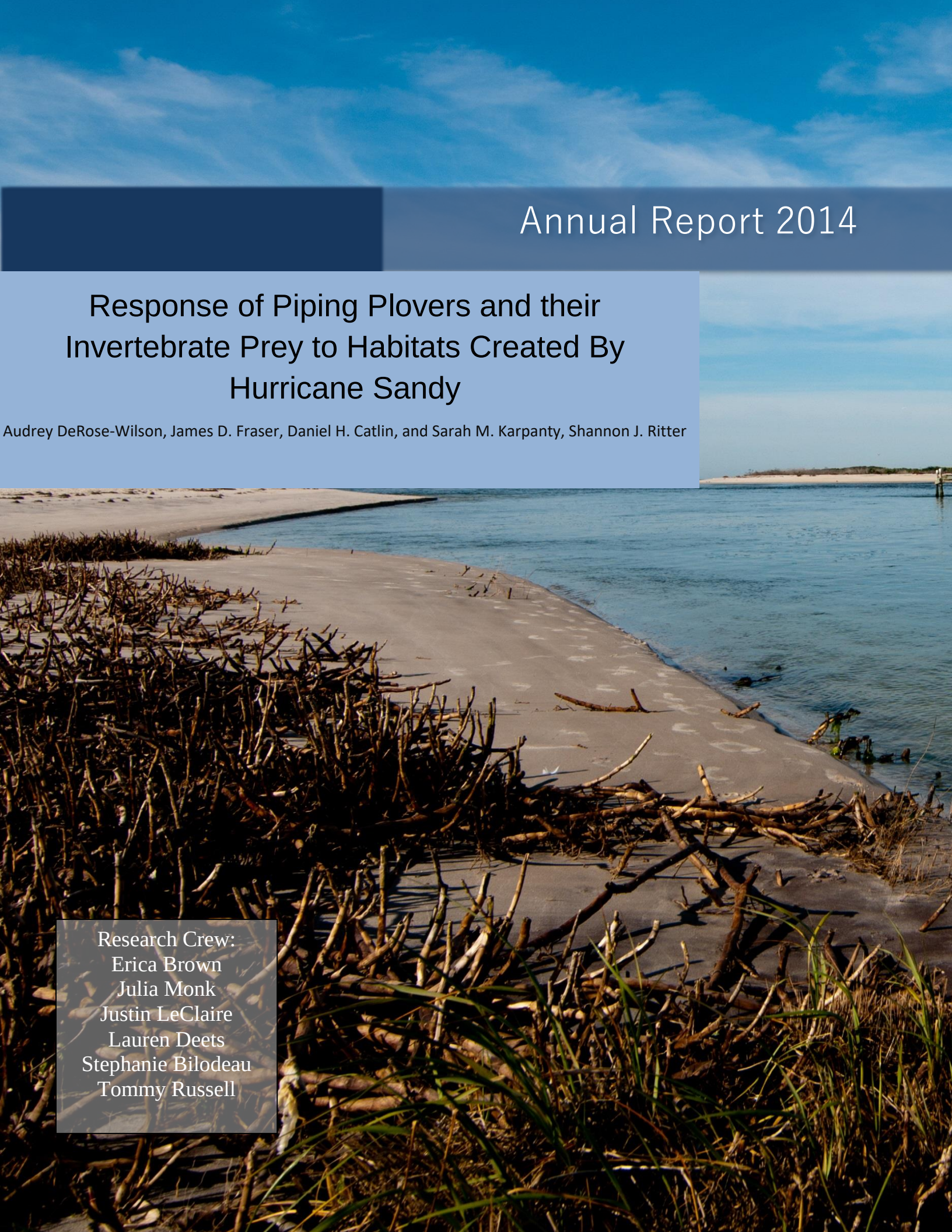


The background image is a photograph of a coastal environment. In the foreground, there is a large pile of dry, brown driftwood and some green grass. Beyond this, a wide, flat sandy beach stretches towards the water. The water is a calm, light blue color. In the distance, a thin strip of land with some vegetation is visible on the horizon under a clear, bright blue sky.

# Annual Report 2014

## Response of Piping Plovers and their Invertebrate Prey to Habitats Created By Hurricane Sandy

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## INTRODUCTION

A key unknown in managing breaches and overwashes is how long a breach needs to be open to provide benefits to piping plovers, or whether the currently used breach fill designs are suitable for piping plovers. At Westhampton Dunes, the island was breached in December of 1992, and the breach was closed by the 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 the USACE breach fill project, 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 of the USACE Westhampton Storm Damage Protection Project as well as housing and roads, even now, some 20 years after the breach, approximately 13 pairs of plovers still use the area (Steve Papa, USFWS, personal communication, 2014).

This study was contracted by the U.S. Fish and Wildlife Service (USFWS) Cooperative Agreement Number F13AC00194, with funding from the U.S. Department of the Interior Hurricane Sandy Resiliency Funding and a U.S. Army Corps of Engineers (USACE), New York District Military Interagency Purchase Request. The USACE was obligated to study the effects of the implementation of their Breach Contingency Plan (USACE 1996) in accordance with the USFWS Biological Opinion dated 1995. The Breach Contingency Plan was implemented immediately following the creation of breaches on Fire Island and Westhampton Island by Hurricane Sandy on October 29, 2012. Two breaches, within Smith Point County Park and Cupsogue County Park were closed within 45 days. Under this plan, a third breach, located in the Fire Island National Seashore's Otis Pike Federal Wilderness Area, is still being monitored.

Moreover, 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 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...insure 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 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, 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 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 to August 2014.

## FIELD METHODS

### *Study area*

We focused monitoring efforts on a 17.4-km stretch of barrier islands within the administrative boundaries of the National Park Service (5.8 km of Otis Pike Wilderness Area) and County of Suffolk (Cupsogue County Park and Smith Point County Park), on Fire Island and Westhampton Island. 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).

All beaches were open to pedestrians throughout the season. Recreational vehicles are typically permitted to drive on the beach at Smith Point County Park, however, this park was closed to recreational off-road-vehicle traffic 9 June –1 August, 2014. Law Enforcement Officers, park staff, and researchers drove 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 units of habitat small enough that monitoring activities could be completed throughout the entire unit on each visit. In 2014, we expanded our study area to include resighting surveys on two new subsites (in addition to the 14 monitored in 2013) where our study population of piping plovers foraged (Figure 1, Table 1). Each subsite consisted primarily of beach, storm-created habitats (natural breaches and overwashes), or artificially filled breach areas and stabilized overwashes. 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.

**Table 1. Subsites names, relative locations and general habitat descriptions at Fire Island and Westhampton Island, 2014.**

| Name                     | Subsite Code | Description                                                                                                                                                                                                                                         | Habitat Type               |
|--------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Cupsogue Mud Flats       | CMF          | Mud flats north of the Cupsogue parking lot, and south of the high bare Island in Moriches Bay.                                                                                                                                                     | Mud flat                   |
| Cupsogue Sandbar         | CSB          | Large low energy sandbar/shoal north of Cupsogue West Beach and narrow strip of bayside intertidal zone at east end of the Cupsogue Beach County Park. Begins at the east edge of the breach-fill and extends east the west end of the parking lot. | Sand bar                   |
| Cupsogue East            | CSE          | Breach-fill and Moriches Inlet area of the Cupsogue County Park. Begins at Moriches Inlet and extends east to the west edge of the breach-fill.                                                                                                     | Beach                      |
| Cupsogue West            | CSW          | Begins on west side of Moriches Inlet and extends west to to Cut 3 on Burma Road.                                                                                                                                                                   | Filled breach              |
| Smith Point East         | SPTW         | Begins at Cut 3 on Burma Road and extends to Cut 2 of Burma Road.                                                                                                                                                                                   | Beach                      |
| Smith Point West         | NBE          | Begins at Cut 2 on Burma Road and extends west to the west end of the Hazardous Area.                                                                                                                                                               | Beach                      |
| Narrow Bay East          | NBW          | Includes the overwash and small breach-fill west of the Hazardous Area.                                                                                                                                                                             | Overwash                   |
| Narrow Bay West          | PSE          | Stretch of beach with primary duneline between Narrow Bay West and Pattersquash overwashes.                                                                                                                                                         | Overwash and filled-breach |
| Pattersquash East        | PSO          | Overwash west of Pattersquash East.                                                                                                                                                                                                                 | Beach                      |
| Pattersquash Overwash    | BRE          | Begins where the primary duneline beings at west end of Pattersquash Overwash and extends to the Otis Pike Wilderness at NPS Visitor Center.                                                                                                        | Overwash                   |
| Bridge East              | BRO          | Overwash in the Otis Pike Wilderness, just west of the NPS Visitor Center.                                                                                                                                                                          | Beach                      |
| Bridge Overwash          | BRW          | Stretch of beach with primary duneline between Bridge Overwash and Old Inlet East.                                                                                                                                                                  | Overwash                   |
| Bridge West              | OIE          | Begins where the primary duneline ends and extends west to Old Inlet.                                                                                                                                                                               | Beach                      |
| Old Inlet East           | OIW          | Begins at west side of Old Inlet and extends to the point where large primary dunes begin.                                                                                                                                                          | Overwash and inlet         |
| Old Inlet West           | OIWR         | Stretch of beach between the east end of Old Inlet West and extends west to Bellport Beach.                                                                                                                                                         | Overwash and inlet         |
| Old Inlet West Reference | FS           | Flood shoals associated with Old Inlet. Big Flood Shoal and Little Flood Shoal combined with shoals that have formed since the 2013 plover seasons.                                                                                                 | Beach and overwash         |
| Flood Shoals             |              |                                                                                                                                                                                                                                                     | Flood shoals               |



**Figure 1.** The study area at Fire Island and Westhampton Island, depicted from east to west, with subsites delineated in yellow. Background imagery is from June 2014. The three frames are not shown at equivalent scale.

### *Habitat sampling and mapping*

We used a Trimble Geo7X (Trimble Navigation, Ltd., Sunnyvale, California, USA) equipped with Terrasync Centimeter Edition software to collect latitude, longitude, elevation, and habitat information at 500 random points, 100 per overwash (including artificially closed breach fill areas) at Cupsogue West, Narrow Bay East, Narrow Bay West, Pattersquash, and Old Inlet East, at plover nests, and at locations where broods were observed. Random points were constrained to overwashed areas that were mapped after the first breeding season in July and August 2013. We visited each of the random, nest, and brood points once to record location, whether the point was suitable or unsuitable plover nesting habitat, and reason(s) for suitability or lack of suitability. A point was classified as unsuitable if it was located on a > 45% slope, densely vegetated, wet or moist, or located on a kind of substrate that a plover would not use for nesting (i.e., a rock). We used the Trimble to record latitude, longitude and elevation for each point calculated from  $\geq 100$  logged locations at  $\leq 10$  cm accuracy. This level of accuracy was achieved by using a real-time connection to a virtual reference station.

### *Habitat classification*

For the purposes of generating random points, suitable habitat was determined based on a raster classification of aerial imagery within the perimeter of overwashes mapped in August 2013. We obtained aerial imagery from the New York State GIS Clearinghouse website: <http://gis.ny.gov/gateway/mg/2013/suffolk/13ic t brookhaven seolie l06 4bd.htm>. The imagery was in New York State Plane coordinate system, Long Island Zone, NAD 83, US Survey Feet 6-inch resolution, 4 band. The imagery was flown April 3, 2013. Imagery panels were 3,000ft E-W by 2,000ft N-S. We merged panels covering each overwash area into a mosaic and then clipped the mosaic to the perimeter of the overwash polygons as mapped in 2013. This was done to reduce the range in pixels being classified, especially in the water/vegetation range, so that more subtle variations in sand color could be distinguished. We performed a raster classification with 50 randomly assigned classes on the imagery in ArcMAP. An observer then compared pixels in each raster class to pixels in the original imagery to determine which classes represented habitat that was suitable for nesting plovers. The suitable habitat area was converted to a polygon. We buffered vegetation and moist sand patches that were  $\geq 1$  m<sup>2</sup>, and bay and ocean high tide lines (defined by mapping the high tide line in 2013) by 8 m (based on the distance of our closest nest to the digitized tide line) and subtracted the buffered areas from the suitable habitat area. We did this because 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).

### *Adult survey*

We surveyed the entire study area for adult piping plovers every 1–3 days, April–August, 2014. We surveyed subsites on foot and by ATV. Subsites that did not have bay side habitat and

consisted of only narrow ocean beach were surveyed by driving an ATV slowly along the ocean intertidal zone and then along the backshore habitat. ATV travel, for surveys or other reasons, only occurred outside of areas protected by symbolic fence 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. When conducting foot surveys, observers walked regular routes through each subsite, usually along the east-west axis and used spotting scopes to observe plovers (Figure 2). The transect width varied depending on topography and vegetation, and weather conditions that affected visibility, as we adjusted the distance between transects in order to be able to see half the area between adjacent routes. We usually surveyed beach subsites in two passes, one pass along the ocean intertidal zone and one in the backshore area. One–four observers made each pass walking parallel 50–100 m 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. We recorded a location within 30 m of each plover with a GPS unit (Garmin International, Olathe, KS).



**Figure 2. Surveying for piping plovers at Cupsogue Beach County Park. View facing west toward 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, Figure 3).

### ***Egg masses***

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

### ***Nest checks***

We checked nests every 1–3 days throughout the incubation period and once per day as the hatch date approached to check for hatching (Figure 3).



**Figure 3. Piping plover hatchlings in the nest bowl.**

### ***Brood observations and chick behavior***

After eggs hatched, we searched the area to locate and count the chicks. We attempted to locate and band all piping plover chicks on the initial visit, and to resight them on subsequent visits, until they fledged (Figure 4). 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. 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 dune) every ten seconds (Altmann 1974). 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.



**Figure 4. A 21 day-old Piping plover chick foraging at Narrow Bay West in Smith Point County Park.**

#### ***Trapping and banding***

We captured incubating piping plover adults on nests with complete clutches using a drop-box nest trap (Figure 5). We placed the trap over the nest and propped it up with a stick. When the plover entered the trap to incubate, we deployed the trap by pulling a string tied to the stick. Once captured the plover was removed from the trap, weighed, measured, and banded. If the second adult was had not yet been trapped in 2014, we reset the trap while banding the first adult. We attempted to capture both unbanded plovers and plovers banded in 2013, to check bands and flags for fading and/or warping.



**Figure 5. A piping plover in a drop-box trap.**

### *Banding schemes*

Plover adults and chicks banded in 2014 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 b) a piping plover chick with an alphanumeric band.**

### *Terrestrial invertebrates*

We sampled terrestrial invertebrates on two transects at each subsite where plover chicks were present. One transect followed either the bay shoreline or ocean shoreline, depending on what type of moist foraging habitat was available at the subsite, the other transect was placed in dry upper beach habitat. On the shoreline transects, sample stations were placed at the upper edge of the intertidal zone. If land managers used symbolic fence (flagged string attached to fiberglass or metal t-posts) to protect plover breeding areas at the subsite, stations on the upper beach transect were always placed within the area protected by the symbolic fencing. We collected insects on each transect every 2–3 days from the time the first brood hatched until the last brood fledged at each subsite. We established the first station at the west end of the subsite and moved eastward throughout the season. At each visit, we navigated to the previous sample location (or west edge of the subsite on the initial visit) and paced a randomly selected number of meters eastward to establish a new sample station. If we reached the east end of a subsite, we began moving back westward in the same way. 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 cm<sup>2</sup> and 129 cm<sup>2</sup> on the vertical stick. We placed a chicken-wire 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.



**Figure 7. A terrestrial arthropod trapping station.**

### *Human use*

To generate an index of human activity, we recorded the number of people present each time we entered a subsite (Figure 8). We recorded the number of people categorically as 0, 1-50, 51-100, or >100.



**Figure 8. Human activity on the ocean beach at Pattersquash Overwash in Smith Point County**

## **ANALYTICAL METHODS**

### *Nesting habitat use*

We compared nesting habitat use versus availability in three ways. First we calculated the area of three types of potential nesting habitat (natural overwash, filled/stabilized breach or overwash, and beach) 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 three habitat types as the measure of habitat availability. Finally, we compared use versus availability for beach habitat versus overwash habitat (natural overwash and filled/stabilized breach or overwash combined). 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 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, Pattersquash Overwash, Narrow Bay East, and Cupsogue West, hereafter overwash-nesting plovers) and no direct access to bay side intertidal habitat (Old Inlet West Reference, Old Inlet East, Narrow Bay East, Smith Point West, and Smith Point East), 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. We then calculated the average survival rate by raising the daily survival rate to the 34<sup>th</sup> power (Heisey et al. 2007) for nests with and without exclosures. For this calculation, we classified nests that were exclosed at any point during the incubation period as exclosed nests.

### ***Egg mass***

We used a Wilcoxon rank sum test to determine whether clutch mass differed between nests in overwashes with direct bay side access (Pattersquash Overwash and Cupsogue West) and nests in subsites with no direct access to bay side intertidal habitat (Watch Hill, Old Inlet West Reference, Old Inlet East, Smith Point West, and Smith Point East).

### ***Chick behavior***

We classified broods into four groups based on the location of the foraging home range (ocean or bay, based on a minimum convex polygon created from coordinates of all points where the brood was observed) and exposure to human activity (high or low). The groups were, 1) ocean side home range and low human activity, 2) ocean side home range and high human activity, 3) bay side home range and low human activity, 4) bay side home range and high human activity. Broods were classified as experiencing high levels of human activity if they foraged in subsites that were easily accessible to the public (Cupsogue and Otis Pike Wilderness east of the breach). Broods that foraged in less accessible areas, i.e., subsites in Otis Pike Wilderness west of the breach and Smith Point County Park experienced low levels of human activity. We used a Multi-response permutation procedure (MRPP) in the software package Blossom (Blossom Version W2008.04.02, [www.fort.usgs.gov](http://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 Cormack-Jolly-Seber model with nine encounter periods in Program MARK. Each encounter interval was three days long, covering the time from hatch to day 25. The final encounter period included resights from chicks seen at 25 days or

after. We ran all possible subsets of models where survival rate and resight rate were held constant, varied with time or varied by management unit (Otis Pike Wilderness, Smith Point County Park, and Cupsogue County Park), location (Ocean or Bay foraging home range), and human activity level (low, high). We used the daily survival rates from the best model raised to the 25<sup>th</sup> power to predict the probability of surviving to the fledging.

### *Terrestrial insects*

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

## RESULTS

### *Banding*

We banded 17 adults and 41 chicks (Table 2). We recaptured 10 additional adult plovers that were banded in 2013, nine were banded as adults, and one was banded as a chick. We banded all of the chicks that we found as hatchlings. By the end of the 2014 breeding season, all of the breeding adults in our population were banded.

**Table 2. A summary of piping plover adults and chicks banded on Fire Island and Westhampton Island during May–July in 2014. Subsite abbreviations are included in parenthesis for each management unit. See Table 1 for a detailed description of subsites.**

| Management Unit                                                       | Adults  |       | Chicks |
|-----------------------------------------------------------------------|---------|-------|--------|
|                                                                       | Females | Males |        |
| Fire Island National Seashore – west of breach (OIW, OIWR)            | 0       | 0     | 4      |
| Fire Island National Seashore – east of breach (OIE, BRW, BRO)        | 1       | 2     | 7      |
| Smith Point County Park (BRE, PSO, PSE, NBW, NBE, SPTW, SPTE)         | 4       | 4     | 13     |
| Cupsogue Beach County Park (CSE, CSW, CMF, CSB)                       | 3       | 2     | 16     |
| Fire Island National Seashore – east of breach (off-site: Watch Hill) | 0       | 1     | 1      |
| Total                                                                 | 8       | 9     | 41     |

### *Nest location*

We observed 15 pairs nesting concurrently within the study area. We also monitored three pairs that nested outside of the study area (hereafter off-site pairs) as time permitted. The 15 focal pairs produced 20 nests (Table 3). The three off-site pairs produced five nests, however these nests and the chicks they produced were excluded from nest survival and chick survival analyses because we were not able to monitor them as frequently as nests in the study area.

**Table 3. Piping plover nest distribution and nest fates at Fire Island and Westhampton Island, May-July 2014.**

| Management Unit                                      | Habitat                           | Nests |         |        |                             |
|------------------------------------------------------|-----------------------------------|-------|---------|--------|-----------------------------|
|                                                      |                                   | Found | Hatched | Failed | Reason for loss             |
| Fire Island National Seashore - west of breach       | Natural breach/overwash           | 1     | 1       | 0      |                             |
| Fire Island National Seashore - east of breach       | Natural breach/overwash           | 5     | 2       | 3      | Predated (1), Abandoned (2) |
| Smith Point County Park                              | Filled breach/stabilized overwash | 8     | 3       | 5      | Predated (5)                |
| Smith Point County Park                              | Beach                             | 1     | 1       | 0      |                             |
| Cupsogue Beach County Park                           | Filled breach/stabilized overwash | 3     | 3       | 0      |                             |
| Cupsogue Beach County Park                           | Beach                             | 2     | 1       | 1      | Predated                    |
| Fire Island National Seashore (off-site: Watch Hill) | Beach                             | 5     | 1       | 4      | Abandoned (4)               |
| Total                                                |                                   | 25    | 12      | 13     |                             |

### *Nesting habitat use*

The area-based use vs. availability analysis showed that nesting piping plovers used habitats (filled/stabilized overwash, natural overwash, and beach) 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 three habitat categories, and length of beach frontage as a measure of availability, the overall test was not significant, however, Bonferroni adjusted confidence intervals on proportion of use did not overlap the proportion available for beach and filled breaches/stabilized overwashes as shown by the symbols in the selection column in Table 5. The length based test with two categories showed selection for overwashes (natural overwash and filled/stabilized breach or overwash combined) and against beaches ( $\chi^2 = 7.35$ , df 1,  $P=0.0067$ , Table 6).

**Table 4. Proportion of availability ( $P_a$ , area of each habitat type) versus use ( $P_u$ , proportion of breeding pairs in each habitat,  $N=15$ ) and Bonferroni-corrected confidence intervals on proportion of use from a chi-square test of equal proportions for three different habitat types used by nesting piping plovers at Fire Island and Westhampton Island, May-July 2014. 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                      | Area (ha) | $P_a$ | $P_u$ | CI (95%) |      | Select <sup>a</sup> |
|-----------------------------------|-----------|-------|-------|----------|------|---------------------|
| Beach                             | 36        | 0.25  | 0.33  | 0.09     | 0.58 | =                   |
| Natural breach/overwash           | 50        | 0.34  | 0.19  | -0.02    | 0.40 | =                   |
| Filled breach/stabilized overwash | 59        | 0.41  | 0.48  | 0.21     | 0.74 | =                   |

<sup>a</sup>Selection (Select): for (+), against (-), and no selection (=).

<sup>b</sup>Overall chi-square test  $\chi^2 = 1.35$ ,  $df=2$ ,  $P=0.51$

**Table 5. Proportion of availability ( $P_a$ , length of each habitat type) versus use ( $P_u$ , proportion of breeding pairs in each habitat,  $N=15$ ) and Bonferroni-corrected confidence intervals on proportion of use from a chi-square test of equal proportions for three different habitat types used by nesting piping plovers at Fire Island and Westhampton Island, May-July 2014. 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 <sup>a</sup> |
|-----------------------------------|------------|-------|-------|----------|------|---------------------|
| Beach                             | 9917       | 0.62  | 0.33  | 0.09     | 0.58 | =                   |
| Natural breach/overwash           | 2851       | 0.18  | 0.19  | -0.02    | 0.40 | =                   |
| Filled breach/stabilized overwash | 3214       | 0.20  | 0.48  | 0.21     | 0.74 | =                   |

<sup>a</sup>Selection (Select): for (+), against (-), and no selection (=). The  $P$  value for the overall test was not significant.

<sup>b</sup>Overall chi-square test  $\chi^2 = 4.30$ ,  $df=2$ ,  $P=0.12$

**Table 6. Proportion of availability ( $P_a$ , length of each habitat type) versus use ( $P_u$ , proportion of breeding pairs in each habitat,  $N=15$ ) and Bonferroni-corrected confidence intervals on proportion of use from a chi-square test of equal proportions for two different habitat types used by nesting piping plovers at Fire Island and Westhampton Island, May-July 2014. 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 <sup>a</sup> |
|--------------|------------|-------|-------|----------|------|---------------------|
| Beach        | 9917       | 0.62  | 0.33  | 0.09     | 0.58 | -                   |
| Overwash     | 6065       | 0.38  | 0.67  | 0.42     | 0.91 | +                   |

<sup>a</sup>Selection (Select): for (+), against (-), and no selection (=). The  $P$  value for the overall test was significant.

<sup>b</sup>Overall chi-square test  $\chi^2 = 7.35$ , df 1,  $P=0.0067$

### **Adult movements**

The median distance marked adult plovers with active nests were observed from their nest did not differ between 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,  $N=118$  observation on 14 individuals) and those that did not ( $N=166$  observations on 22 individuals,  $W=408$ ,  $P=0.974$ , Figure 9).

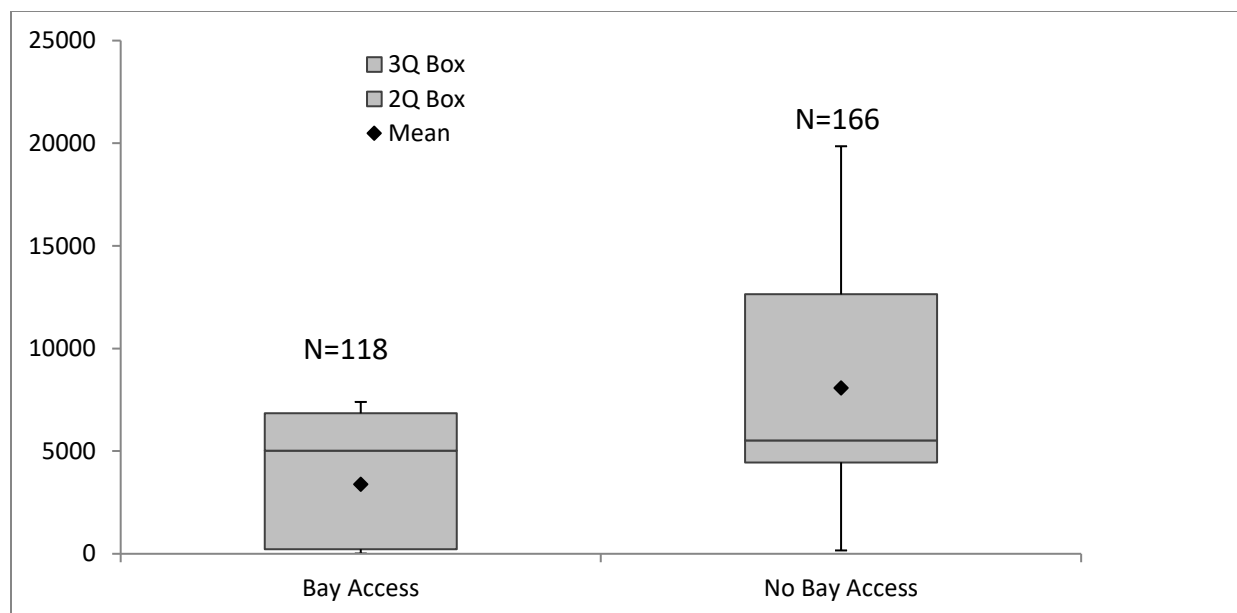


**Figure 9.** The median distance marked adult plovers with active nests were observed from their nest did not differ for plovers that nested at locations with or without direct access to the bay at Fire Island and Westhampton Island, May-August 2014. Direct access was defined by habitat that a plover could walk through to access bay intertidal habitat without encountering dense vegetation. Subsites with direct access included Pattersquash Overwash, Narrow Bay East, and Cupsogue West, and subsites with no direct access to bay side intertidal habitat were Old Inlet West Reference, Old Inlet East, Narrow Bay East, Smith Point West, and Smith Point East. Box plots include the mean (diamond), median (solid line in the box) the 25<sup>th</sup> and 75<sup>th</sup> quartile range (solid boxes), and the maximum and minimum (the error bars).

### *Nest survival*

The daily survival rate for exclosed nests was 0.9770, and 0.9772 for nests that were not exclosed. Nests that were exclosed when the clutch was complete had a 45.3% predicted probability of surviving to hatch, while nests that were never exclosed had a 45.7% 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 ( $Z=0.03$ ,  $df=6$ ,  $P=0.790$ ).

### *Chick behavior*

Chicks on ocean beaches with high levels of human activity pecked less frequently (MRPP,  $S=-1.86$ ,  $P=0.003$ ; Figure 10) and spent less time foraging (MRPP,  $S=-3.86$ ,  $P=0.028$ ; Figure 11; gray bars) than chicks that had bay side home ranges. Human activity levels alone did not explain peck rate or time spent foraging for either bay or ocean foraging chicks, but when coupled with

habitat, chicks spent progressively less time eating and looking for food as habitat quality decreased (bay habitat = high quality, ocean habitat = lower quality) and human activity increased. There was no difference in time spent mobile (blue bars), inactive (green bars), or brooding (orange bars) for any habitat, activity level combinations.

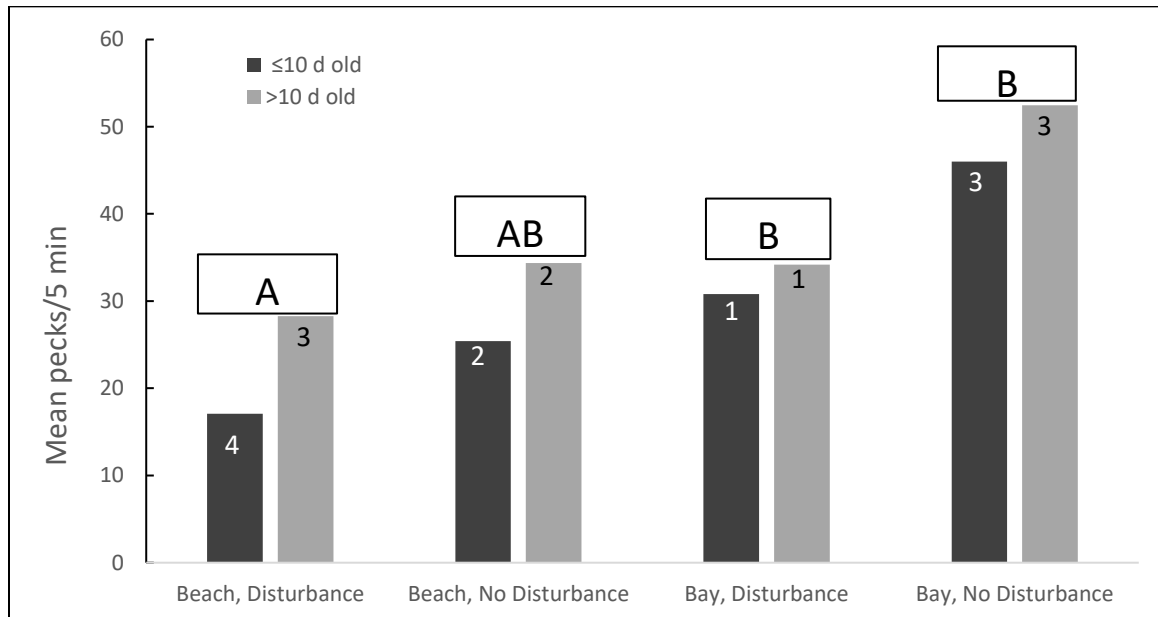


**Figure 10.** Chicks that foraged on bay shorelines had higher peck rates than chicks that foraged on ocean beaches with high levels of human disturbance (MRPP,  $S=-3.86$ ,  $P=0.003$ ). Numbers in bars are sample sizes. Capital letters shared among groups indicate no significant difference between those groups. For example, chicks that foraged on the beach (capital A) had lower peck rates than chicks that foraged on the bay (capital B).

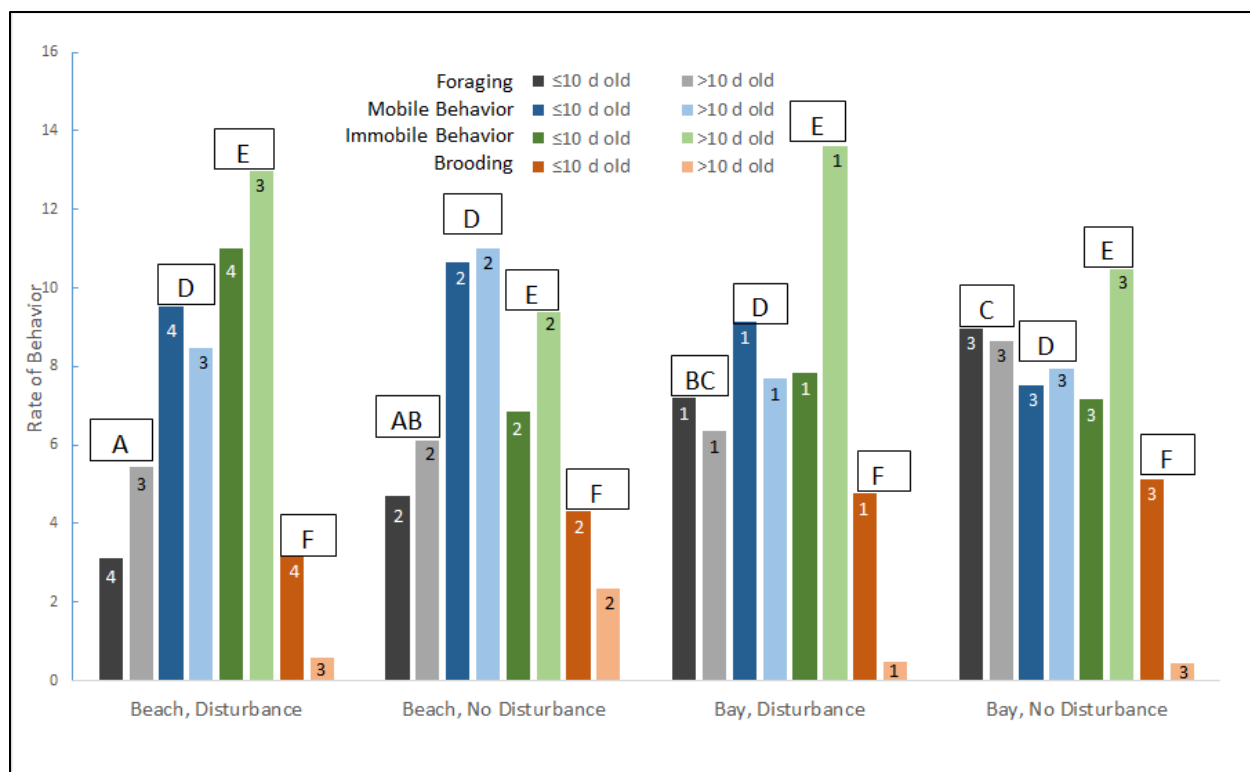


**Figure 11.** Chicks on bay shorelines spent progressively more time foraging (gray bars) as habitat quality improved and human activity decreased (MRPP,  $S=-3.86$ ,  $P=0.028$ ). Numbers in bars are sample sizes. Capital letters shared among groups indicate no significant difference between those groups. For example, chicks that foraged on the beach (capital A) spent less time foraging than chicks that foraged on the bay (capital C).

### Chick survival

Daily chick survival varied by management unit, ranging from 0.904 at Cupsogue County Park to 1.00 at Smith Point County Park (Table 7). Across the study area, the probability of surviving to fledging was 55.20%, which was slightly lower than the observed fledging rate of 58.54%.

**Table 7. Estimated daily survival rate (DSR) and probability of surviving to fledging for piping plover chicks in three different management units at Fire Island and Westhampton Island, May-July 2014.**

| Management Unit      | # Hatched | DSR    | SE     | probability of surviving to fledging |
|----------------------|-----------|--------|--------|--------------------------------------|
| Otis Pike Wilderness | 12        | 0.9782 | 0.0102 | 57.66%                               |
| Smith Point          | 13        | 1.0000 | 0.0000 | 100.00%                              |
| Cupsogue             | 16        | 0.9036 | 0.0157 | 7.93%                                |

### *Brood home range*

Broods that foraged on ocean beaches had larger home ranges than broods on the bay side of the overwashes (Wilcoxon rank sum,  $Z=-2.19$ ,  $df=4$ ,  $P=0.028$ ; Figures 12 & 13).

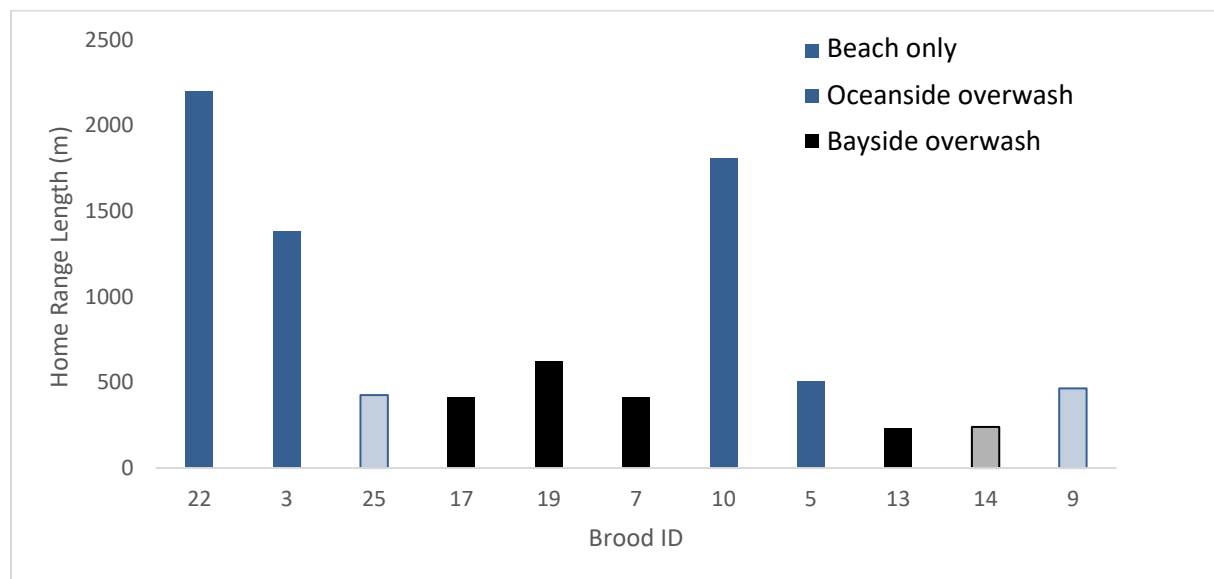


**Figure 12. Brood home range lengths for piping plovers that foraged on ocean beaches, on beaches adjacent to overwashes, or on the bay side of an overwash. Transparent bars represent broods from which no chicks survived to fledging, which could have affected home range size. Blue bars represent broods 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.**



**Figure 13. Brood home ranges of piping plovers at Fire Island and Westhampton Island, NY, May–August 2014. Background imagery is from June 2014. The three frames are not shown at equivalent scale.**

### *Terrestrial invertebrates*

More arthropods were captured in the bay intertidal habitat than on the ocean beach or along the ocean or bayside of the toe of the dune (ANOVA,  $F=39.84$ ,  $df=2$ ,  $P<0.0001$ , Table 8).

**Table 8. Mean numbers of arthropods captured during a 30 minute period at bay shoreline, ocean shoreline, and dune toe on Fire Island and Westhampton Island, June-August, 2014. Capital letters shared among groups indicate no significant difference between those groups.**

| Geologic Location | Mean insects/30 min | Std Error | N   |
|-------------------|---------------------|-----------|-----|
| Bay shoreline     | 6.88 <sup>A</sup>   | 1.00      | 186 |
| Dune Toe          | 0.43 <sup>B</sup>   | 0.06      | 298 |
| Ocean shoreline   | 1.98 <sup>B</sup>   | 0.36      | 111 |

### *Human use*

Cupsogue East and Bridge East, the two subsites that were adjacent to large parking lots, and thus most easily accessible to pedestrians had the highest numbers of visitors (Figures 14, 15, and 16). In 2013, Pattersquash Overwash and Narrow Bay West experienced a high volume of visitors because recreational driving was allowed along the ocean beach throughout the plover breeding season at these subsites. In 2014, recreational driving was not allowed at Smith Point County Park from 9 June – 30 July, 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 mean numbers of people are less robust for some time periods (especially at Cupsogue County Park and the Wilderness Area east of the breach), because we began our work day at 6am and were usually out of these areas before many beachgoers arrived.

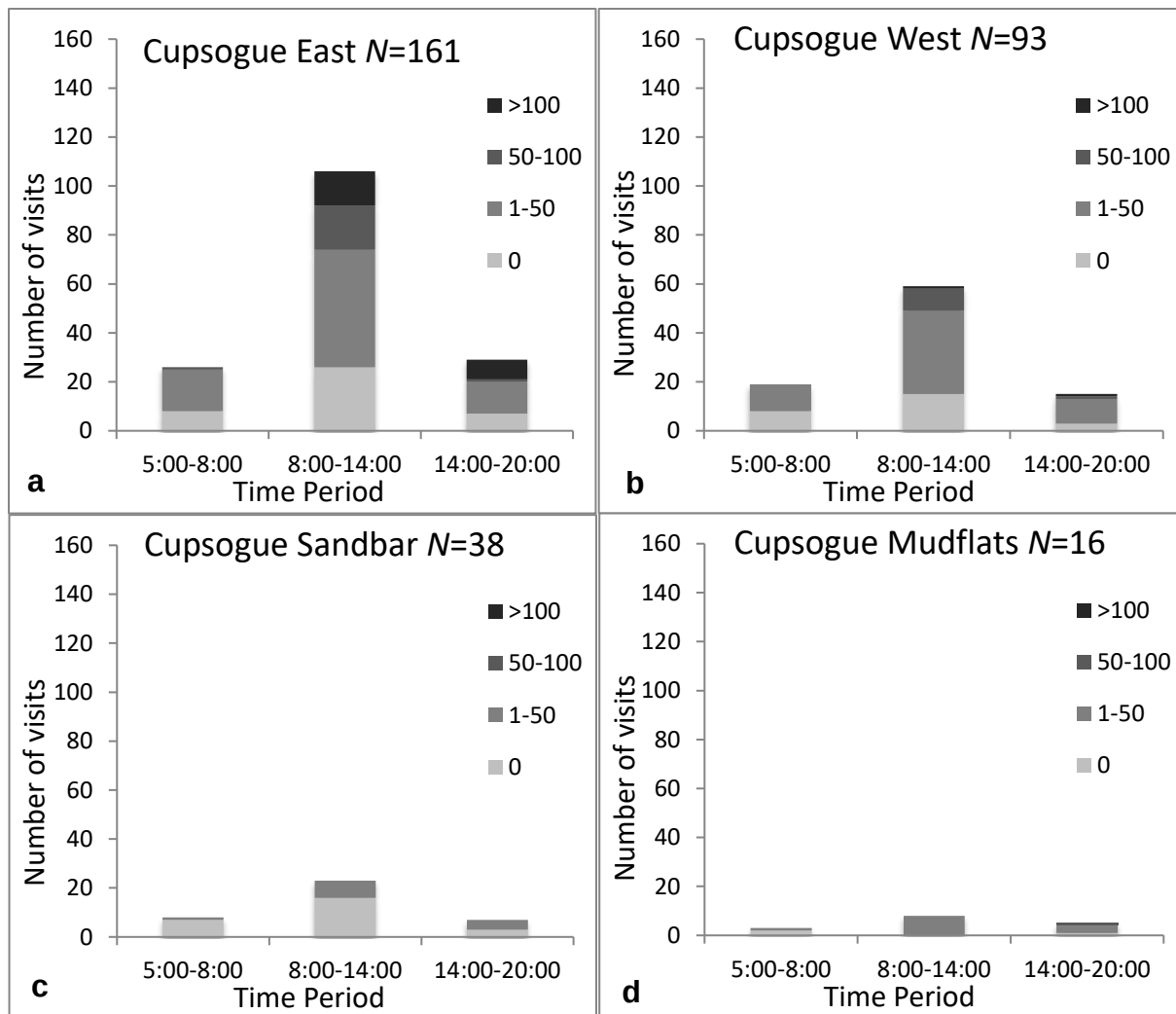


**Figure 14. Frequency of subsite visits with number of people (0, 1-50, 50-100, >100) present during three time periods (5:00-8:00, 8:00-14:00, and 14:00-20:00) in Cupsogue Beach County Park, a) Cupsogue East, b) Cupsogue West, c) Cupsogue Sandbar, and d) Cupsogue Mudflats.**

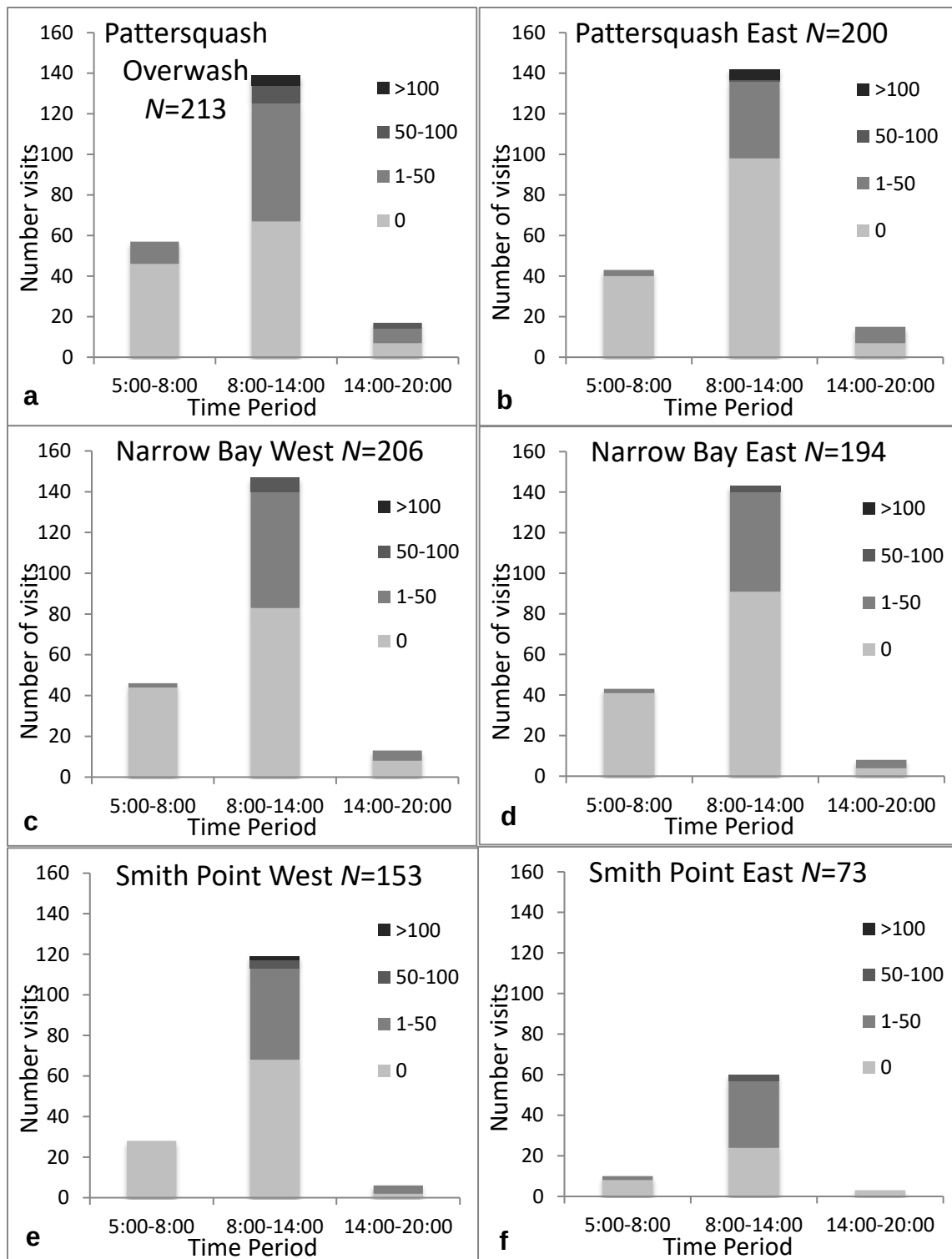


**Figure 15. Frequency of subsites visits with number of people (0, 1-50, 50-100, >100) present during three time periods (5:00-8:00, 8:00-1400, and 14:00-20:00) in Smith Point County Park a) Pattersquash Overwash, b) Pattersquash East, c) Narrow Bay West, d) Narrow Bay East, e) Smith Point West, and f) Smith Point East.**

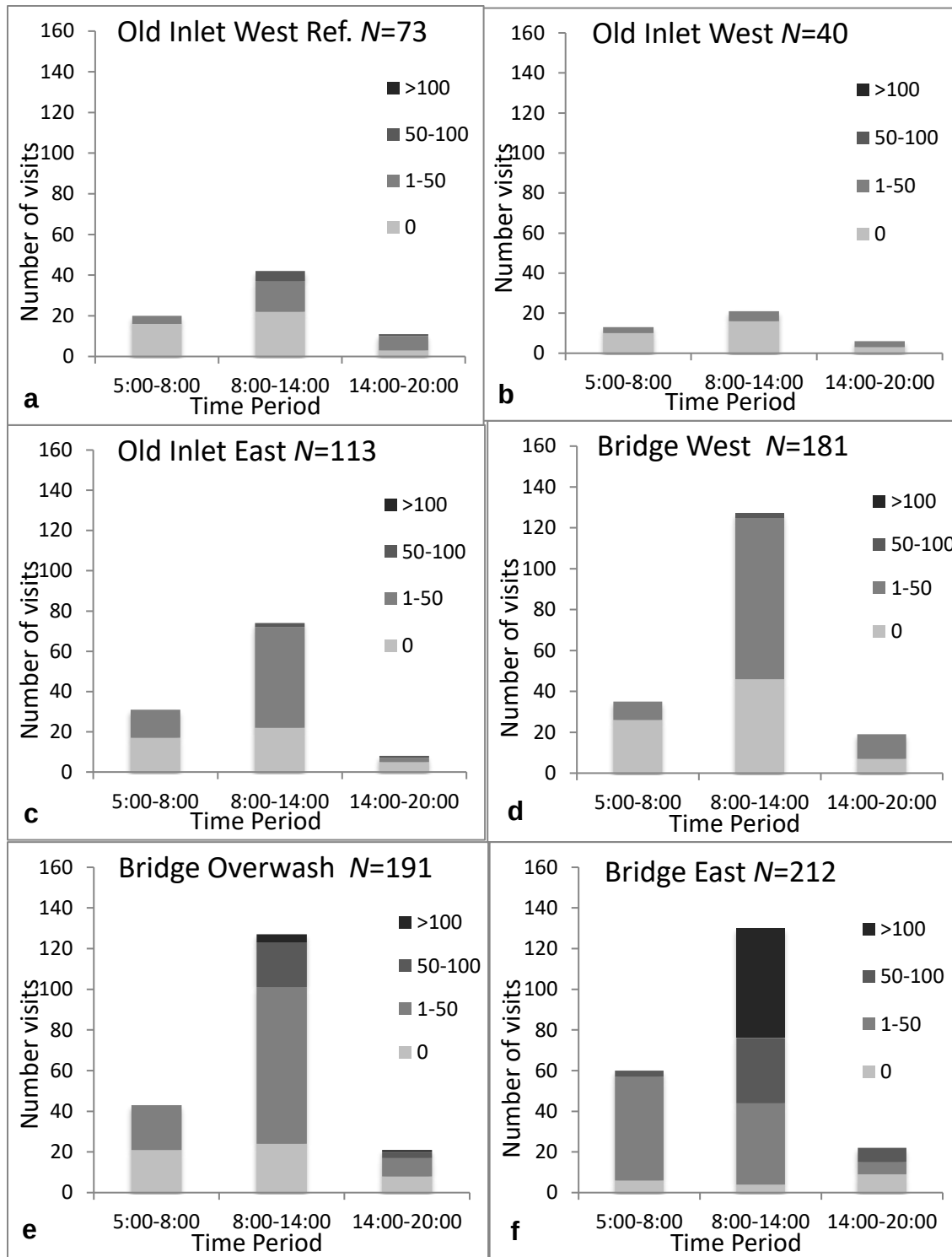


**Figure 16. Frequency of subsites visits with number of people (0, 1-50, 50-100, >100) present during three time periods (5:00-8:00, 8:00-1400, and 14:00-20:00) in the Otis Pike Wilderness a) Old Inlet West Reference, b) Old Inlet West, c) Old Inlet East, and Smith Point County Park, d) Bridge West, e) Bridge Overwash, and f) Bridge East.**

## DISCUSSION

### *Nesting distribution and population response*

Previous work has shown that piping plovers return to the same nesting territory year after year as long as it is available (Cohen 2006, Gieder et al. 2014, Freidrich et al. 2014) and colonization of new habitat usually occurs in the second year after new habitat is created (Wilcox 1959, Cohen et al 2009, USACE, Omaha District, unpublished data).

Our use versus availability analysis showed that plovers selected for overwashes, but did not show a preference for natural overwashes over stabilized overwashes and breach fills, or vice versa. In the first few years following habitat creation, quality may be similar for both natural overwashes and those where the beach elevation profile has been raised by engineering, however, the long term the trajectory for plover nesting habitat may be different if the overwash frequency and vegetation encroachments rates vary between natural and modified overwashes.

Overall, nesting distribution in 2014 was similar to the distribution in 2013 (Figure 17a, b & c). Local changes from 2012 to 2013 around Old Inlet appear to have reversed in 2014. In 2013, on the east side of the breach at Old Inlet, plovers nested in the newly-created overwash, on average about 100 m bayward of 2012 nest locations, while on the west side of the breach they moved west, away from a narrow beach to an area that overwashed during Hurricane Sandy, and on to a storm-created flood shoal. However, in 2014, no plovers nested on the flood shoal and nests east of Old Inlet were oceanward of 2013 nest locations. The overwash east of Old Inlet was vegetated with shrubs and phragmites before Hurricane Sandy, and in the course of a growing season, this fast growing vegetation encroached on open habitat making it less suitable for plovers. We were only able to obtain GPS coordinates for pre-2013 nests for the Otis Pike Wilderness, however, piping plovers did nest in Smith Point and Cupsogue County Parks prior to 2013.



**Figure 17. Piping plover nest locations for 2012 (black; Otis Pike Wilderness only), 2013 (red), and 2014 (yellow) breeding seasons in a) the Otis Pike Wilderness, b) Smith Point County Park, and c) Cupsogue County Park. Background imagery is from June 2014. The three frames are not shown at equivalent scale.**

### *Nest survival*

The probability of a nest surviving to hatch was 45% for both nests that were exclosed and those that were not. Although nests had similar survival rates regardless of exclosure use, the most common cause of nest failure differed. For exclosed nests, abandonment was the main cause of failure, while most nests that failed without exclosures were predated. Nests we considered to be abandoned if eggs were present, but there was no evidence of adult plover activity at the nest bowl for at least one week and three consecutive visits. There was evidence that foxes dug into two exclosures in Smith Point County Park and ate the eggs. At one of these nests, we found adult plover feathers at the exclosure and suspect that a fox ate one of the banded adults as well, as we did not see this plover again after the nest predation. At another Smith Point nest, the male disappeared while the nest was hatching, and was never seen again. We suspect that this male was killed by foxes because we observed at least two foxes digging around the nest for three days prior to hatch. The foxes never succeeded in entering the exclosure, and the female successfully hatched and raised four chicks to fledging.

All of the nests that were abandoned were in the Otis Pike Wilderness, two east of the breach and four in Watch Hill, the off-site area that we monitored infrequently. In all cases, if both members of the pair were banded, at most one (the female in every case) was seen after the nest was abandoned, suggesting that adult mortality may have played a role in the abandonments. The spatial pattern of abandonments was also suggestive of a predator hunting in a localized area, however, we were never able to find evidence of adult predation at abandoned nests.

### *Chick survival*

At 1.5 chicks/pair, productivity at our study site exceeded the rate of 1.01 chicks per pair required for a stationary population for the New York-New Jersey piping plover recovery unit (Hecht and Melvin 2009). On average plovers produced one more chick per pair in 2014 than they did in 2013. Nest survival was similar in both years, so the increase in productivity was due to an increase in chick survival. Across the study area, chicks did better in 2014 than 2013, (fledging rates were 58% and 14%, respectively) however, survival rates varied by management unit. Survival was highest at Smith Point County Park, and lowest at Cupsogue County Park. The driving ban at Smith Point County Park greatly reduced human activity at plover nesting and brood-rearing sites in Smith Points County Park, allowing plover chicks to forage without interruption and eliminated the risk of chicks being run over. The brood that foraged exclusively on the ocean beach probably benefited the most from the driving ban. In 2013, all of the chicks from both broods that foraged on the ocean beach at the east end of Smith Point County Park (subsites Smith Point East and Smith Point West) died, but in 2014, the pair that nested in this area produced three fledglings. In 2014, we noted that a wrack line formed on portions of the ocean beach where we had not observed a wrackline in 2013. We suspect that the driving ban

prevented ORVs from burying and compressing wrack into tire tracks, allowing for the formation of a wrack line. Wrack is associated with a higher abundance of invertebrate prey than barren sand (Cohen et al. 2009) and we observed that chicks foraged more often in the wrack than they did on barren sand.

At Cupsogue, the amount of foraging habitat that was protected was inadequate for the number of plovers that nested there. Although a large amount of the island interior was protected by symbolic fencing, no moist shoreline habitat was protected on either the ocean or the bay. During weekends and holidays, times of high human activity, plover broods were prevented from accessing foraging habitat because people and dogs (often off-leash, 50% of dogs recorded during brood observations were off-leash) walked along the shorelines. Boaters also anchored along the bay shoreline (Figure 18). During busy times, we observed that chicks moved to the interior of the island and sat or stood in the same places for hours instead of foraging or moving around. We observed that plover broods began to respond to people when they were within about 150–200 m, and to dogs as soon as they were visible to us, and presumably also to the adult plovers. Thus, although a large portion of the island interior was protected, the fact that people and dogs had access to the entire perimeter, limited the actual area where broods could forage or rest without responding the humans to little or nothing. If, as we observed, plovers require a 200 m buffer distance from beachgoers to forage and behave normally, completely closing a portion of the Cupsogue breach fill area to people, including preventing boats from anchoring on the bay side, during weekends, holidays and other high use times is the only way to prevent harassment of plovers.



**Figure 18. Fourth of July weekend 2014 at Cupsogue County Park. At the time, two broods used this area. One was west (in front) of the observer and the other east (behind) the observer. The third brood attempted to forage at the eastern edge of this site, but boats, human activity and the narrowness of the beach prevented normal behavior and caused the brood to move constantly, come into conflict with the other broods, and eventually to be displaced up Dune Road.**

Because of limited access to foraging habitat and high human disturbance at Cupsogue, one plover brood was unable to establish a foraging territory. Within the course of one Saturday, we observed that this brood attempted to forage on the ocean beach, then, after people pushed the chicks away from ocean shoreline, they crossed the dunes and attempted to gain access to bay shoreline near the east end of the Cupsogue breach fill. The beach was very narrow at the east end of the breach fill, and people walking along the bay shoreline and using the ocean-to-bay paths pushed this brood west into another brood's territory. Piping plovers with chicks can be very territorial and will sometimes kill chicks from another pair if they intrude on their territory (Catlin 2009). These two territorial pairs fought almost continuously for 2.5 hours as we watched. Eventually we had to leave, and although they appeared exhausted, the pairs were still fighting because they were constrained from moving away from each other by people at the perimeter of the symbolic fencing. Eventually the brood that was unable to establish a territory moved up Dune Road and into the RV parking area where one chick disappeared and the other three were separated from their parents. All of these chicks, and a chick belonging to a pair that temporarily adopted two of the separated chicks died, potentially as a result of this disturbance. See Appendix A for detailed description of this incident.

#### *Prey abundance and foraging behavior*

Our arthropod abundance study revealed low numbers of insects on dune transects relative to bay intertidal transects. When piping plover chicks were constrained to foraging on the upper beach protected by symbolic fencing to avoid people, their access to food resources was extremely limited. Our results are consistent with other studies that have found that moist, intertidal habitats support more arthropod prey than upland areas (Loefering and Fraser 1995, Elias et al. 2000, Cohen et al. 2009). Although some chicks survived foraging on ocean beaches in 2014, invertebrate abundance was as low as Loefering and Fraser (1995) reported in zones where many chicks starved. Broods that foraged on the ocean beach ranged further than bay foraging broods, likely in an attempt to compensate for low prey abundance. In areas with high human activity, broods may have been constrained by humans or more likely to encounter humans, dogs, and other threats, if they did cover a large area. High levels of disturbance coupled with low food resources on ocean beaches likely worked together to cause the 100% mortality rate we saw on ocean beaches in 2013.

Chicks that foraged on ocean beaches, where prey abundance was low, spent less time foraging and pecked less frequently when they were foraging. Time spent foraging and peck rate further decreased if the chicks also experienced high levels of human activity. Loefering and Fraser (1995) found that 3-10 day-old ocean foraging chicks had a mean peck rate of 5.9 pecks per minute, higher than the peck rates for ocean foraging chicks in our study, yet these chicks weighed less and survived at a lower rate than bay foraging chicks.

We observed that chicks that experienced both low prey abundance and high levels of human activity took more than 30 days to fledge, while chicks in prey rich habitat with no human activity fledged at about 24 days of age. Food deprivation can also have long term consequences for plovers that survive. Catlin et al. (2014) found that chicks raised in food deprived conditions experience lower lifetime survival and reproductive success.

## CONCLUSIONS

Hurricane Sandy created habitat that would have likely been excellent for plovers and other shorebirds on Fire Island and Westhampton Island, namely flat wide beaches near bay side intertidal flats. However, the breaches were filled and some of the intertidal habitat was covered with sand piled high above the water table before the quality of the storm-created habitat could be fully assessed.

Piping plover distribution and abundance in the study area was similar to the distribution and abundance in 2013. Although the greatest population responses to new habitat typically occur in the second breeding season after habitat creation (Wilcox 1959, Cohen et al 2009, USACE, Omaha District, unpublished data), in our case, the population response may have been limited by the locally and regionally low plover productivity in 2013 (Anne Hecht, USFWS, personal communication). It remains to be seen whether the population will respond to the new habitat in 2015 or later in view of habitat modifications made in 2013, and additional modifications that are proposed for winter 2014/2015, including the installation of Burma Road through overwashes in Smith Point County Park. If the plover population does respond to the storm-created habitat, we may expect the plover density to approach about 0.5 – 1.0 pairs /ha of nesting habitat in various sites depending on the habitat quality (Cohen et al. 2009). After that, additional increases in abundance will require additional habitat.

Although reproductive output was much higher in 2014 compared to 2013, human disturbance and lack of access to foraging habitat continued to be a major factor in chick mortality, especially at Cupsogue County Park where only six out of 16 chicks fledged. The inability of one of the three broods that hatched near the breach fill area to establish a foraging territory because of lack of space when the beach was crowded with people on a weekend period in June during the study, likely resulted in the loss of this brood, and possibly also the loss of the remaining chick in another brood.

Our observations during this study suggest predation by red foxes is not a significant cause of chick mortality, and that plovers can achieve adequate nest and fledging success in proximity to foxes if there are broad beaches and moist foraging habitats available to them. However foxes might prey more heavily on plovers if the population increased and plover chicks became a more abundant food source.

## **MANAGEMENT RECOMMENDATIONS**

We recommend that land managers take the following measures to increase piping plover productivity on Fire Island and Westhampton Island.

- After chicks hatch, protect foraging habitat (bay side intertidal habitat, ephemeral pools, and other moist habitat) in addition to nesting habitat (especially at Cupsogue Beach County Park).
- Strictly enforce a no off-leash dog policy.
- At Cupsogue Beach County Park, foraging habitat should be re-created.
- At Cupsogue Beach County Park, confine boat landing to one spot, and protect the rest of the bay side intertidal habitat so that plovers may forage there.
- Decrease disturbance to chicks by using signs or other methods to make all park personnel driving and otherwise working on the beach aware that piping plover chicks are present.
- Increase the buffer around nests to help prevent beach visitors from destroying nests.
- Overall, we believe piping plover conservation would be enhanced by developing a culture of multiagency collaboration with the common goal of protecting this threatened species.

## **VIRGINIA TECH MONITORING RECOMMENDATIONS**

We propose that substrate invertebrate prey monitoring be added to monitoring activities in 2015. Continued daily monitoring of nests and chicks will help us to accurately evaluate causes of nest failure and chick mortality on Fire Island and Westhampton Island.

## **ACKNOWLEDGMENTS**

Funding for this study was provided by the US Army Corps of Engineers and US Fish and Wildlife Service, and conducted in cooperation with the National Park Service and Suffolk County Parks. We thank Steve Papa (FWS) and Robert Smith (USACE) 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 E. Brown, S. Biladeou, J. LeClaire, J. D. Monk, L. Deets, and T. Russell for their enthusiastic and tireless work during the 2014 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: Chick mortality incident report*

What follows is an incident report filed with the USFWS on June 24, 2014.

June 23, 2014

#### Cupsogue Plover Adoption Report

This morning at Cupsogue (June 23, 2014) we spotted the adults from brood 14 along the ocean just west of the first footpath in Cupsogue West. We only noticed one chick from brood 14 with both adults and the day before they had four chicks. We are able to tell which chicks and adults belong with each brood because all the birds are banded. We watched the one chick for just over a half an hour and did not observe any more chicks. Both parents stayed with the chick while we were observing him.

After observing the one chick from brood 14, we moved over to watch brood 9. While walking over we noticed the male from brood 9 on the beach and fly down to the intertidal zone. While scanning with spotting scopes we noticed two chicks foraging along with the female from brood 9. For the past week this pair has only had one chick. The two chicks were from brood 14. We observed both chicks and adults foraging by the water for over a half an hour.

After observing the chicks from brood 14 with the brood 9 parents, we decided to leave the area and look for the one chick that belongs in this brood. We found this chick just higher up on the beach from his parents disturbed by us. The male from this brood flew up from the intertidal zone to where the chick was and started to walk him back down to the intertidal zone where the two other chicks from brood 14 were foraging. We observed all three chicks for a little while foraging together along the beach. The two chicks from brood 14 were following the adults around and both chicks and adults seemed to accept each other.

We were surprised that two chicks from brood 14 had moved over to be with the adults from brood 9. We talked with the Suffolk County Plover Stewards and found out that on Sunday (June 22, 2014) the beach was really crowded with people. The males from brood 13 and brood 14 had been fighting over foraging territory on Sunday and moving their chicks around. The Plover Stewards observed the male from brood 14 try and move his chicks to the bayside but were pushed out by people. They moved to the ocean and were also pushed out. Near the end of their day, the Plover Stewards observed the birds along the closed road in Cupsogue East in between the dunes. Brood 14 was moving toward the RV campground along the road with four chicks and two adults. The Plover Stewards said this area was extremely crowded with people, cars, and RVs, so they tried to corral the birds down to the ocean

beach. They had observed one chick get separated (which could be the chick from brood 14 that we were unable to resight today).

Just south of the RV Campground is where brood 9 has been hanging out. Brood 14 must have gotten separated at one time Sunday afternoon allowing the adults from brood 9 to adopt two chicks from brood 14.

Update for June 24, 2014

We observed the pair from brood 9 scraping and singing and could not find their chick or the adopted chick. We observed the male from brood 14 flying throughout Cupsogue and could not find any of his chick. We searched throughout Cupsogue from 7:30 until 13:00, but did not any of the missing chicks or the female from brood 14.

### ***Appendix B: Negative impacts of research***

We observed three banded adult piping plovers and one chick limping on their flagged leg during the 2014 breeding season. All of the adults were limping after their nests were predated and were seen later with no sign of limping or injury. We recaptured one of the injured adults and the injured chick. The adult had slight abrasions under the flag, but no swelling. Out of an abundance of caution, we moved the flag from the injured leg to the other leg, and removed the orange band altogether. The limping chick had a small blister on the lower part of its leg that could have been caused by the flag rubbing against the leg when it was held in a raised position. The primary injury to the leg did not seem to be this blister, as the chick continued to limp and did not use the injured leg after the flag was removed. This chick continued to limp, did not grow at the same rate as its broodmates, and disappeared when its broodmates fledged.

On 5/23/2014, we fractured one egg from a clutch of four while floating it. We removed the egg from the nest and buried it. The birds returned and incubated the remaining three eggs immediately after the fractured egg was removed. We reported the incident to Anne Hecht and NPS immediately. On 5/27/15, Lindsay Ries (NPS) reported that the nest was being incubated, but at our subsequent visit on 5/29/2015, the nest appeared to be abandoned. The exclosure was encircled by fox tracks, and the adult plovers were not seen within the study area again. Both adults were marked.

*Appendix C: Ancillary data for the US Fish and Wildlife Service*

**Table 1. Inventory of specimens collected by Virginia Tech at Fire Island and Westhampton Island, May-August, 2014. Abandoned piping plover eggs were turned over to the Wildlife Rescue Center of the Hamptons for incubation and rehabilitation, however none of the eggs hatched.**

| Sample Type                   | # Samples | Location                               |
|-------------------------------|-----------|----------------------------------------|
| Piping plover eggs            | 15        | Wildlife Rescue Center of the Hamptons |
| Piping plover fecal samples   | 36        | Virginia Tech                          |
| Piping plover feather samples | 21        | Fish and Wildlife Service              |

**Table 2. Linear miles of shoreline for different habitats at Fire Island and Westhampton Island, May-August, 2013 and 2014. Habitats were measured in 2013.**

| Habitat Type                    | Ocean shoreline (meters) | Ocean shoreline (miles) |
|---------------------------------|--------------------------|-------------------------|
| Beach                           | 9917                     | 6.16                    |
| Breach-fill/stabilized overwash | 3214                     | 2.00                    |
| Natural overwash                | 2851                     | 1.77                    |
| Flood shoal length              | 310                      | 0.19                    |

**Table 3. Nest distance from the ocean intertidal zone at Fire Island and Westhampton Island, May-August, 2014. Distance was measured in ArcGIS using the highest spring tide line for the breeding season and nest locations collected in the field. The high tide line was collected by carrying a GPS while walking or driving an ATV along the highest wrack line formed during the breeding season in July 2014.**

| Nest ID | Habitat                           | Distance (m) |
|---------|-----------------------------------|--------------|
| 1       | Natural overwash                  | 70           |
| 2       | Filled breach/stabilized overwash | 39           |
| 3       | Natural overash                   | 32           |
| 4       | Filled breach/stabilized overwash | 37           |
| 5       | Filled breach/stabilized overwash | 76           |
| 6       | Beach                             | n/a          |
| 7       | Filled breach/stabilized overwash | 214          |
| 8       | Natural overwash                  | 39           |
| 9       | Beach                             | 41           |
| 10      | Beach                             | 75           |
| 11      | Beach                             | n/a          |
| 12      | Beach                             | n/a          |
| 13      | Filled breach/stabilized overwash | 87           |
| 14      | Filled breach/stabilized overwash | 91           |
| 15      | Blowout                           | n/a          |
| 16      | Beach                             | 54           |
| 17      | Filled breach/stabilized overwash | 69           |
| 18      | Filled breach/stabilized overwash | 110          |
| 19      | Dredge spoil                      | 139          |
| 20      | Filled breach/stabilized overwash | 167          |
| 21      | Filled breach/stabilized overwash | 22           |
| 22      | Natural overwash                  | 111          |
| 23      | Natural overwash                  | 73           |
| 24      | Beach                             | n/a          |
| 25      | Natural overwash                  | 40           |

**Table 4. A summary of unique pairings of piping plover on Fire Island and Westhampton Island during May–July in 2014. The number of unique pairs in each subsite should not be summed for the total number of pairs that used the study area, because some pairs may have nested in multiple management units. Subsite abbreviations are included in parenthesis for each management unit. See Table 1 for a detailed description of subsites.**

| Management Unit                                                       | Unique pairings |
|-----------------------------------------------------------------------|-----------------|
| Fire Island National Seashore – west of breach (OIW, OIWR)            | 1               |
| Fire Island National Seashore – east of breach (OIE, BRW, BRO)        | 4               |
| Smith Point County Park (BRE, PSO, PSE, NBW, NBE, SPTW, SPTE)         | 8               |
| Cupsogue Beach County Park (CSE, CSW, CMF, CSB)                       | 5               |
| Fire Island National Seashore – east of breach (off-site: Watch Hill) | 4               |

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