PIPING PLOVER FORAGING ECOLOGY ON PIKE'S BEACH, SOUTHAMPTON, NEW YORK

NATIONAL PARK SERVICE
GNRA JAMAICA BAY
RESOURCES LIBRARAY

SUSAN P. ELIAS-GERKEN, *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0321*

JAMES D. FRASER, *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0321*

Final Report to the U.S. Fish and Wildlife Service
Region 5, Weir Hill Road, Sudbury, MA 01776

November 22, 1994

B-1994-005

NK Info # 92877

INTRODUCTION

The Atlantic coast population of the piping plover (*Charadrius melodus*) was listed as federally threatened in 1986 (Federal Register 1985). The decline of plover numbers on the Atlantic coast is attributed to loss of habitat, predation, and disturbance from human recreation (e.g., Wilcox 1959, Goldin 1993a).

Studies of piping plover foraging ecology have highlighted the importance of several habitats to piping plover broods. Goldin (1993a) and Hoopes (1993) found that broods in New York and Massachusetts, respectively, exhibited preferences for wrack. Preference for wrack was attributed to greater abundances of arthropods (plover prey items) in wrack relative to habitats on ocean beaches such as the intertidal zone or berm (backshore). However, bay tidal flats and ephemeral pools were not available in Goldin's study area and on most of Hoopes' study area.

Other studies have shown that broods select bay tidal flats and ephemeral pools on beaches where theses habitats are available. On Assateague Island National Seashore, broods which hatched on ocean beaches used overwash paths to move to bay tidal flats to forage (Patterson 1988, Loegering 1992). Broods using bay tidal flats were exposed to greater arthropod abundances, had greater foraging rates, weighed more, and had greater survival rates than broods raised on ocean beaches in Virginia (Loegering 1992). In

Rhode Island, broods with access to mudflats (created by drawing down a coastal salt pond) had greater survival rates than broods without access to the mudflats (Goldin 1993b). On the Jones Beach barrier island, New York, broods with access to ephemeral pools used them much more than other habitats (Elias-Gerken 1994). When in ephemeral pools, broods were exposed to greater arthropod abundances and had greater foraging rates than broods using ocean beach habitats. Elias-Gerken (1994) also found that broods with access to bay tidal flats used them far more than other ocean beach habitats.

Broods on central barrier islands of Long Island, New York had access to bay tidal flats on beaches where overwash created vegetation-free paths from oceanside to bayside (Elias-Gerken 1994). They also had access to bay tidal flats on beaches with unjettied (or functionally unjettied) barrier island tips, where recurved sandspits extended into the bay. Bay tidal flats were found along the bay-facing margins of the sandspits.

Overwashes and recurved sandspits are examples of early successional-stage features of barrier islands important to piping plovers (others are, for example, ephemeral pools and open vegetation). Early successional-stage habitats are periodically created and maintained by storms where anthropogenic beach stabilization structures are absent, or where catastrophic storms have surmounted stabilizing structures (Leatherman and Allen 1985).

Beachfront stabilization (e.g., construction of jetties, groin fields, seawalls, and beach renourishment) has decreased the impacts of storms on shorelines (Leatherman and Allen 1985). This in turn appears to have decreased the availability and accessibility of early successional stage, storm-maintained habitats on Long Island, such as bay tidal flats, which are important to plovers (Elias-Gerken 1994).

Since the hurricane of 1938, storms on Long Island, New York, have been followed by human efforts to stabilize the shoreline (Leatherman and Allen 1985). Additionally, the amount of developed shoreline has increased dramatically (Schubel et al. 1991). Therefore, it is likely that there is less storm-maintained habitat available to plovers now than before 1939.

Pike's Beach, Long Island, provides an example of rapid colonization of storm-created and maintained habitats. From 1983-1992, records indicate that there were no breeding activities on this heavily developed beach (Downer and Leibelt 1990, Spellman pers. comm. 1992, Elias-Gerken 1994). The northeaster of 11-13 December, 1992, opened 2 inlets in the vicinity of Pike's Beach (Governor's Coastal Erosion Task Force 1994). This and subsequent winter storms overwashed the Pike's Beach area of the barrier island 16 times and destroyed 85 residences. One inlet closed naturally, but "Little Pike's Inlet" expanded to more than 900 m

wide and over 3.7 m deep. A recurved sandspit on the west side of the inlet grew and extended into bay waters, allowing extensive development of unvegetated bay intertidal flats in its shelter. Five pairs of plovers colonized the area in spring of 1993. The U.S. Army Corps of Engineers (ACOE) filled in Little Pike's Inlet, beginning in May, 1993 and ending in November, 1993.

The purpose of this study was to describe piping plover use of the Pike's Beach area in 1994. Specific objectives were to 1) estimate numbers of breeding pairs, 2) estimate nest survival, brood survival, and overall productivity, 3) to determine causes of nest and chick loss, when possible, 4) to estimate percentage of time broods spent in specific behaviors and habitats, percentage of time disturbed, and foraging rates, 5) estimate arthropod abundances in various habitats, 6) determine habitat preferences of broods, 7) compare productivity and foraging ecology between 1993 and 1994, and to 8) compare productivity between Pike's Beach and neighboring Westhampton Beach.

STUDY AREA

Location and Physical Description.--Pike's Beach is located approximately 3 km east of Moriches Inlet on the Westhampton barrier island off the south shore of Long Island, New York (Fig. 1). The nesting portion of the study area was approximately 2.8 km long, extending west from a point about 100 m west of groin 15 of

the Westhampton Beach groinfield (Fig. 1).

A surge of beachfront real estate development began in the 1950's (Schubel et al. 1991), which lead to a high density of houses on Pike's Beach and installation of the groin field to the east. Rapid erosion of Pike's Beach left many houses standing in the intertidal zone. By 1992, most homeowners on the beach were not permitted to occupy their homes due to dangerous structural damage and lack of utilities. Signs of storm damage included houses crumpled in the intertidal zone, uprooted chunks of tarmac, portions of septic systems, and household goods strewn across the beach. Telephone poles were knocked askew.

In 1992, there was little island interior vegetation, as most of the interior was covered by vestiges of a road, houses, yards, and driveways. Most of the bay shore was vegetated with *Phragmites sp.* and *Spartina spp.* Pedestrian and off-road vehicle (ORV) use was light because most homeowners did not have permission to live in the damaged houses, and because there were no utilities. Fox and cat tracks were seen leading into and out of abandoned houses.

The ACOE began to close Little Pike's Inlet in July 1993, and completed the work in November 1993. The bayside sandspit remained in place in 1994, and bay tidal flats persisted. American beach grass grew in along the margins of overwash areas, but the nesting area remained predominantly unvegetated.

History of Physiographic Changes and Nesting.--The authors of this report know of no records that refer specifically to piping plover breeding at Pike's Beach before 1983. However, Wilcox's (1959) study area included what is now known as Pike's Beach. According to Wilcox, nesting from Moriches to Shinnecock Inlets reached a peak from 1940-1942, then gradually declined as human activities stabilized and altered the coastline of the barrier island.

METHODS

Distribution of Nests and Breeding Biology

We searched for nests every other day, beginning in May and ending in early July. When we first located nests, we observed them every 2 to 3 days ($\bar{x}$=2.5 days) from a distant location to determine hatch dates and causes of loss, if any. When logistically feasible, The Nature Conservancy (TNC) of Long Island installed predator exclosures around nests to protect them from red fox (*Vulpes*) and crow (*Corvus spp.*) predation.

We considered observed nest survival to be the number of nests that hatched 1 or more eggs/the number of nests laid. We also calculated nest success using techniques described in Mayfield (1975) and Heisey and Fuller (1985). We considered observed egg success to be the number of eggs hatched/the number laid.

After the eggs of known nests hatched, each brood was located every 2 to 3 days ($\bar{x}$=2.5 days) for a period of ≥25 days to estimate rates of survival to fledging, and to determine habitat use and foraging behavior. We observed broods from a distant or concealed position so that brood movements were unaffected. We observed broods through 25 days of age, and considered brood and chick survival to be the number of broods (chicks) fledged/the number of broods (chicks) hatched).

If chicks were missing from a brood, we searched the area for at least one hour. If the chicks failed to reappear over the course of the pre-fledged period, they were presumed dead.

Habitat Use, Activity Budgets, and Foraging Rates

When we located a brood, we commenced behavioral observations on a focal chick (Altman 1974, Lehner 1979, Tyler 1979). We used an instantaneous sampling method to estimate time spent in habitats and behaviors (Altman 1974, Lehner 1979, Tyler 1979). Once every 10 seconds for the 5-minute period, we recorded foraging habitat (Table 1), behavior (Table 2), and source of disturbance (if any) for the focal chick. We calculated the percentage of time that broods spent in various foraging habitats, the percentage of time that broods spent in various behaviors (including disturbed behavior), and the proportion of disturbance from various sources.

We used a continuous sampling method to estimate foraging rates (Tyler 1979, Tacha et al. 1985). During the same 5-minute observation in which we made instantaneous observations, we continuously recorded foraging behavior to determine foraging rate. We calculated foraging rate by dividing the number of foraging attempts by the observation time, and expressed the results in attempts per minute. Foraging rates and prey density have been considered good indicators of prey availability for other shorebirds (e.g., Goss-Custard 1977, Myers et al. 1980, Pienkowski

1983a 1983b 1983c, Maron and Myers 1985, but see Goss-Custard 1970, Baker and Baker 1973, Pienkowski 1983b, Wilson 1990).

The foraging behavior data were non-normal, even after log and arcsin transformations. Hence, we used 1-tailed Wilcoxon rank-sum tests on the original, untransformed data to test the hypotheses that foraging rates were greater in bay intertidal zone and bay fresh wrack than in ocean intertidal zone and fresh wrack.

Arthropod Abundance Indices

We collected surface arthropod samples from transects through 3 randomly selected brood-rearing territories plus 3 randomly selected points. Sampling lasted for 7 consecutive weeks beginning June 15th and ending August 10th. Whenever possible, we sampled all territories on the same day to reduce temporal variability, but during 2 weeks logistic constraints necessitated sampling over 2 days. We sampled in the first half of the day, except on June 30 when sampling was in the early afternoon due to logistic constraints. The sampling period was 3 hours, chosen on the basis of preliminary sampling. A shorter period would have risked capturing insufficient numbers of arthropods for analysis in the habitats with few arthropods. A longer period would have been logistically infeasible.

We coated paint stirrers (except for the handles) with

Tanglefoot Insect Trap Coating (The Tanglefoot Company). We set them out in pairs, with one stirrer stuck vertically into the sand and the other laid horizontally on the ground about 10 cm away. The uncoated handle of the vertical stirrer was sunk completely into the sand. The area exposed was 64.5 cm^2 (21.5 cm x 3 cm) for the horizontal stick and 129 cm^2 for the vertical stick (Loegering 1992). We set out one pair in each beach habitat along 6 transects perpendicular to the long axis of the beach. The habitats sampled were ocean intertidal zone, ocean fresh wrack, ocean berm, ocean old wrack, bay open vegetation, bay fresh wrack, and bay intertidal zone.

We treated each set of sticky sticks as a sample. The arthropod data were non-normal, even after log and arcsin transformations. Hence, we used 1-tailed Wilcoxon rank-sum tests on the original, untransformed data to test the hypothesis that relative arthropod abundances were greater in the combined habitats of bay intertidal zone and bay fresh wrack than in ocean intertidal zone and ocean fresh wrack.

Habitat Availability

We considered the westernmost nest to mark the western boundary of the study area, and the easternmost nest to mark the eastern boundary. The study area was approximately 2.8 km long. We established 6 evenly-spaced transects along the length of the

study area, each perpendicular to the long axis of the island. The position of the first transect (in meters) was randomly selected relative to the western boundary of the site. The other 5 transects were placed at 500 m intervals to the east.

We paced up the beach along the transects perpendicular to the long axis of the beach beginning at water's edge on the ocean side and ending at dense vegetation or water's edge on the bay side (Table 3). Along each transect, we recorded the number of paces in the ocean and bay habitats of intertidal zone, fresh wrack, berm, old wrack, and open vegetation, and recorded the total number of paces. We considered the boundary between the ocean and bay beaches to be the crest of the berm on ACOE-renourished areas, and the natural peak of the berm otherwise. Weekly measurements began on May 25 and ended on August 10, a total of 12 weeks.

For calculating average width of habitats, we averaged the measurements over all weeks for each of the 6 transects. Using the transect as the sample unit, we then derived average widths for the entire beach. We converted paces to meters. To estimate relative percent availability of habitats for each transect, we divided average individual habitat widths by the average total width for each transect. Using the transect as the sample unit, we then derived average relative percent availability of habitats for the entire beach. For the use-availability analysis, we used 2-tailed 2-sample Wilcoxon rank-sum tests to test for differences in percent

use versus percent availability for each habitat, and for all ocean beach habitats combined and all bay beach habitats combined.

Predator Abundance Indices

We adapted a "point intercept-step" technique from Hays et al. (1981) to develop estimates for percent of the substrate covered by cat and fox trails on the berm and in the open vegetation. During our pacing along transects to determine relative habitat availabilities, we used a mechanical hand-held counter to determine the number of paces in habitats. Each time the toe of the field technician's shoe intersected a cat or fox trail, she recorded 1 "hit" and the type of trail. Percent trail coverage was calculated by dividing the total hits by the total number of paces and multiplying by 100.

Weekly measurements along 6 transects began on May 25 and ended on August 10, a total of 12 weeks. We developed the indices for Pike's Beach, and also for a 500 m stretch along Westhampton Beach (between groins 15 and 14), so comparisons between beaches would be possible.

RESULTS

Breeding Biology

Reproductive Success.--Thirteen pairs of piping plovers initiated at least 1 nest on Pike's Beach (Fig. 2), while a 14th pair was seen tending a chick (nest location undetermined, Table 4, Appendix A). Thus, fourteen pairs of plovers used Pike's Beach for nesting and/or brood-rearing in 1994, up from 5 pairs in 1993. Nesting density on Pike's Beach in 1994 was 6.9 pairs/km, up from 4.5 pairs/km in 1993 (Table 5).

The total number of known nest attempts was 17 up from 5 known attempts in 1993. There were 14 first and 3 second nest attempts, of which 11 hatched. Observed nest success was 64.6%, while Mayfield (1985) nest survival was 43.5% (Table 4). Nest success was above average compared to other studies on the Atlantic coast (Table 7). However, use of predator exclosures was not consistent among studies and confounds comparisons of nest survival.

Sixty eggs were laid, and hatching success was 58.3%, similar to 55.0% success in 1993 (Table 4). Egg hatching success was about average compared to other Atlantic coast studies (Table 5). Thirty-five chicks hatched and 14 chicks fledged, up from 11 hatched and 5 fledged in 1993 (Table 4). Chick survival was 40.0%, similar to 45.4% in 1993, and about average compared to other

studies (Table 6). Productivity was 1.00 chick fledged per pair in both years, below the 1993 Atlantic coast average of 1.46 and the 1987-1993 average of 1.27 chicks fledged per pair (U.S. Fish and Wildlife Service 1993).

Causes of Nest and Egg Loss.--Causes of nest loss were known or strongly suspected (Table 8). One pair of plovers abandoned their nest 13 days after a predator exclosure was constructed around it. Abandonment was attributed to fox harassment; fox tracks encircled the exclosure for several days before abandonment. We believe this pair renested, and that its second, unenclosed nest was depredated by foxes. Fox predation was strongly suspected as the cause of loss of 3 nests; fox tracks were abundant around the nest scrapes. Fox and gull predation were definitively ascribed to loss of 2 nests. All egg loss was associated with the nest loss described above, with the exception of 2 eggs left in the scrape after the rest of the clutches hatched and 3 eggs missing at the time of hatch (Table 8). No nests were lost to storm tides.

Chick Mortality.--Twenty-one chicks died (Table 4). Sixty-seven percent of mortality occurred in the first 5 days of life, and 100% occurred in the first 15 days of life (Figure 3). Causes of chick loss were unknown (Table 4).

Predator Exclosures.--The proportion of nests surviving to hatch was not statistically greater for those with predator

exclosures (80.0%) than for those without (58.3%, 1-tailed Z-test for a difference in proportions, Z=-0.85177, P=0.35, Table 9), but sample sizes were small (n=5, n=12, respectively), reducing the power of the tests. Similarly, Mayfield nest survival rates did not differ statistically for nests with predator exclosures (53.0%) versus those without (38.4%, 1-tailed Z-test for a difference in interval survival, Z=0.58602, P=0.36). All nests predated were not protected by predator exclosures (Table 10). However, the nest abandoned due to fox harassment did have a predator exclosure.

Disturbance and Nest and Brood Survival.--There was no evidence that nest survival was a function of disturbance from pedestrians, ORV's, or dogs based on instantaneous counts or track counts of these potential disturbance sources. The average number of pedestrians within 100 m of the nest did not differ for nests that survived ($\bar{x}$=0.35) or were lost ($\bar{x}$=0.12, 1-tailed Wilcoxon rank-sum test, Z=-0.7988, P=0.21, Table 11). Likewise, the number of pedestrian tracks within 30 m of the nest did not differ for nests that survived ($\bar{x}$=1.7) or were lost ($\bar{x}$=2.2, 1-tailed Wilcoxon rank-sum test, Z=-0.1066, P=0.46). No ORV's or dogs were seen within 100 m of nests.

The proportion of broods surviving to hatch was not less for those broods disturbed at least once by any source (80.0%) than for those not disturbed (60.0%, 1-tailed Z-test for a difference in proportions, Z=-0.6901, P=0.37, Table 12).

Fox trails covered 1.7% of the berm on Pike's Beach, and 0.1% of the berm on Westhampton (Table 13). Cat trails covered 0.5% and 0.4% of the berm on Pike's Beach and Westhampton Beach, respectively. Quantity of open vegetation on Pike's Beach was negligible, hence there were no open vegetation trail indices. The fox trails index was 0% in Westhampton Beach open vegetation, but cat trails covered 6.8% of sand substrate within open vegetation (Table 13).

Foraging Ecology

Time Budgets.--Broods spent the majority of their time foraging (77%), as in 1993 (79%, Table 14). They spent 11%, 5%, 4%, and 3% of their time resting, disturbed, alert, and in locomotion, respectively. Distribution of time was similar in 1993. Broods were disturbed 2% of the time by humans, 1% of the time by avian species other than gulls (usually terns), and less than 1% of the time by territorial encounters, gulls, and other sources. Distribution of disturbance by source was similar in 1993 (Table 15).

Habitat Use.--Broods spent more than a third of their time in the bay intertidal zone (38%), 20% of their time in bay fresh wrack, 21% of their time in bay berm, and 1%-8% of their time in the remaining habitats (Table 16). In 1993, they spent more time on the berm and less time in bay tidal flats than in 1994. Reasons

for the drop in use of tidal flats are unknown. However, use of bay versus ocean habitats was consistent: in both years broods spent 87% of their time in all bay habitats combined, and 13% of their time in all ocean habitats combined (Table 16).

Time Budgets within Habitats.--Broods spent most of their time (83%) foraging when they were in bay old wrack, 63% when in the bay berm, 82% when in bay fresh wrack, and 89% when in the bay intertidal zone (Table 17). The pattern was similar in 1993. Estimates of time spent in foraging behaviors within the remaining habitats are varied, and are less reliable as few broods made use of them, making samples sizes small.

Foraging Rates.--Foraging rates were greatest in bay tidal flats (8 attempts per minute, Table 18). Foraging rates were 5 in both bay fresh wrack and bay old wrack, and 4 in the ocean intertidal zone. Foraging rates were low in ocean fresh wrack, ocean berm, ocean old wrack, bay open vegetation, and bay berm (0-3 attempts per minute).

Foraging rates in bay intertidal zone and fresh wrack combined were greater than foraging rates in ocean intertidal zone and ocean fresh wrack combined (6 vs. 1, 1-tailed Wilcoxon rank-sum test for differences in the mean, Z=-2.0035, P=0.02, Table 18). 1993 foraging rates in these combined habitats were similar to those of 1994, and it appeared that bay rates were greater than ocean rates,

though small sample size (number of broods) in the ocean side precluded statistical testing.

Arthropod Composition.--Most arthropods caught were insects (78%), and most insects were dipterans (73%, Table 19). Twenty-one percent of arthropods caught were amphipods. Amphipods were found almost exclusively in the ocean and bay intertidal zones and fresh wrack.

Relative Arthropod Abundances.--Relative arthropod abundances were greatest in bay fresh wrack (20) and bay intertidal zone (18, Table 20). They were intermediate in ocean fresh wrack (11). Relative abundances ranged from 3 to 7 in the remaining habitats sampled.

Relative arthropod abundances in bay intertidal zone and fresh wrack combined were greater (19) than those in ocean intertidal zone and ocean fresh wrack combined (9, 1-tailed Wilcoxon rank-sum test for differences in the mean, $Z=4.5137$, $P<0.01$, Table 20). In 1993 as well, relative arthropod abundances in bay tidal flats and fresh wrack combined were greater (19) than those in ocean intertidal zone and ocean fresh wrack combined (10, 1-tailed Wilcoxon rank-sum test for differences in the mean, $Z=2.0067$, $P=0.02$, Table 20).

Habitat Availability.--The widest habitat on Pike's Beach was

the berm (122.9 m), and the narrowest habitats were the ocean and bay wracklines (0.1-0.7 m, Table 21). Bay and ocean intertidal zone widths were intermediate (6.45 m, 26.6 m, respectively).

Use-Availability Analysis.--Broods' use of the bay side of Pike's Beach was greater than expected, and their use of the ocean side was less than expected (86.6 vs. 44.4, Z=-2.6192, P=0.0088; 13.3 vs. 55.6, Z=2.6630, P=0.0077, respectively, Table 22). Broods' use of the bay tidal flats, bay fresh wrack, and ocean fresh wrack was greater than expected (38.4 vs. 3.5, Z=-2.7318, P=0.0063; 20.2 vs. 0.06, Z=-2.8075, P=0.0050; and 1.2 vs. 0.2, Z=2.0275, P=0.0426, respectively). Broods' use of the ocean intertidal zone and ocean berm were less than expected (2.1 vs. 18.4, Z=2.9543, P=0.0031; 36.5 vs. 2.4, Z=3.3402, P=0.0008, respectively). There was no statistical evidence that they spent proportionally more or less time in ocean old wrack, bay berm, and bay open vegetation compared to those habitats' availability (7.6 vs. 0.5, Z=1.3021, P=0.1929; 21.2 vs. 36.5, Z=1.7910, P=0.0733; and 3.5 vs. 4.3, Z=0.8572, P=0.3913, respectively, Table 22).

DISCUSSION

Short Term Impacts

Persistence of Bay Tidal Flat.--In the short-term, over the course of one breeding season, the inlet-filling project did not discourage plovers from breeding on Pike's Beach in 1994. After the inlet was closed, bay tidal flats persisted. The bayside sandspit associated with the former inlet remained in place, the bay tidal flats persisted, and the bayside shoreline did not revegetate from 1993 through the 1994 breeding season.

Foraging Ecology.--The filled inlet and renourished beach did not appear to alter the general foraging ecology of broods from 1993 to 1994. Based on 1) foraging rates, 2) prey abundances, and 3) habitat selection (use-availability analyses), Pike's Beach was a high-quality brood-rearing beach in 1994. Foraging rates and arthropod abundances in bay intertidal zone and fresh wrack were greater than in the analogous ocean habitats. Broods selected (used more than expected given availability) bay habitats, especially tidal flats and bay fresh wrack, over ocean habitats. Note that although the use-availability analysis indicated that broods also selected ocean fresh wrack, actual percentage of time in this habitat was only 1.2% of the total time budget. Broods spent most of their time in bay habitats in both years.

Studies in Virginia, Rhode Island, Massachusetts, and New York have indicated that bay tidal flats attract plovers. Broods with access to both ocean beach habitats and bay tidal flats used the flats more than other available habitats (Patterson 1988, Loegering 1992, Goldin 1993b, Hoopes 1993, Elias-Gerken 1994). On Pike's Beach in 1994, broods preferred bay mudflats and wrack over any other habitats available to them.

Nesting Density.--Fourteen pairs of plovers used the area for breeding in 1994 compared to 5 in 1993. Nests were distributed in such a way that all broods had access to bay tidal flats. Nesting density increased from 4.5 pairs/km in 1993 to 6.9 pairs/km in 1994. The latter density was the highest observed in the area over a 3 year period (Table 5), and was much greater than densities observed at adjacent Westhampton Beach from 1992 through 1994 (2.5 to 3.0 pairs/km). The only other central Long Island nesting site exhibiting similar densities was Jones West, found at the western end of the Jones Beach barrier island (Elias-Gerken 1994). At Jones West, nests aggregated around ephemeral pools, a foraging habitat superior to ocean beach habitats (Elias-Gerken 1994).

It is possible that filling the breach increased the amount of substrate available for nesting at Pike's Beach, hence the carrying capacity of the area. However, this would assume that Pike's Beach was at carrying capacity in 1993 at 5 pairs, which cannot be substantiated. Although the area was quickly colonized in 1993

after the breach, it is possible that it may require more than one season for an area to "fill up" with plovers. Regardless of whether filling the breach increased the amount of nesting substrate, the gain or loss of bay tidal flat, the key foraging habitat, cannot be quantified.

Nest/Chick Survival and Productivity.--Productivity on Pike's Beach was the same in 1994 and 1993 (1.00 chicks fledged per pair), but a greater number of chicks fledged in 1994 (14) than in 1993 (5) because there were more pairs in 1994. Nest survival declined from 70% to 43%, but still compared favorably with nest survival of 13% to 20% on adjacent Westhampton Beach in 1992 and 1993 (Elias-Gerken 1994). Chick survival was approximately the same between years (45% to 40%), and greater than 1992 Westhampton chick survival (27%), but less than 1993 Westhampton chick survival (86%). Still, abysmal nest survival on Westhampton Beach in both years drove productivity down to 0.33 and 0.62 chicks fledged per pair in 1992 and 1993, respectively. Thus, Pike's Beach productivity was superior to that of Westhampton Beach.

Confounding Effects of Predation.--Predation may have confounded the effects of presence of superior foraging habitat on productivity. Though cause of chick loss could not be determined in any cases, red foxes were the primary nest predator. Thus it would not be surprising if foxes also were the primary chick predator.

H. Rollo, the field technician on this project, observed many fox tracks on the berm and leading into and out of abandoned houses. She also observed a fox running across the berm in the middle of the day. Predator exclosures seemed to be effective as a deterrent to fox predation, although the nest abandonment due to fox harassment was of concern. Elimination of red foxes from the area would remove the problem of fox harassment of nests with exclosures. At the same time it might allow a test of the hypothesis that foxes were a primary chick predator in 1994 (though cat predation on chicks might increase with elimination of foxes).

Predator trail indices indicated that cats used open vegetation as cover while hunting on Westhampton Beach, to the likely detriment of piping plover and other shorebird chicks on Westhampton. However, open vegetation was practically non-existent around much of the Pike's Beach nesting and brood foraging areas. Cats are associated with areas of high housing density such as Westhampton Beach (Spellman, pers. comm. 1992; pers. obs. 1992-1994) and communities on Fire Island (Ebert, pers. comm. 1992; pers. obs. 1992-1993) and on Breezy Point (Goldin 1993a). At the time of the study, housing density was very low in the immediate vicinity of Pike's Beach brood foraging areas.

Long Term Impacts

Historic Barrier Island Configuration and Plover Numbers.--

Before 1939, lack of anthropogenic intervention allowed dynamic geological processes to periodically overwash barrier islands, and freely open and close inlets along the Long Island, New York barrier islands (Leatherman and Allen 1985). Periodic overwashes and breaches create and/or maintain early successional stage beach features such as open vegetation (Elias-Gerken 1994), recurved sandspits, and unvegetated overwash fans and bay tidal flat. These features are either preferred foraging habitats for piping plover broods or support the habitats broods prefer.

Wilcox (1959) found that from Moriches Inlet to Shinnecock Inlet, plovers colonized beaches with storm-created, early successional stage habitats, and failed to return when the beaches progressed to later successional stages (e.g., high, densely vegetated dunes). For example, only 3-4 pairs of plovers nested along a 17-mile stretch of beachfront from Moriches Inlet to Shinnecock Inlet when Wilcox began banding in 1929. But after catastrophic storms from 1931 to 1938 breached the barrier island and levelled dunes, the number of pairs peaked in 1941 at 64 pairs. This number gradually declined after humans renourished beaches (built dunes back up to their original height) and planted the dunes with beach grass. Wilcox speculated that the plovers left the area for more suitable habitat elsewhere on Long Island. This pattern can be expected to recur if Pike's Beach is redeveloped.

Pike's Beach Scenarios.--There are four possible scenarios

relative to the quality of Pike's Beach as a piping plover breeding area. The first scenario describes Pike's Beach had the breach not been filled, whereas the following 3 scenarios describe possible future events.

Scenario One.--In the first scenario, Pike's Inlet would not have been filled. The recurved spit and unvegetated bay tidal flats would have persisted for some unspecified length of time (e.g., Leatherman and Allen 1985). The density of nesting plovers and productivity would likely have remained greater than that observed on Westhampton Beach for a number of years, at least until the area naturally, gradually revegetated, and/or the breach filled in naturally.

Scenario Two.--The second scenario will ensue if the beach remains undeveloped and doesn't breach again, but is periodically overwashed. In this case, recolonizing vegetation will be periodically buried. Depending on frequency and magnitude of overwash, bay tidal flats would likely persist. Density and productivity will be greater than on Westhampton Beach.

Scenario Three.--The third scenario will ensue if the beach remains undeveloped, doesn't re-breach, and is not overwashed. Emergent vegetation will recolonize the edge of the bay shore, and upland vegetation will recolonize the beach toward the barrier nucleus (Leatherman and Allen 1985). Density of nesting will

decrease, probably approaching densities of neighboring Westhampton Beach. Brood foraging opportunities will succeed from very good to fair or even poor for plovers as availability of bay tidal flats declines to zero. Productivity will decline. Loegering (1992) observed a decline of both numbers of nesting pairs of piping plovers and productivity on the northern end of Assateague Island National Seashore, Maryland, when lack of overwash events allowed woody island interior vegetation to close off overwash fans and prevent movement of broods from ocean to bay (Loegering 1992).

Scenario Four.--The final scenario would ensue if Pike's Beach is redeveloped to resemble Westhampton Beach to the east, in terms of dune height, berm width, and density of housing. A dune road and artificial dunes would serve as barriers to chicks hatched on the ocean side attempting to reach the bay side. The road itself will destroy habitat where plovers nested in 1993 and 1994, and increase the potential of ORV's crushing chicks. Construction of houses will also destroy nesting habitat. Docks on the bayside will disturb tidal flats. These actions will lead to regrowth of dense vegetation on the bay shoreline and berm. Although the vestigial sandspit will be protected as a shorebird nesting sanctuary and will probably support bay tidal flats, its elevation may be insufficient for avoiding inundation of nests during above average high tides. No plovers used the spit for nesting in 1993 and 1994.

Though foxes will be displaced, re-development will bring in crows and cats, important nest and chick predators of shorebird nests and chicks on Westhampton Beach. Nest losses to crows could be controlled through a predator exclosure program, but current plans contain no proposals for cat control. In short, anthropogenic stabilization and development will lead to a decrease foraging and nesting habitats, an increase in human disturbance, and an increase in crows and cats. Density of nesting and productivity will decline to levels observed on Westhampton Beach, which has consistently exhibited extremely low levels of productivity.

CONCLUSIONS

Filling Little Pike's Inlet produced no discernable, short-term, negative impacts on piping plover breeding biology and foraging ecology on Pike's Beach based on a comparison of the breeding biology and foraging ecology data gathered in 1993 and 1994. Pike's Beach was a good brood-rearing beach based on 1) the presence and accessibility of bay tidal flats, 2) the aggregation of piping plover nests around the mudflats, 3) foraging rates and 4) arthropod abundances in bay tidal flats and fresh wrack versus the analogous ocean habitats, and 5) broods' selection of bay habitats, especially tidal flats and fresh wrack, over ocean habitats.

However, patterns of beach succession and piping plover habitat selection suggest that filling the breach may hasten a decline in plover habitat suitability. Breach-filling alters sandspit growth and is likely to speed ecological succession to later barrier island seres not useful to plovers (interior woody vegetation, for example). Moreover, in a natural system, breach closures in one area are likely to be balanced with breaches and/or overwashes elsewhere. Anthropogenic breach-filling is rarely, if ever, balanced by allowing breaches and overwashes to persist in nearby areas. This in turn would prevent renewal of the early-successional stage, storm-created habitats to which piping plovers are adapted.

ACKNOWLEDGEMENTS

We give special thanks to Anne Hecht of the U.S. Fish and Wildlife Service for suggesting the study, and providing time, information, and valuable input. We thank Bob Murray for comments on the first draft. We thank the U.S. Fish and Wildlife Service for funding for the project.

We also are grateful for assistance from Cathy Brittingham and all other staff of the Long Island Chapters of The Nature Conservancy. TNC provided field assistance, equipment, office services, and personnel, without which this project would not have been possible. We thank also TNC stewards for constructing symbolic fencing and predator exclosures.

We give warm thanks to Heather Rollo, the nuts-and-bolts person of the field operation. We acknowledge the many long hours she spent in the field searching for plovers, nests, and chicks, the time she spent peering through binoculars and spotting scopes observing chick behavior, and the time she spent sampling prey, transcribing data, and sweating all of the other details on the project.

LITERATURE CITED

Altman, J. 1974. Observational study of behavior sampling methods. Behaviour. 49:227-267.

Bottitta, G. E., W. Hulslander, Jr., J. Kumer, and L. Herbeck. 1993. Management and Monitoring of the piping plover at Assateague Island national Seashore, MD, 1993 Summary Report. Unpubl. rep. to the National Park Service.

Cairns, W. E. 1982. Biology and behavior of breeding piping plovers. Wilson Bull. 94(4):532-545.

Coutu, S. D., J. D. Fraser, J. L. McConnaughey, and J. P. Loegering. 1990. Piping plover distribution and reproductive success on Cape Hatteras National Seashore. Unpubl. rep. submitted to the National Park Service. 67pp.

Downer, R. H., and C. E. Leibelt. 1990. 1989 Long Island colonial waterbird and piping plover survey. Research Report of the New York State Department of Environmental Conservation, Stony Brook, N.Y. 200 pp.

Ebert, J. 1992. Personal Communication. Fire Island National Seashore Headquarters, Office of Natural Resources Management. Patchogue, N.Y.

_____. 1994. Personal Communication. Fire Island National Seashore Headquarters, Office of Natural Resources Management. Patchogue, N.Y.

Elias-Gerken, S. P. 1994. Piping plover habitat suitability on central Long Island, New York barrier islands. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 248 pp.

Eddings, K. J., and S. M. Melvin. 1992. Biology and conservation of piping plovers at Breezy Point, New York, 1991. Unpubl. rep. submitted to the U.S. Fish and Wildlife Service.

Federal Register. 1985. Determination of endangered and threatened piping plover. 50:50726-50734.

Goldin, M. R., C. R. Griffin, and S. M. Melvin. 1989. Reproductive and foraging ecology, human disturbance, and management of piping plovers at Breezy Point, Gateway National Recreation Area, New York. Progress Report, University of Massachusetts, Amherst. 58pp.

_____. 1993a. Effects of human disturbance and off-road vehicles on piping plover reproductive success and behavior at Breezy

Point, Gateway National Recreation Area, New York. M.S. Thesis, Univ. of Massachusetts, Amherst. 128 pp.

_____. 1993b. Piping plover (*Charadrius melodus*) management, reproductive ecology, and chick behavior at Goosewing and Briggs Beaches, Little Compton, Rhode Island, 1993. Unpubl. rep. to The Nature Conservancy, Providence, RI.

Goss-Custard, J. D. 1970. The responses of redshank (*Tringa totanus* (L.)) to spatial variations in the density of their prey. J. Anim. Ecol. 39:91-113.

_____. 1977. Responses of redshank, *Tringa totanus*, to the absolute and relative densities of two prey species. J. Anim. Ecol. 46:867-874.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49(3): 668-674.

Howard, J. M., R. J. Safran, and S. M. Melvin. 1993. Biology and conservation of piping plovers at Breezy Point, New York, 1992 Progress Report. Unpubl. rep. to the U.S. Fish and Wildlife Service.

Leatherman, S. P., and J. R. Allen, eds. 1985. Geomorphic analysis, Fire Island Inlet to Montauk Point, Long Island, New York. Reformulation study submitted to the U.S. Army Corps of Engineers, New York District.

Lehner, P. N. 1979. Handbook of ethological methods. Garland STPM Press, N.Y. 403pp.

Loegering, J. P. 1992. piping plover breeding biology, foraging ecology, and behavior on Assateague Island National Seashore, Maryland. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 248 pp.

MacIvor, L. H. 1990. Population dynamics, breeding ecology, and management of piping plovers on outer Cape Cod, Massachusetts. M.S. Thesis, University of Massachusetts, Amherst. 100 pp.

Maron, J. L., and J. P. Myers. 1985. Seasonal changes in feeding success, activity patterns, and weights of non-breeding sanderlings (*Calidris alba*). Auk 102:580-586.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87(4):456-466.

McConnaughey, J. L., and J. D. Fraser, S. D. Coutu., and J. P. Loegering. 1990. piping plover distribution and reproductive

success on Cape Lookout National Seashore. Unpubl. rep. submitted to the National Park Service. 67pp.

Murray, R. G. 1994. Personal Communication. U.S. Fish and Wildlife Service, Long Island Field Office. Islip, N.Y.

Myers, J. P., S. L. Williams, and F. A. Pitelka. 1980 An experimental analysis of prey availability for sanderlings (Aves:Scolopacidae) feeding on sandy beach crustaceans. Can. J. Zool. 58:1564-1574.

Patterson, M. E. 1988. Piping plover breeding biology and reproductive success on Assateague Island. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 131 pp.

Pienkowski, M. W. 1983a. Changes in the foraging pattern of plovers in relation to environmental factors. Anim. Behav. 31:244-264.

_____. 1983b. Development of feeding and foraging behavior in young ringed plovers, *Charadrius hiaticula* in Greenland and Britain. Dansk Orn. Foren. Tidsskr. 77:133-147.

_____. 1983c. Surface activity of some intertidal invertebrates in relation to temperature and the foraging behavior of their shorebird predators. Mar. Ecol. Prog. Ser. 11:141-150.

Schubel, J. R., T. M. Bell, and H. H. Carter, eds. 1991. The Great South Bay. Marine Sciences Research Center, State University of New York, Stony Brook, N.Y. State University of New York Press. 107 pp.

Spellman, C. 1992. Personal communication. December 1992 meeting of the Long Island Colonial Waterbird Ass'n., Quogue, N.Y.

Tacha, T. C., P. A. Vohs, and G. C. Iverson. 1985. A comparison of interval and continuous sampling methods for behavioral observations. J. Field Ornithol. 56:258-264. 143 pp.

Tyler, S. 1979. Time-sampling: a matter of convention. Anim. Behav. 27:801-810.

U.S. Fish and Wildlife Service. 1993. 1993 Status Update, U.S. Atlantic coast piping plover. Sudbury, MA.

U.S. Fish and Wildlife Service. 1994. Fish and Wildlife Coordination Act Report. Section 2(B). Atlantic Coast of Long Island, Fire Island Inlet to Shinnecock inlet interim storm damage reduction project. Ecological Services, Region 5, Long Island Field Office, Islip, N.Y.

Wilson, W. H. Jr. 1990. Relationship between prey abundance and

foraging site selection by semipalmated sandpipers on a bay of Fundy mudflat. J. Field Ornithol. 61:9-19.

Wilcox, L. 1959. A twenty year banding study of the piping plover. Auk 76:129-152.

Table 1. Terms used to describe piping plover nesting, foraging, and associated habitats on ocean and bay beaches of Pike's Beach, Southampton, New York, 1994.

Habitat Type	Definition
Ocean Intertidal Zone	Zone between high and low tides with damp to saturated sand.
Bay Tidal Flat	Zone between high and low tides with damp to saturated sand or silt.
Fresh Wrack	Fresh, wet lines of (usually) vegetation at the peak of the last high tide (ocean and bay).
Old Wrack	Dry, older lines of wrack deposited on the berm by storm tides/winds (ocean and bay).
Berm (Backshore)	Zone of dry sand, shell, cobble, and beach debris landward of the high water mark and seaward or bayward of open or continuous vegetation, scarp, man-made structures, or crest of the berm where ocean and bay are not divided by other features.
Open Vegetation	Strips or clumps of vegetation, usually American Beach Grass (*Ammophila breviligulata*) which chicks may move through freely for foraging and cover (ocean and bay). Grows on dunes, fordunes, between the berm and dense vegetation. Mean cover 21%, median cover 10% (from Elias-Gerken 1994).
Dense Vegetation	Live or dead, thick and matted grasses, forbs, and/or shrubs, too thick for chicks to move through; 90%-100% cover (ocean and bay).
Dune	Elevated areas of dry sand deposited by wind action; well drained, often covered with open vegetation sea- or bayward, dense vegetation landward.
Foredune	Slightly elevated areas of dry sand at the toe of dunes (if any); well drained, often covered with open vegetation.

continued.

Table 1. Continued.

Scarp	Vertical wall (0.5 m -10 m) of sand backing the berm on ocean beaches where erosion has cut into dunes; can also form in the intertidal zone (0.5 m-1.0 m).
Overwash Fan	A break in a continuous dune line or line of vegetation where storm tides carried sand from oceanside to bayside; often clears a vegetation-free path from ocean to bay.
Breach	New inlet created when storm tides and overwash break through a barrier island.
Recurved Spit	A bar of sand extending from the unjettied tip of a barrier island adjacent to an inlet, curving from oceanside to bayside; its development depends on current, sand supply; bayside tidal flats form along margins.
Barrier Tip	End of a barrier island adjacent to an inlet.

Table 2. Behaviors used in the analysis of piping plover brood time budgets on Pike's Beach, Southampton, New York, 1994.

Behavioral Categories Used in the Analysis	Behaviors or Behavioral Sequences Recorded in the Field
Foraging	Run/Peck, Stand/Peck, Glean, Aerial Snap, Foot Tremble, Foraging Run[a], Foraging Walk[a], Foraging Stand[a], Probe
Disturbed	Crouch, Disturbed Run, Disturbed Walk, Disturbed Stand
Resting	Sit, Brood, Preen
Alert	Undisturbed, Non-Foraging Stand
Locomotion	Run, Walk, Fly, Hop

[a]A run, walk, or stand between foraging attempts.

Table 3. Width measurements[a] taken on Pike's Beach, Southampton, New York, 1994.

Intertidal Zone Width (Ocean and Bay)
Wrackline Width (Ocean and Bay)
Berm Width (Ocean and Bay)
Open Vegetation Width (Bay)

[a]Determined by pacing up the beach perpendicular to the long axis of the beach, starting at the water's edge on the ocean and stopping at the border of dense vegetation or water's edge on the bay. Habitats were measured along 6 transects once per week for 12 weeks.

Table 4. Summary of known piping plover reproductive success on Pike's Beach, Southampton, New York, 1983-1994.

	1983-1992[a]	1993	1994
Breeding Pairs	0	5	14[b]
Known Nest Attempts	0	~5[c]	17
1st Attempts	-	?	14
2nd Attempts	-	?	3
Nests Hatched	0	5	11
Observed Hatching Success	-	100%	64.7%
Mayfield Nest Survival	-	67.9%	43.5%
Loss-Known Causes	-	0%	35.3%
Loss-Unknown Causes	-	0%	0%
Eggs Laid	0	20	60
Eggs Laid/Nest Attempt	-	4.0	3.5
Eggs Hatched	0	11	35
Observed Hatching Success	-	55.0%	58.3%
Loss-Known Causes	-	0%	35.0%
Loss-Unknown Causes	-	0%	0%
Eggs Hatched/Pair	-	2.2	2.5
Chicks Fledged/Chicks Hatched	0	5/11	14/35
Broods Fledged/Broods Hatched	0	2/5	8/14
Chicks Fledged/Eggs Laid	-	25.0%	23.3%
Chick Survival	-	45.4%	40.0%
Brood Survival	-	40.0%	57.1%
Loss-Known Causes	-	0%	0%
Loss-Unknown Causes	-	100%	100%
Chicks Fledged/Pair	-	1.00	1.00

[a]Two adults were sighted in 1985 but breeding status was unknown.
[b]13 pairs were seen nesting; the 14th pair was found tending a chick, although the pair's nest was never found.
[c]Early attempts were probably missed, therefore there may have been more than 5 nest attempts.

Table 5. Nesting density (pairs per km) of piping plovers on beaches of central Long Island, New York, 1992-1994.

Beach	1992[a]	1993[a]	1994
Jones West	5.1	6.9	-
Jones Mid	1.3	1.5	-
Jones East	4.1	4.1	-
Democrat Point	2.5	2.5	-
Fire Island National Seashore	0.06	0.06	0.12[b]
Smith Point	5.8	3.3	-
Cupsogue	3.5	3.5	-
Pike's Beach	0	4.5	6.9
Westhampton Beach	3.0	2.7	2.5[c]

[a]Elias-Gerken 1994.
[b]Ebert, pers. comm. 1994.
[c]Murry, pers. comm. 1994.

Table 6. Observed nest success (number of nests that hatched 1 or more eggs/number of nests) and observed egg success (number of eggs/number laid) for piping plovers reported from various studies. Use of predator exclosures among studies was variable.

Area	Year(s)	Observed Success	Source
Nests			
Mass.	1985-1988	24%	MacIvor 1990
Va.	1993	37%	Bottitta et al. 1993
Md.	1988-1990	40%	Loegering 1992
N.C.	1989	40%	McConnaughey et al. 1990
N.Y.	1992-1993	49%	Elias-Gerken 1994
N.C.	1989	63%	Coutu et al. 1990
N.Y.	**1994**	**65%**	**This study 1994**
		$\bar{x}$=45%	
Eggs			
Mass.	1985-1988	25%	MacIvor 1990
Md.	1988-1990	35%	Loegering 1992
N.Y.	1992-1993	38%	Elias-Gerken 1994
Va.	1993	38%	Bottitta et al. 1993
N.Y.	1992	46%	Howard et al. 1992
N.Y.	1988	57%	Goldin et al. 1988
N.Y.	**1994**	**57%**	**This study 1994**
N.C.	1991	60%	Eddings and Melvin 1992
Nova Scotia	1982	76%	Cairns 1982
N.Y.	1937-1958	92%	Wilcox 1959
		$\bar{x}$=52%	

Table 7. Piping plover brood survival (number of broods fledged/number hatched) and chick survival (number of chicks fledged/number hatched) reported from various studies.

Area	Year(s)	Survival	Source
Broods			
Va.	1986-1987	59%	Patterson 1988
N.Y.	**1994**	**70%**	**This study 1994**
N.Y.	1992-1993	76%	Elias-Gerken 1994
		$\bar{x}$=68%	
Chicks			
R.I.[a]	1993	0%	Goldin 1993b
N.Y.[b]	1991	19%	Eddings and Melvin 1992
N.C.	1989	27%	Coutu et al. 1990
N.Y.	1988-1989	30%	Goldin 1993a
N.Y.[c]	1991	34%	Eddings and Melvin 1992
N.Y.	**1994**	**40%**	**This study 1994**
Md.	1988-1990	43%	Loegering 1992[e]
N.Y.[b]	1992	46%	Howard et al. 1992
N.Y.[c]	1992	46%	Howard et al. 1992
Va.	1986-1987	50%	Patterson 1988
N.Y.	1992-1993	51%	Elias-Gerken 1994
Mass.	1985-1988	54%	MacIvor 1990
R.I.[d]	1993	56%	Goldin 1993b
N.C.	1989	74%	McConnaughey et al. 1990
Va.	1993	87%	Bottitta et al. 1993
		$\bar{x}$=44%	

[a]Briggs Beach
[b]Gateway National Recreation Area
[c]Breezy Point Cooperative
[d]Goosewing Beach
[e]Mayfield (1985) estimate was 33%

Table 8. Causes of loss of piping plover nests and eggs on Pike's Beach, Southampton, New York, 1994.

Cause of Loss	Number of Nests	%	Number of Eggs	%
Abandoned	1[a]	16.7	6[b]	23.1
Predated				
Fox Suspected	3	50.0	11	42.3
Fox	1	16.7	4	15.4
Gull	1	16.7	2	7.7
Eggs Missing at Hatch	-	-	3	11.5
TOTAL	6	100.0	26	100.0

[a]Probably due to harassment by red fox(es) (*Vulpes vulpes*) 13 days after predator exclosure constructed around the nest.
[b]Four eggs were from 1 nest abandoned due to probable harassment from red fox(es); 1 egg left in each of 2 nests after other eggs hatched.

Table 9. Proportion of piping plover nests apparently surviving to hatch and Mayfield (1985) survival rates for nests with and without predator exclosures, Pike's Beach, Southampton, New York, 1994.

Exclosure Status	Proportion Surviving to Hatch (H/L)[a]	n[b]	Daily Survival	SE	Interval Survival[c]
Exclosure Present	80.0% (4/5)	5	0.985	0.0065	0.530
Exclosure Absent	58.3% (7/12)	11	0.974	0.0032	0.384
Significance	P=0.35[d]				P=0.36[e]
ALL NESTS	64.7% (11/17)	16	0.977	0.0022	0.435

[a]The number nests hatched/the number of nests laid.
[b]The number of nests on which Mayfield survival estimates are based.
[c]The probability that a nest initiated will survive to hatching. Interval survival rates are bias adjusted (Heisey and Fuller 1985).
[d]1-tailed Z-test for a difference in proportions Z=-0.85177).
[e]1-tailed Z-test for a difference in interval survival (Z=0.58602).

Table 10. Proportion of piping plover nests with and without predator exclosure predated by specific predators, Pike's Beach, Southampton, New York, 1994.

Exclosure Status	Abandoned Due to Fox Harassment	Fox or Probable Fox	Gull
Exclosure Present	1 (100%)	0 (0%)	0 (0%)
Exclosure Absent	0 (0%)	4 (100%)	1 (100%)

Table 11. Nest mortality versus instantaneous[a] counts of potential sources of human disturbance within 100 m of nests and counts of tracks within 30 m of nests, Pike's Beach, Southampton, New York, 1994.

Nest Status	Instantaneous Counts						Track Counts	
	Pedestrians		ORV's[b]		Dogs		Pedestrians	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Nest Survived (n=6)	0.3	0.23	0	0	0	0	1.7	0.54
Nest Lost (n=4)	0.1	0.12	0	0	0	0	2.2	1.38
Significance[c]	P=0.21		-		-		P=0.46	

[a]The number of potential disturbance sources within 100 m of the nest are counted when the observer first encounters the nests during periodic nest surveys.
[b]Off-road vehicles.
[c]1-tailed Wilcoxon rank-sum tests (Z=-0.7988, Z=-0.1066, respectively).

Table 12. Proportion of disturbed and undisturbed piping plover broods fledging on Pike's Beach, Southampton, New York, 1994.

Disturbed	Proportion Fledging
Brood Disturbed	80.0% (4/5)
Brood Not Disturbed	60.0% (3/5)
Significance	P=0.37[b]

[a]As determined by behavioral observations throughout the pre-fledged period. Any brood disturbed at least once was considered to be disturbed.
[b]1-tailed Z-test for a difference in proportions (Z=-0.6901).

Table 13. Trail indices (percent coverage of habitat by trails of potential predators) on Cupsogue, Pike's, and Westhampton Beaches, Long Island, New York, 1992-1994.

	Berm				Open Vegetation			
	Fox		Cat		Fox		Cat	
Year/Beach	n	$\bar{x}$%	n	$\bar{x}$%	n	$\bar{x}$%	n	$\bar{x}$%
1992								
Cupsogue	33	<0.1	33	0	32	0.1	32	0.1
Westhampton Beach	136	0	136	0.1	132	0	132	1.0
1993[a]								
Westhampton Beach	216	0	216	0.1	215	0	215	1.0
1994								
Pike's Beach[b]	22	1.7	22	0.5	-	-	-	-
Westhampton	9	0.1	9	0.4	9	0	9	6.8

[a]There were no trail indices for Pike's Beach or Cupsogue in 1993.
[b]Quantity of open vegetation was negligible on Pike's Beach, hence no trail indices for open vegetation.

Table 14. Mean time (%) piping plover broods spent in various behaviors as determined by behavioral observations on Pike's Beach, Southampton, New York, 1993 and 1994.

	1993 (n=4)		1994 (n=10)	
Behavior	$\bar{x}$%	SE	$\bar{x}$%	SE
Foraging	79	7.0	77	5.4
Disturbed	2	1.8	5	2.1
Resting	16	8.4	11	4.2
Alert	1	1.0	4	1.5
Locomotion	<1	0.1	3	1.2

Table 15. Mean time (%) piping plover broods spent disturbed by various sources as determined by behavioral observations on Pike's Beach, Southampton, New York, 1993 and 1994.

	1993 (n=4)		1994 (n=10)	
Behavior	$\bar{x}$%	SE	$\bar{x}$%	SE
Overall	2	1.8	5	2.1
Human	1	1.0	2	1.6
Territorial	<1	0.2	<1	0.5
Avian	0	0	1	0.7
Gull spp.	0	0	<1	0.3
Other	<1	0.2	<1	0.1

Table 16. Mean time (%) piping plover broods spent in foraging habitats as determined by time-budget observations on Pike's Beach, Southampton, New York, 1993 and 1994.

Habitat	1993 (n=4)		1994 (n=10)	
	$\bar{x}$%	SE	$\bar{x}$%	SE
Ocean ITZ	0	0	2	1.7
Ocean Fresh Wrack	7	6.0	1	1.0
Ocean Berm	5	4.6	2	1.2
Ocean Old Wrack	0	0	8	6.6
Bay Open Vegetation	5	5.0	3	2.7
Bay Old Wrack	1	1.0	3	1.3
Bay Berm	1	1.0	21	4.9
Bay Fresh Wrack	15	9.1	20	5.0
Bay Tidal Flat	65	15.1	38	5.7
Oceanside	13	12.5	13	9.9
Bayside	87	12.5	87	9.9

Table 17. Mean time (%) piping plover broods spent in various behaviors within habitats as determined by behavioral observations on Pike's Beach, Southampton, New York, 1993 and 1994.

	1993			1994		
Habitat/Behavior	n	$\bar{x}$%	SE	n	$\bar{x}$%	SE
Ocean ITZ						
Foraging	0	0	-	2	50	50.0
Disturbed	0	0	-	2	50	50.0
Resting	0	0	-	2	0	0
Alert	0	0	-	2	0	0
Locomotion	0	0	-	2	0	0
Ocean Fresh Wrack						
Foraging	1	58	-	2	50	50.0
Disturbed	1	2	-	2	50	50.0
Resting	1	40	-	2	0	0
Alert	1	0	-	2	0	0
Locomotion	1	0	-	2	0	0
Ocean Berm						
Foraging	1	100	-	3	65	32.4
Disturbed	1	0	-	3	33	33.3
Resting	1	0	-	3	2	1.8
Alert	1	0	-	3	0	0
Locomotion	1	0	-	3	0	0
Ocean Old Wrack						
Foraging	0	0	-	3	67	33.3
Disturbed	0	0	-	3	33	33.3
Resting	0	0	-	3	0	0
Alert	0	0	-	3	0	0
Locomotion	0	0	-	3	0	0

continued.

Table 17. Continued.

Habitat/Behavior	1993 n	1993 $\bar{x}$%	1993 SE	1994 n	1994 $\bar{x}$%	1994 SE
Bay Open Vegetation						
Foraging	1	44	-	2	0	0
Disturbed	1	33	-	2	12	12.0
Resting	1	12	-	2	32	15.7
Alert	1	9	-	2	38	19.9
Locomotion	1	1	-	2	17	16.7
Bay Old Wrack						
Foraging	1	58	-	6	83	16.7
Disturbed	1	2	-	6	0	0
Resting	1	40	-	6	0	0
Alert	1	0	-	6	17	16.7
Locomotion	1	0	-	6	0	0
Bay Berm						
Foraging	1	47	-	8	63	7.0
Disturbed	1	53	-	8	5	2.1
Resting	1	0	-	8	17	5.7
Alert	1	0	-	8	3	1.7
Locomotion	1	0	-	8	11	4.6
Bay Fresh Wrack						
Foraging	2	100	0	9	82	5.8
Disturbed	2	0	-	9	5	2.6
Resting	2	0	-	9	3	3.3
Alert	2	0	-	9	2	1.4
Locomotion	2	0	-	9	8	3.6
Bay Tidal Flat						
Foraging	4	88	8.9	9	89	2.8
Disturbed	4	1	0.9	9	4	1.9
Resting	4	9	9.0	9	1	0.3
Alert	4	<1	0.4	9	3	1.9
Locomotion	4	0	0	9	4	2.7

Table 18. Foraging rates (attempts per minute) of piping plover broods in foraging habitats as determined by time-budget observations on Pike's Beach, Southampton, New York, 1993 and 1994.

	1993			1994		
Habitat	n	$\bar{x}$%	SE	n	$\bar{x}$%	SE
Ocean ITZ	0	-	-	1	4	-
Ocean Fresh Wrack	1	2	-	2	0	0
Ocean Berm	1	6	-	3	<1	0.2
Ocean Old Wrack	0	-	-	3	2	1.0
Open Vegetation	0	-	-	2	0	0
Bay Old Wrack	1	1	-	9	5	1.1
Bay Berm	1	4	2.4	8	3	1.4
Bay Fresh Wrack	3	6	2.4	9	5	1.1
Bay Tidal Flat	4	10	2.4	9	8	1.2
Ocean ITZ and Fresh Wrack	1	2	-	2	1	0.9
Bay Tidal Flat and Fresh Wrack	4	8	1.8	9	6	0.8
Significance[a]		-			P=0.02	

[a]1-tailed Wilcoxon rank-sum test for differences between means (Z=-2.0035).

Table 19. Composition of surface arthropods as determined by sticky-stick sampling on Pike's Beach, Southampton, New York, 1994.

	Composition	
	n	$\bar{x}$%
Insects	250	78
Dipterans	250	73
Coleoptera	236	5
Siphonaptera	236	<1
Lepidoptera	236	<1
Homoptera	236	<1
Hemiptera	236	<1
Hymenoptera	250	<1
Unidentified Larvae	250	<1
Amphipods	250	21
Arachnids	250	<1
Mussels	250	<1

Table 20. Relative arthropod abundances in piping plover brood broods foraging habitats as determined by sticky-stick sampling on Pike's Beach, Southampton, New York, 1993 and 1994.

Habitat	1993			1994		
	n	$\bar{x}$%	SE	n	$\bar{x}$%	SE
Ocean ITZ	5	17	4.5	48	7	1.2
Ocean Fresh Wrack	15	7	1.2	51	11	1.2
Ocean Berm	20	8	1.2	51	3	0.4
Ocean Old Wrack	20	6	1.4	51	6	1.4
Bay Open Vegetation	-	-	-	7	7	7.3
Bay Fresh Wrack	20	20	6.2	44	20	2.3
Bay Tidal Flat	12	18	4.4	42	18	2.5
Ocean ITZ and Fresh Wrack	20	10	1.7	99	9	0.7
Bay Tidal Flat and Fresh Wrack	32	19	4.1	86	19	1.7
Significance[a]		P=0.02			P<0.01	

[a]1-tailed Wilcoxon rank-sum test for differences between means (Z=-2.0067, Z=4.5137, respectively).

Table 21. Mean widths (m) and percent relative[b] availabilities of habitats on Pike's Beach, Southampton, New York, 1994.

Habitat	n[a]	$\bar{x}$ (m)	SE	$\bar{x}$ (%)	SE
Ocean ITZ	6	26.6	3.81	18.4	4.55
Ocean Fresh Wrack	6	0.4	0.03	0.2	0.02
Ocean Old Wrack	6	0.7	0.14	0.5	0.16
Berm	6	122.9	23.31	73.0	6.12
Bay Open Vegetation	6	5.6	2.62	4.3	2.37
Bay Fresh Wrack	6	0.1	0.09	0.06	0.05
Bay Tidal Flat	6	6.4	3.05	3.5	1.76
Ocean Side[c]	6	89.1	12.58	55.6	1.83
Bay Side[d]	6	73.6	12.75	44.4	1.83
TOTAL	6	162.7	25.12	100.0	

[a]Habitat widths were estimated once per week for 12 weeks along 6 transects during the breeding season.
[b]Percent relative availability determined by dividing mean width of habitat along each transect by mean total width of all habitats combined.
[c]Ocean ITZ, fresh wrack, berm, and old wrack.
[d]Bay ITZ, fresh wrack, berm, and old wrack.

Table 22. Use-availability analysis for Piping Plover broods on Pike's Beach, Southampton, New York, 1994. Sample size is the number of broods.

Habitat	Availability[a] n=6	Use[b] n=10	Significance[c]	Use Relative to Availability
Ocean				
ITZ	18.4	2.1	0.0031	USE LESS
Fresh Wrack	0.2	1.2	0.0426	USE MORE
Old Wrack	0.5	7.6	0.1929	NS
Berm[d]	6.5	2.4	0.0008	USE LESS
Bay				
Berm[d]	36.5	21.2	0.0733	NS
Open Veg.	4.3	3.5	0.3913	NS
Fresh Wrack	0.06	20.2	0.0050	USE MORE
Tidal Flat	3.5	38.4	0.0063	USE MORE
Ocean Side[e]	55.6	13.3	0.0077	USE LESS
Bay Side[f]	44.4	86.6	0.0088	USE MORE

[a]Percent relative availability (expected use).
[b]Percent actual use.
[c]Two-sample Wilcoxon rank-sum test for differences between the means.
[d]For this analysis total berm width was divided by 2 to derive values for ocean and bay berm widths.
[e]Ocean ITZ, fresh wrack, berm, and old wrack.
[f]Bay tidal flat, fresh wrack, berm, and old wrack.

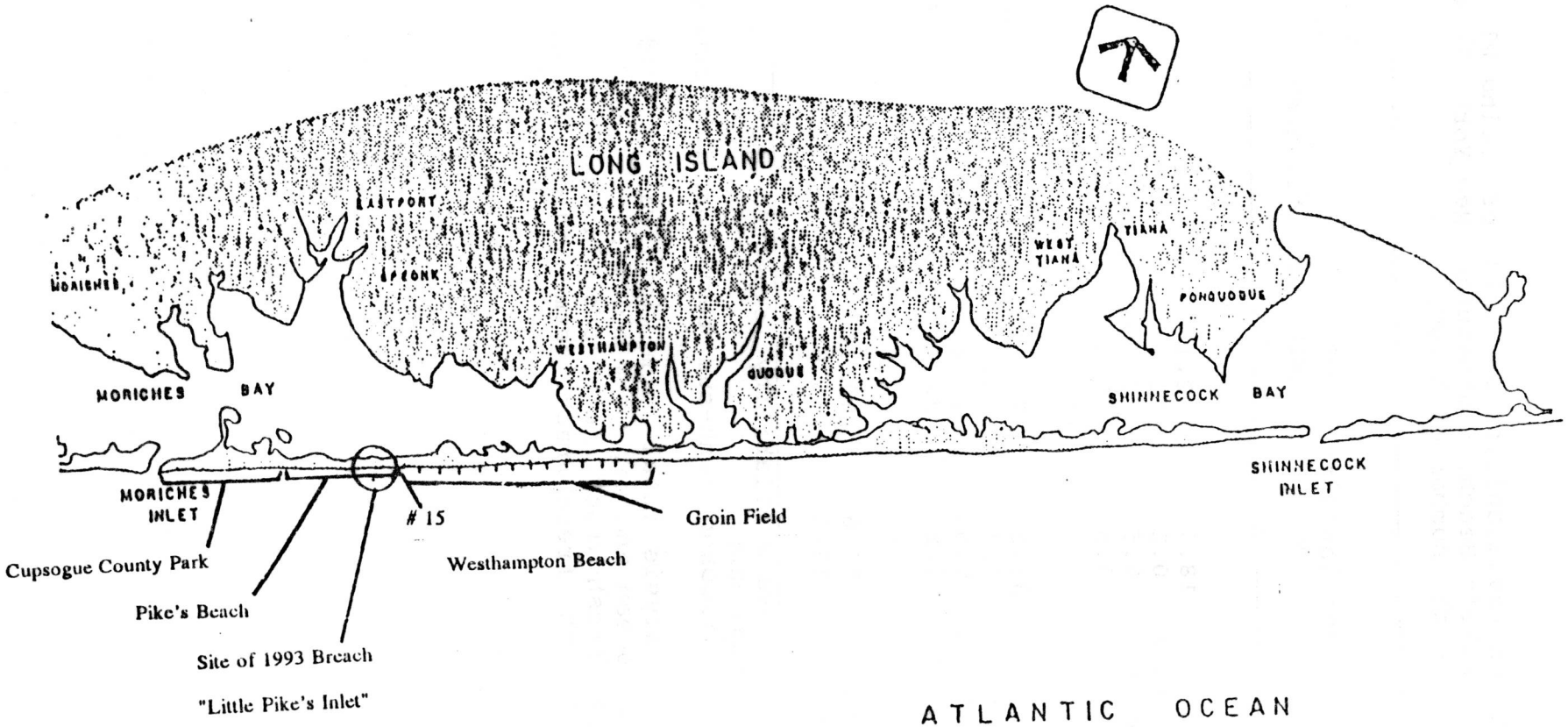


Figure 1. Pike's Beach and vicinity, Long Island, New York. Source: U.S. Army Corps of Engineers, 1980.

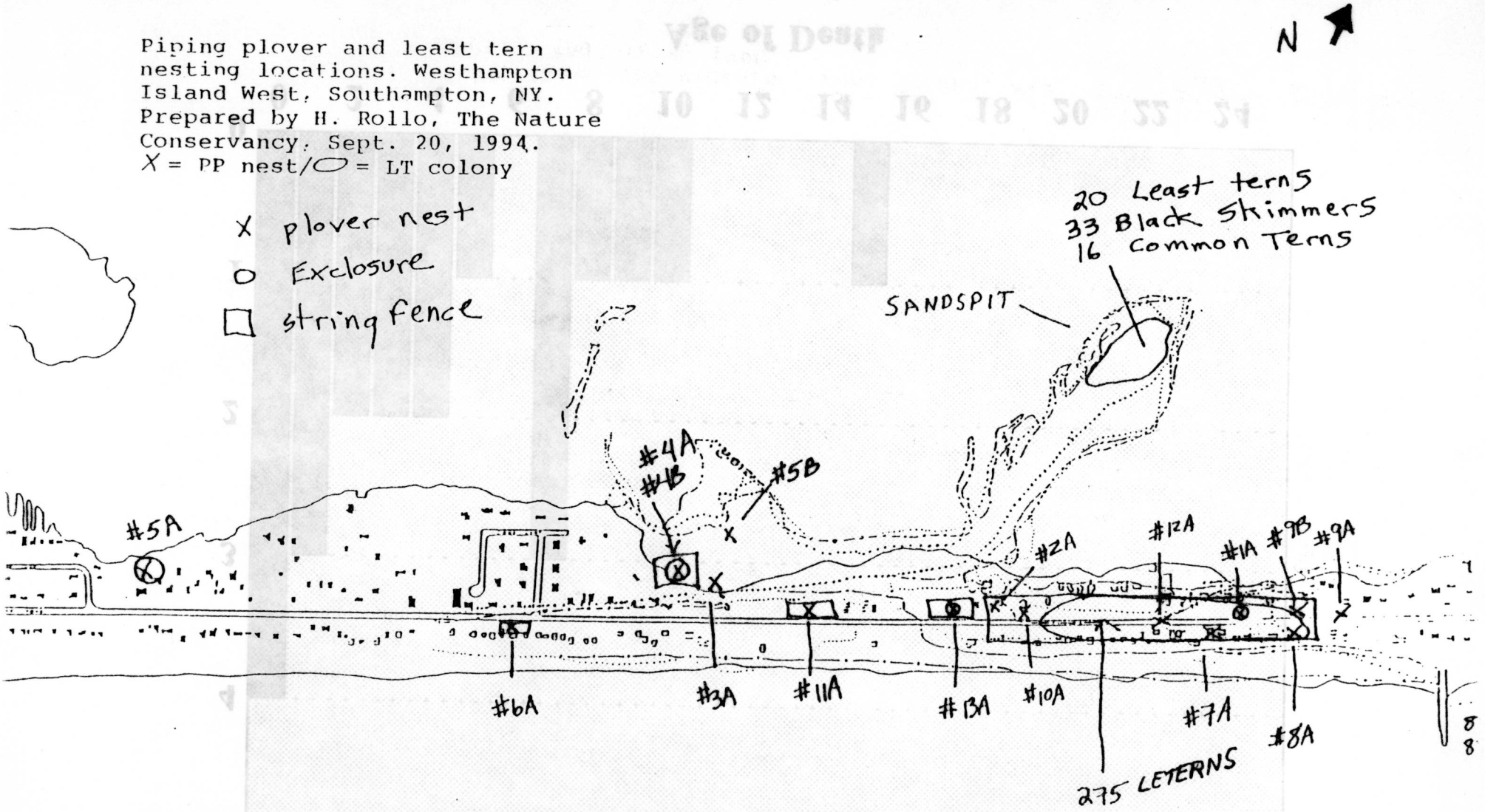


Figure 2. Diagram of Pike's Beach physiography and piping plover nest distribution from April through July, 1994, on Long Island, New York. Courtesy of Heather Rollo, 1994

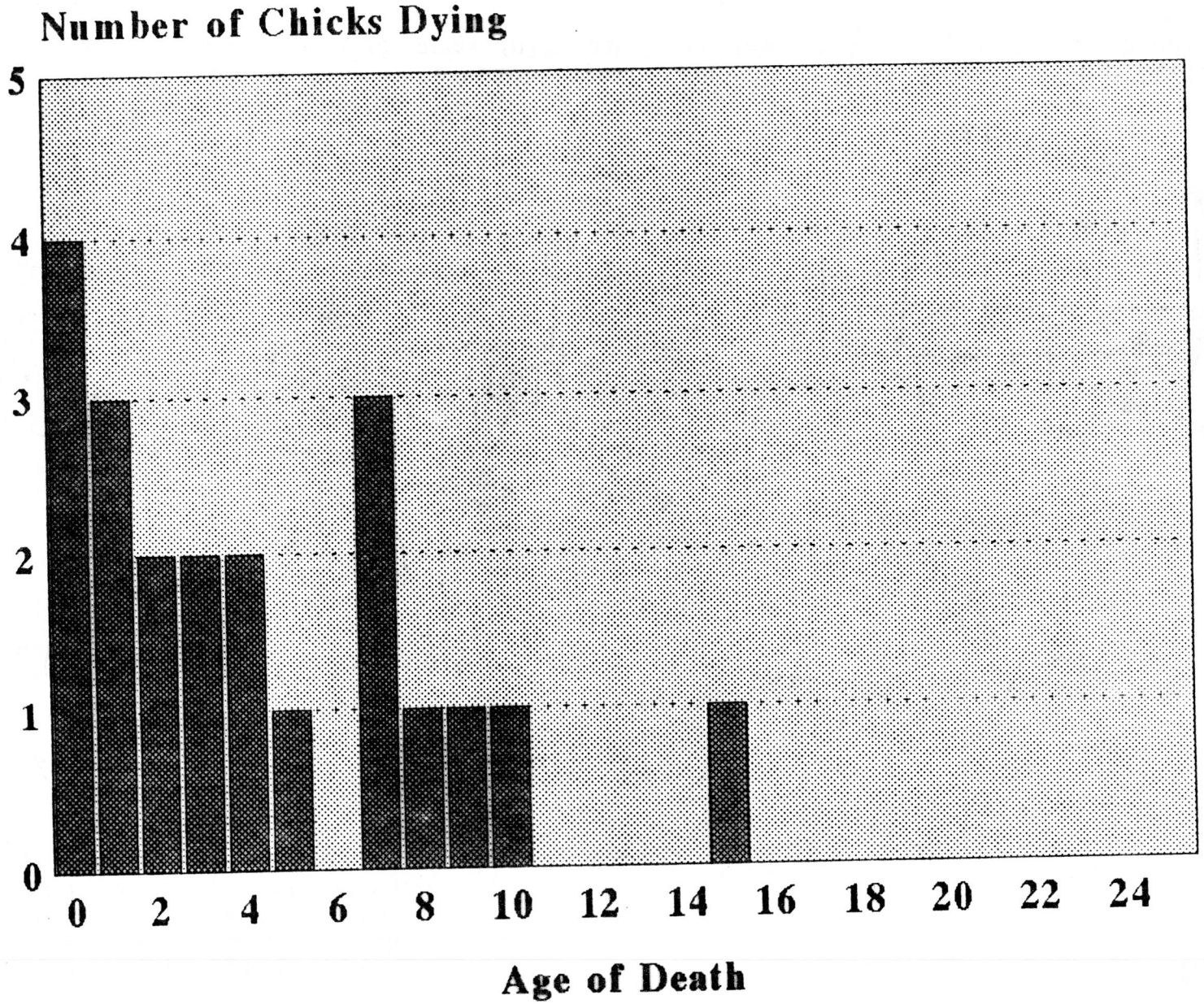


Figure 3. Age distribution of piping plover chick mortality on Pike's Beach, Long Island, New York, 1994.