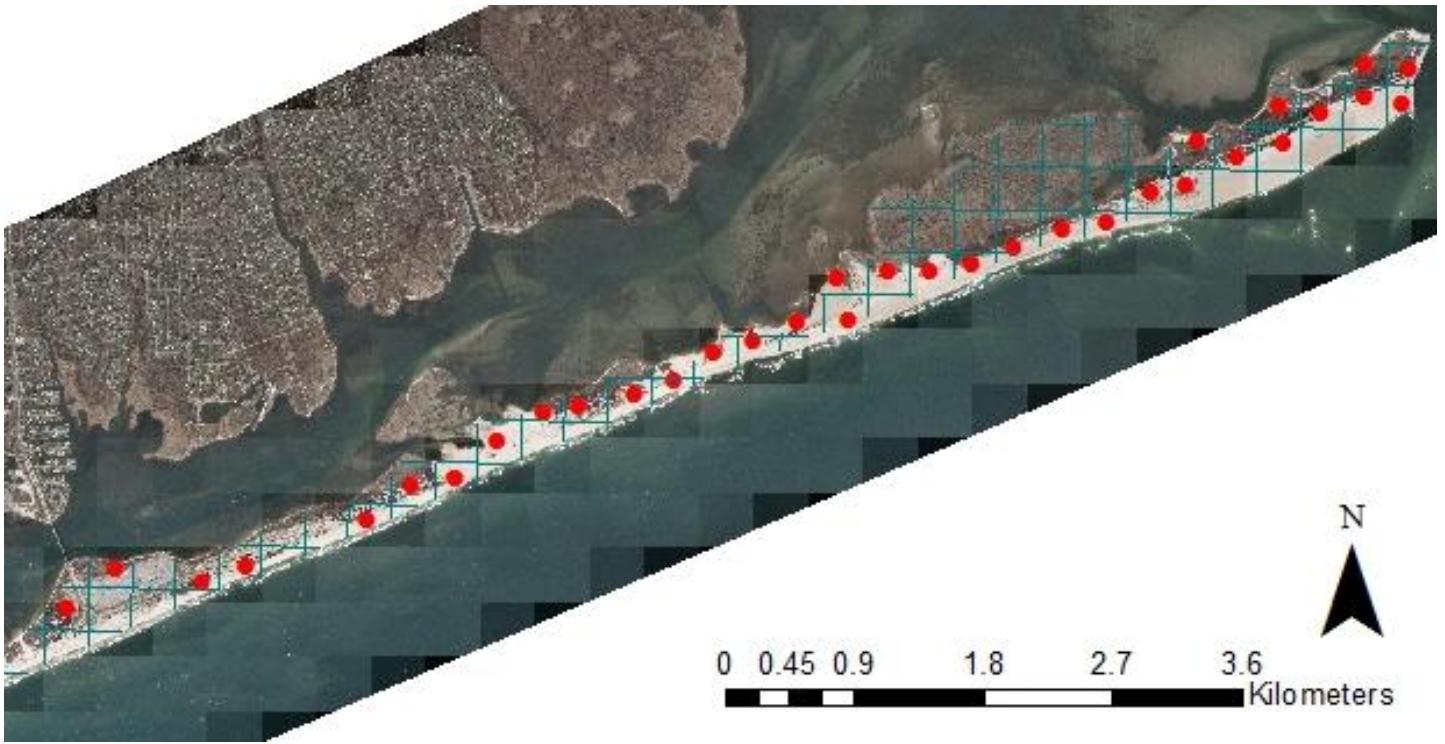


Figure 5a. Camera station locations at Smith Point County Park.

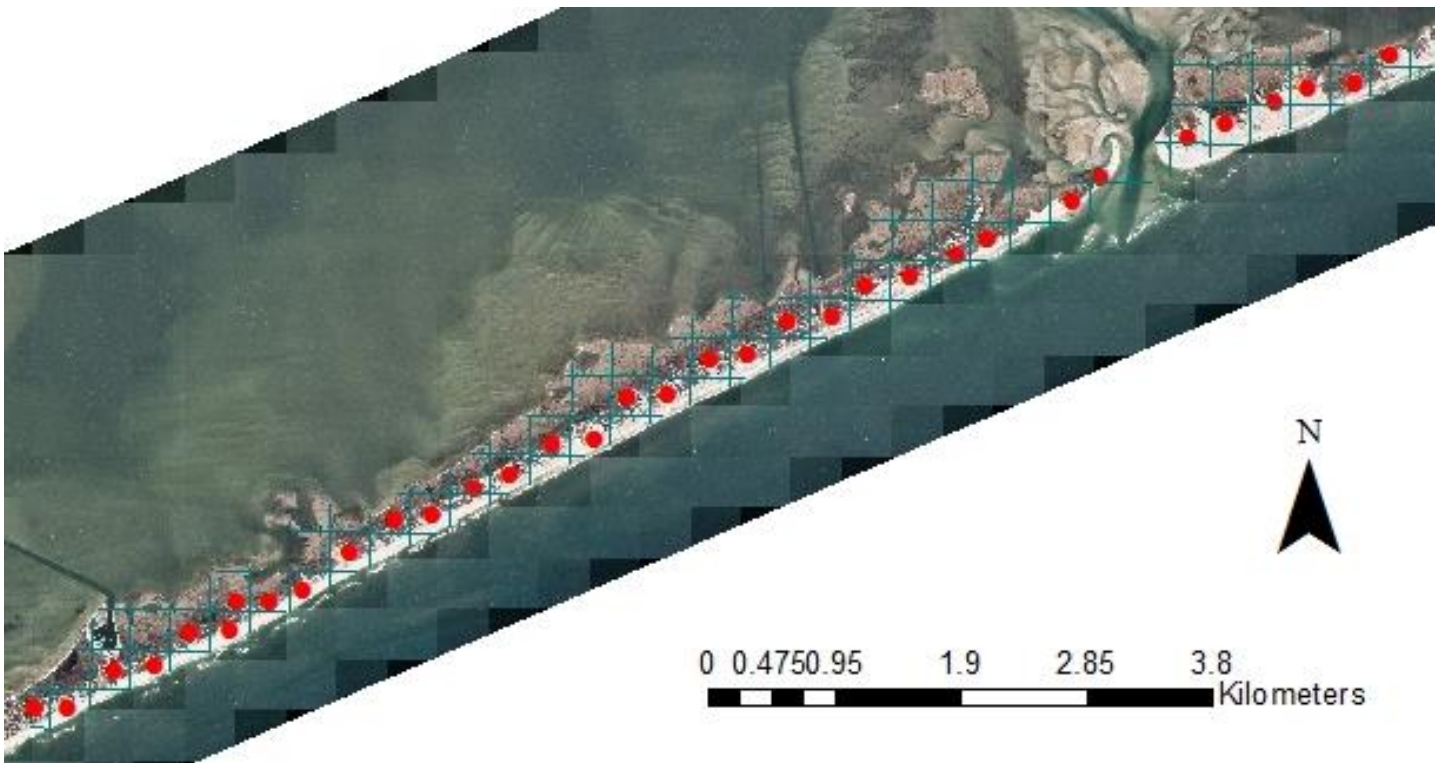


Figure 5b. Camera station locations at Fire Island National Seashore.

Figures 5a, b. We established camera stations within 50m of grid cell centerpoints, where suitable sites were available, as shown with 300m grid cell overlay.

PRELIMINARY RESULTS

Sign, scat, and den surveys

Of the different management units, Smith Point County Park had the highest amount of fox sign overall, and the highest numbers of dens and tracks (Table 1). Robert Moses State Park had the highest number of scats collected along the transects. The ratio of active to inactive dens varied among the management units, particularly among the 3 different units within the Fire Island National Seashore. Of the dens found, we were unable to positively identify 15 of them as either active or inactive, and categorized them as “unknown.” Additionally, several of the foxes sighted during transects appeared to be habituated to human activities.

Table 1. Sign, scat, and dens located on transect surveys in Smith Point County Park, Robert Moses State Park and Fire Island National Seashore, June-July 2015.

Management Unit	Fox sightings	Dens- active	Dens- inactive	Dens- unknown ^a	Dens- total	Scats	Tracks
Smith Point County Park	6	17	9	10	36	17	12
Fire Island National Seashore – east of breach	0	0	3	1	4	4	1
Fire Island National Seashore – west of breach	4	4	9	3	16	16	9
Fire Island National Seashore – Lighthouse Tract	0	0	0	0	0	5	0
Robert Moses State Park	6 ^b	2	2	1	5	33 ^c	5
Total	16	23	23	15	61	75	27

^aDens-unknown includes any dens that could not be positively identified as either active or inactive.

^bOne of these fox sightings was a decomposing carcass.

^cWe found one additional scat in the park opportunistically, outside of our surveys. It is not included in this total.

Trapping, ear-tagging, and collaring

We trapped 21 foxes from July through November 2015 (Table 2) over 15 nights at Robert Moses State Park, 14 nights in Fire Island National Seashore, and 14 nights in Smith Point County Park. Trapping is ongoing at Smith Point County Park.

For each fox captured, we recorded physical and morphological data, and noted its overall physical condition. We outfitted 16 of these 21 foxes with numeric ear tags and/or GPS tracking collars (see Table 2). Four of the 21 foxes were measured, but not outfitted with collars nor eartags; these 4 foxes were captured west of Old Inlet at a time when we were waiting to try to deploy additional collars in the Old Inlet east area, thus they were not collared and ear-tagging was not permitted in this study sub-site. The remaining fox was captured in Robert Moses State Park, but not measured, due to a foot injury sustained during trapping. Following permit

and IACUC protocols, this fox was taken to a local veterinary clinic for assessment and treatment and is currently in rehabilitation; we continue to discuss with the rehabilitation group the possibility of release of the fox back into Robert Moses State Park.

Table 2. Foxes trapped and marked at Smith Point County Park, Robert Moses State Park and Fire Island National Seashore, Fire Island, from July-December 2015. Dashes indicate areas where captured foxes were not ear-tagged, in accordance with permits.

Management Unit	Foxes ear-tagged		Foxes collared	
	Females	Males	Females	Males
Smith Point County Park	2	1	1	1
Fire Island National Seashore – east of breach	-	-	0	1
Fire Island National Seashore – west of breach	-	-	0	3
Robert Moses State Park	5	4	3	2
Total	7	5	4	7

GPS tracking

We have been successful in collecting detailed movement data (once per hour for 30 days, once per hour every other day from day 31 to present) on 4 GPS-collared female red foxes and 5 male red foxes. Unfortunately, 2 of the collared male foxes download mechanisms at Fire Island National Seashore are/were not in operation (one male to east of breach and one male to west of breach). While the download mechanism is not functional, the VHF signal is functional. Thus, we continue to relocate those foxes as well every 10-14 days. The fox with the broken download mechanism in the area east of the breach was found dead (via VHF signal) on 7 December 2015, and we are currently trying to assess whether data has been stored on board. After we complete our trapping efforts at Smith Point County Park, we will attempt to recapture the fox to the west of the breach with the non-functioning collar, remove the collar, and ascertain whether any GPS data has been collected and stored on-board the collar. We are also in discussions with Telemetry Solutions about these unexpected and unacceptable problems and ways to fix these concerns before we decide on a collar company for 2016.

We are just beginning to explore the wealth of data from these GPS-collared animals in the context of our objectives. Our initial explorations have included examining the MCPs for all collared foxes; MCPs are the simplest way to visualize home ranges as they bound all of the observed points of an individual fox within a polygon. For example, we show here some examples of MCPs from our ongoing data downloads. First, one adult male fox collared in late November near the east end of Smith Point County Park appears to be regularly ranging the entirety of the County Park (Figure 6a). Similarly, the male and female foxes collared at Fire Island National Seashore (Figure 6b) and Robert Moses State Park (Figure 6c) in September and October show large, and at least partially overlapping MCPs with other collared foxes in the area.

One interesting finding to date is that 2 collared males from Robert Moses State Park, and one collared male from Fire Island National Seashore, have taken ‘exploratory’ trips eastward and westward from where they were captured, covering the entirety of the beach front area between Fire Island Inlet and Old Inlet multiple

times, over several weeks, before returning to the area where they were initially captured (Figure 7). For example, the red dots on the map are those of an adult male captured at Robert Moses State Park on August 26th, 2015 that took two separate inlet to inlet forays (from 10/5-11/22); the yellow dots are from an adult male captured at Robert Moses State Park on August 14th, 2015 that took an inlet to inlet foray from 10/17/15-11/11/15; and, the blue dots are those of an adult male captured at Fire Island National Seashore on September 16th, 2015 that took an inlet to inlet foray from 10/21/15-11/11/15.

As we continue to analyze these data to their full extent in the context of our objectives, we will use more advanced home range techniques that will allow us to assess differential use of regions of territories and to account for short- and long-range forays out of core ranging areas.

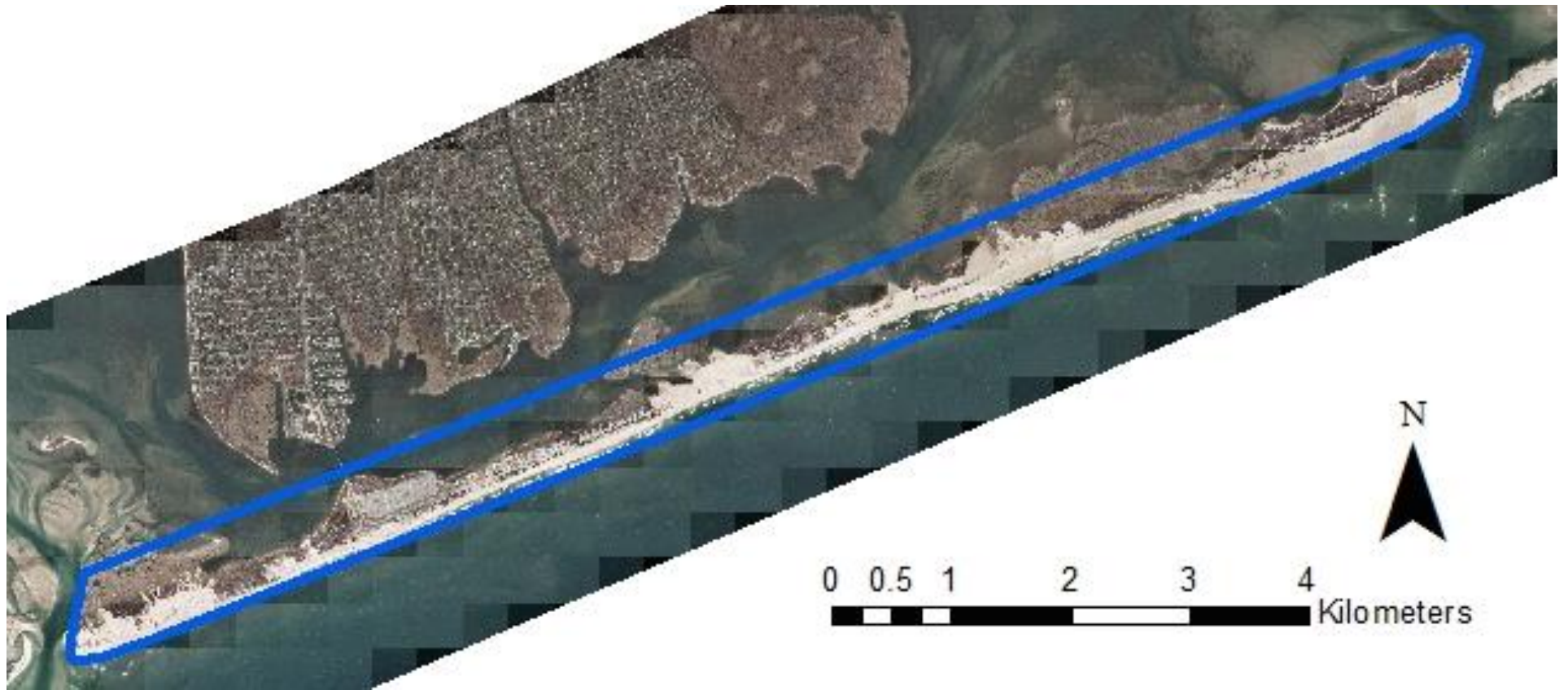


Figure 6a. A minimum convex polygon around all points used by one adult male fox in December 2015 at Smith Point County Park; this male was captured in the eastern portion of the County Park but uses the entirety of the park.



Figure 6b. Minimum convex polygons for 2 adult male red foxes captured at Fire Island National Seashore.

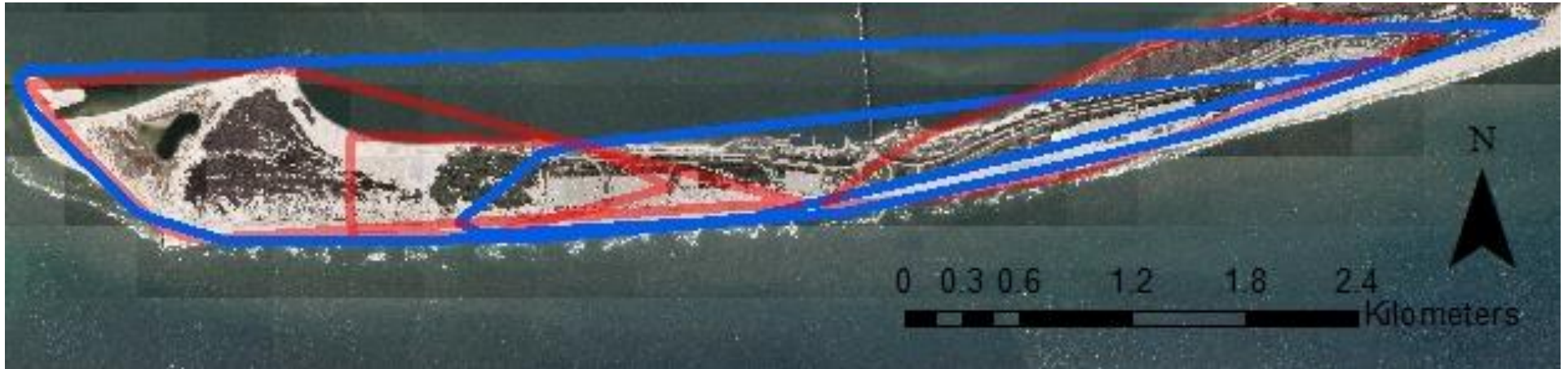


Figure 6c. Minimum convex polygons for 5 red foxes (males in blue, females in red) at Robert Moses State Park and Fire Island National Seashore Lighthouse Tract.

Figure 6a-c. Minimum convex polygons for a sample of the individual foxes captured and GPS-collared to date at each management unit, based on locations obtained via GPS collars. Red polygons indicate female foxes, and blue polygons indicate male foxes.

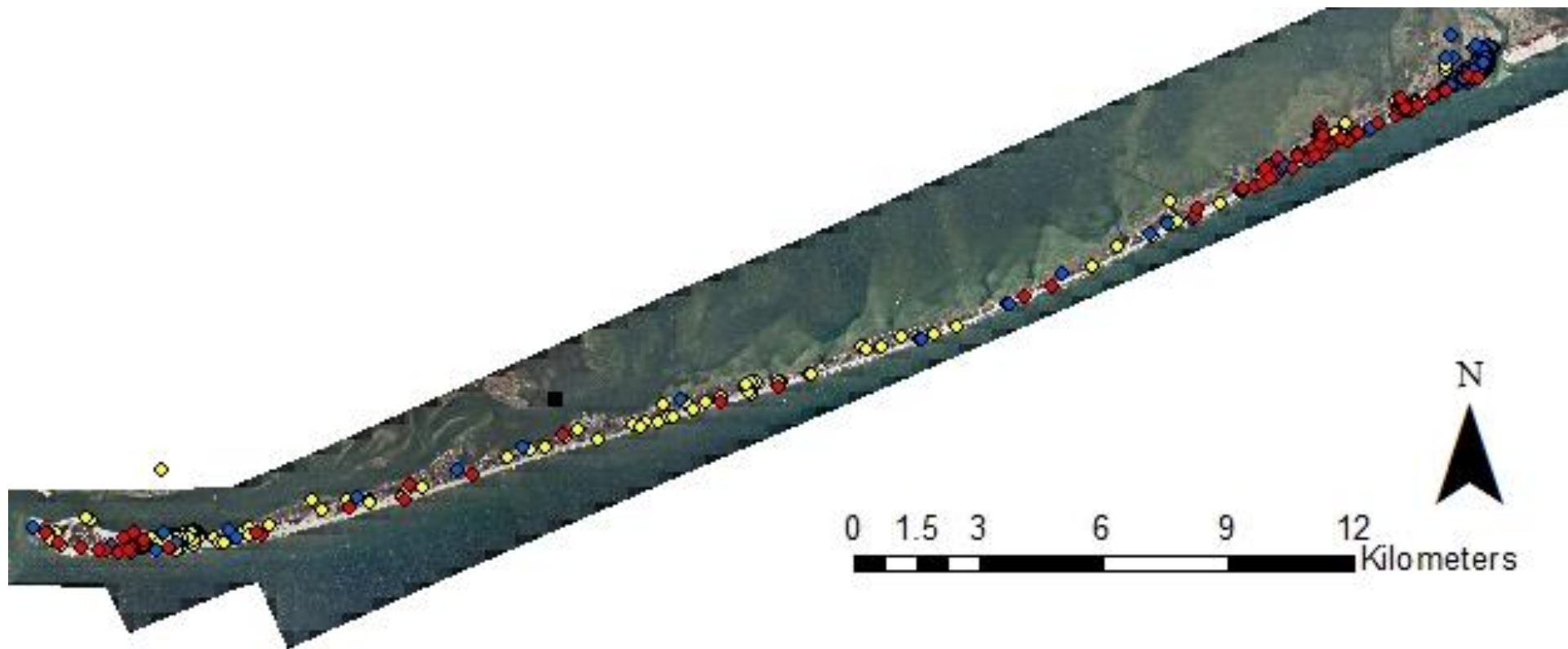


Figure 7. Two male red foxes collared at Robert Moses State Park in August 2015 (GPS locations noted in red and yellow), and one male red fox collared at Fire Island National Seashore in September (blue dots), were recorded taking long forays between Fire Island inlet and Old Inlet in October-November, 2015. The yellow GPS location off image is located on a causeway on the adjacent island; we have not yet ascertained whether that location was spurious or a true foray into a novel environment; however, data collection is ongoing on that collared fox.

Remote camera surveys

Our preliminary results indicate red fox presence, as well as raccoon, white-tailed deer, feral cat, domestic dog, bird, and human activity at numerous camera stations in our ongoing surveys (Figure 8). We relocated 3 stations from initial deployment sites due to camera theft, and 1 due to high tide encroachment, at Smith Point County Park.



Figure 8. A sample of photos collected from ongoing remote camera surveys.

LITERATURE CITED

COHEN, J. B., L. M. HOUGHTON, AND J. D. FRASER. 2009. Piping plover nesting density and reproductive success in response to storm and human-created habitat changes. *Wildlife Monographs* 173.

GIEDER, K. 2015. Assessing the effects of sea-level rise on piping plover (*Charadrius melodus*) nesting habitat, and the ecology of a key mammalian shorebird predator, on Assateague Island. Ph.D. Dissertation, Virginia Tech.

ACKNOWLEDGMENTS

Funding for this study was provided by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, and conducted in cooperation with the National Park Service, Suffolk County Parks, New York State Parks, and New York State Department of Environmental Conservation. We thank Robert Smith (USACE) and Steve Papa (FWS) for funding and support, and Christopher Allen (FWS) for advice and support. We thank NPS staff, especially Mike Bilecki, Lindsay Ries, Kaetlyn Jackson, Jordan Raphael, and seasonal plover technicians for their extensive logistical support and collaboration. We thank Nick Gibbons, Diana Sanford, and all of the Suffolk County plover stewards for their assistance, support, and efforts to protect piping plovers and their habitat. We thank Annie McIntyre, Timothy Byrne, and all the Robert Moses State Park staff for their assistance, support, and efforts to protect piping plovers and their habitat. We are especially grateful to B. Bedwell, H.

Bellman, M. Caggiano, A. Carey, L. Granger, J. Ialeggio, M. Kynoch, C. Kupferman, B. Lin, R. Moylan, E. Peyton for their enthusiastic and tireless work during the 2015 field season. Support from the Virginia Tech Department of Fish and Wildlife Conservation and our colleagues in the Virginia Tech Shorebird Program was essential to the success of this monitoring effort.