

FACTORS AFFECTING PIPING PLOVER CHICK SURVIVAL IN DIFFERENT BROOD-REARING HABITATS

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Abstract: The decline of piping plover (*Charadrius melodus*) populations and subsequent listing as a threatened species has been attributed, in part, to low chick survival. During 1988–90, we observed piping plover chicks daily to evaluate hypotheses of differential food resources, predation, and disturbance explaining differences in chick survival in 3 habitats on Assateague Island National Seashore (AINS), Maryland. Chicks reared on the bay beach and island interior had higher daily survival rates (0.97, 0.99 vs. 0.87; $P < 0.001$), higher foraging rates (13.3, 10.8 vs. 5.9 attempts/min; $P < 0.001$), and spent more time foraging (76, 80 vs. 37%, $P < 0.004$) than chicks reared on the ocean beach. Terrestrial arthropod abundance on the bay beach and island interior was greater than on the ocean beach in 5 of 6 cases ($P \leq 0.01$). Amphipods, however, were more abundant on ocean beaches than in bay and island interior habitats each year ($P \leq 0.03$). Chicks 4–5 days old that were reared on the bay beach or island interior habitats were heavier than those reared on the ocean beach (8.5, 7.8 vs. 6.5 g; $P < 0.01$). Overall disturbance rates did not differ among habitats (behavioral observations; $P = 0.29$). The number of predator trails did not differ among the 3 habitats ($P = 0.2$). Red fox (*Vulpes vulpes*) trails were more numerous in the island interior and ocean beach ($P < 0.001$), ghost crab (*Ocypode quadrata*) burrows were more numerous on ocean beach ($P < 0.001$), and gull (*Larus* spp.) and raccoon (*Procyon lotor*) trails were more numerous on bay beach ($P < 0.001$ and $P = 0.001$, respectively). Piping plover chicks moved from ocean beach nest sites to the bay beach and island interior along ephemeral, vegetation-free paths created during winter storms by waves surging across the island. These paths should be maintained to enable piping plover chicks to move to the island interior and bay habitats where chick survival is greatest. Preserving access to high quality brood-rearing habitat will ensure reproductive rates that will sustain the local population and contribute to the species' recovery.

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In 1986, the piping plover was classified as threatened along the U.S. Atlantic Coast (Fed. Regist. 1985). The population decline leading to this action has been attributed to poor reproductive success (Dyer et al. 1988), which in turn has been attributed to predation, human disturbance, and habitat loss caused by beach development and stabilization (Wilcox 1959, Arbib 1976, Cairns and McLaren 1980, Haig 1985, Flemming et al. 1988, Patterson et al. 1991).

The AINS, Maryland, has supported 14–25 piping plover pairs, all of the known breeding plovers in Maryland and 2% of the Atlantic Coast population (U.S. Fish and Wildl. Serv. 1995). Piping plovers on AINS rear their broods on the

bay beach, in the island interior along the margin of herbaceous vegetation, and on the ocean beach. Survival rates of chicks raised on the ocean beach are lower than those of chicks raised on the bay beach (Patterson et al. 1991). We evaluated 3 hypotheses to explain this difference: (1) poor food resources on the ocean beach results in starvation or weakening of young, leading to lower survival, (2) differential predation pressures lead to higher survival rates on bay beaches, and (3) higher disturbance rates on ocean beaches lead to lower survival (Patterson et al. 1991).

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STUDY AREA

Assateague Island is a 59-km-long barrier island off the coasts of Maryland and Virginia, bounded by the Atlantic Ocean and Sinepuxent and Chincoteague bays. We restricted our work to AINS, Maryland. Patterson et al. (1991) described the island.

The northern 8 km of AINS, which contained 23 of 25 piping plover breeding pairs in 1988, 19 of 20 pairs in 1989, and 13 of 14 pairs in 1990, had a 140–380-m-wide flat beach with a few small (≤ 1 m high), broken dunes. The island was <300 m wide in some places. Ocean beach consisted of sand, shells, pebbles, and small cobble and extended nearly to Sinepuxent Bay at some places; vegetation was nonexistent. The island interior was vegetated with American beach grass (*Ammophila breviligulata*), salt meadow cord grass (*Spartina patens*), seaside goldenrod (*Solidago sempervirens*), and American three-square (*Scirpus americanus*). Woody vegetation included bayberry (*Myrica pensylvanica* and *M. cerifera*) and sea-myrtle (*Baccharis halimifolia*). On the northernmost 1 km of the island was loblolly pine (*Pinus taeda*) and eastern redcedar (*Juniperus virginiana*). Vegetation descriptions follow Hill (1986). Salt meadows, marshes, and mud flats were common bay-side features. Shrubs frequently grew along the bay-side water's edge. Low-lying flat areas were occasionally scoured by waves crossing the island during winter storms, creating vegetation-free pathways between the ocean side and bay side of the island (hereafter called overwash corridors). The only large dune system in the northern 8 km was in the northernmost 1 km of the island; dune elevation seldom exceeded 3 m. This dune system was composed of dredge spoil material deposited by the U.S. Army Corps of Engineers in 1962 (Buckley and Psuty 1986).

Human activity on the northern 8 km of AINS was restricted to pedestrian traffic, except for Park Service and research vehicles. Access was by boat or foot. A hike-in campground was located approximately 700 m north of the study area's southern boundary and was used by 0–20 campers/night during June–August.

METHODS

Chick Survival

After the first piping plover nest scrapes were observed (approx 15 Apr each yr), we searched suitable habitat for nests. We observed, from >100 m, incubating adults daily at all nests to determine hatch dates. After eggs hatched, we located each brood daily to determine foraging habitat used. We observed plovers from a distant or concealed position so brood movements were unaffected.

We captured chicks at 4 days of age, or as soon as possible thereafter, to individually color band and weigh them to the nearest 0.5 g with a Pesola spring scale. We processed and released chicks at the capture site. For mass analysis, we included only chicks captured at 4–5 days of age to reduce age-related variation.

We observed 23 broods daily for ≥ 25 days to estimate survival to fledging. We considered birds ≥ 25 days old to have fledged. Patterson (1988) observed chicks as young as 20 days old in flight. We calculated daily chick survival (Mayfield 1975) using MICROMORT (Heisey and Fuller 1985).

Behavior

We watched randomly selected focal chicks for 5-minute periods (Altmann 1974) and counted foraging attempts. If we lost sight of the focal animal, we resumed the observation if it was resighted in <2 minutes (Lehner 1979); otherwise, the observation was terminated. To the extent possible, we observed each chick in a brood in sequential 5-minute observations.

Each day we attempted to sample every brood with chicks ≤ 25 days old. When time constraints prohibited us from sampling every brood ($<10\%$ of the days), we focused on chicks ≤ 10 days old because this age group usually experiences the highest mortality rate (Cairns 1982, Patterson 1988, MacIvor 1990; but see Fleming et al. 1988).

We gathered time budget data on focal birds at 10-second intervals during the 5-minute foraging observations. We characterized behavior as foraging, locomotion, preening, alert, or resting and recorded disturbance from natural and human sources. We defined disturbance as any influence that caused an abrupt change in behavior.

Table 1. Daily survival rates of piping plover chicks on Assateague Island National Seashore, Maryland, 1988–90.

| Category | n | Daily survival | | 25-day survival ^a | p ^b |
|---------------------------|----|----------------|---------|------------------------------|----------------|
| | | Rate | SE | | |
| Overall | 98 | | 0.00056 | | |
| Chicks ≤10 days old | 98 | | 0.00110 | | <0.001 |
| Chicks 11–25 days old | 49 | | 0.00055 | | |
| No access to the bay side | 50 | | 0.00160 | | <0.001 |
| Access to bay side | 48 | | 0.00078 | | |
| Bay beach | 16 | | 0.00012 | | |
| Island interior | 39 | | 0.00002 | | |
| Ocean beach | 43 | | 0.00039 | | |

^a Interval survival for the first 25 days of life except for chicks ≤10 and 11–25 days old where the interval is 10 and 15 days, respectively.

^b Hensler's (1985) test comparing daily survival of chicks ≤10 and 11–25 days old, chicks with and without access to the bay side, and chicks in different habitats (Z-test).

^c Means with the same letters are not different (pairwise Z-test, $P > 0.05$).

^d Pairwise comparisons: bay side vs. island interior $P = 0.146$; bay side vs. ocean side $P < 0.001$; island interior vs. ocean side $P < 0.001$.

specific foraging sites (e.g., a distinct mudflat) may not be independent within and among years. Also, broods observed in the same place on consecutive days are not independent. Consequently, we plotted all brood locations on aerial photographs and superimposed a 100-m grid system to delimit different foraging locations. For each location, we calculated a mean foraging rate for all observations of a brood at that location to avoid temporal pseudoreplication (Hurlbert 1984). Therefore, we reduced our sample of 337 5-minute observations to 222 brood-days, and further to 112 locations, and analyzed this dataset. We used a G-test (log-likelihood ratio; Sokal and Rohlf 1981) to compare expected and observed frequencies spent in each behavioral category among brood-rearing habitats. We compared foraging rates and behavior among habitats using Kruskal-Wallis tests, or Wilcoxon rank sum tests when data from only 2 habitats were available. We excluded observations of chicks 0–2 days of age when comparing habitats because it generally took 2 days for broods to move to the bay beach or island interior habitats from their nests on ocean beach.

We compared relative, potential prey abundances and disturbance indices among habitats with Kruskal-Wallis tests. To control for temporal variability, we paired samples from random and brood-rearing transects by week and compared the difference with a Wilcoxon signed-rank test. Throughout, we used nonparametric multiple comparisons (Gibbons 1985:181) following Kruskal-Wallis tests. For terrestrial arthropod abundances, we report the total count from both traps per site. For substrate invertebrate samples, we report a total of all taxon and selected taxonomic groups (see Loegering 1992

for analysis by taxonomic group). For ocean beach substrate invertebrate samples, we report a mean of wet and saturated zone cores. For disturbance indices, we analyzed trail abundance from species where we observed ≥1 trail/transect in >70% of the transects, because >30% zeros (ties) violates an assumption of the Kruskal-Wallis test. For species that we did not detect in >30% of the transects, we used a Chi-square test for homogeneity to compare presence or absence of tracks among habitats.

RESULTS

Chick Survival

Most piping plover chick mortality occurred in the first 10 days of life (Table 1). Chicks occupying bay beach and island interior habitats had higher daily survival rates than chicks occupying ocean beach (Table 1). Additionally, chicks with access to the bay side had a higher daily survival rate than those without access. Eleven of 14 broods with access to the bay side moved to bay side.

Mean masses of chicks 4–5 days old surviving to fledging were greater than the mean masses of those not surviving (Wilcoxon rank sum, $Z = 2.5$, $P = 0.013$; Table 2). Masses of chicks 4–5 days old were lowest on ocean beach and highest on bay beach and island interior habitats (Kruskal-Wallis, $\chi^2 = 9.0$, 2 df, $P = 0.011$; Table 2).

Behavior

Foraging rates on ocean beach were lower than on bay beach and island interior habitats for chicks 3–10 and 11–20 days old (Kruskal-Wallis, $\chi^2 = 14.4$, 2 df, $P < 0.001$, and $\chi^2 = 8.0$, 2 df, $P = 0.0186$, respectively; Table 3). Foraging rates did not differ among habitats in the

Table 4. Mean time (%) spent in various behavioral categories in 3 habitats by piping plover chicks on Assateague Island National Seashore, Maryland, 1989–90. Behaviors were inconsistently categorized in 1988 and have been excluded from analysis. We collected disturbance data independently of other behavior data; thus, time spent disturbed is not additive with the other categories.

| Behavior | Habitat | | | | | | | | | P ^a |
|----------------|-----------|----|---|-----------------|-----|---|-------------|-----|----|----------------|
| | Bay beach | | | Island interior | | | Ocean beach | | | |
| | \bar{x} | SE | n | \bar{x} | SE | n | \bar{x} | SE | n | |
| 3–10 days old | | | | | | | | | | |
| Foraging | 76 | 7 | 7 | 80 | 6 | 8 | 37 | 8 | 14 | 0.004 |
| Locomotion | 9 | 4 | 7 | 7 | 2 | 8 | 22 | 5 | 14 | |
| Preening | 0 | 0 | 7 | 0.5 | 0.3 | 8 | 0.5 | 0.5 | 14 | |
| Alert | 7 | 4 | 7 | 8 | 2 | 8 | 22 | 6 | 14 | |
| Resting | 4 | 2 | 7 | 5 | 3 | 8 | 19 | 8 | 14 | |
| Disturbed | 13 | 7 | 7 | 1 | 0.6 | 8 | 15 | 6 | 14 | |
| 11–20 days old | | | | | | | | | | |
| Foraging | 83 | 6 | 2 | 89 | 4 | 8 | 56 | 6 | 24 | 0.005 |
| Locomotion | 10 | 6 | 2 | 4 | 1 | 8 | 17 | 3 | 24 | |
| Preening | 0 | 0 | 2 | 0.3 | 0.2 | 8 | 5 | 2 | 24 | |
| Alert | 6 | 1 | 2 | 7 | 3 | 8 | 15 | 3 | 24 | |
| Resting | 0 | 0 | 2 | 0 | 0 | 8 | 7 | 3 | 24 | |
| Disturbed | 4 | 4 | 2 | 1 | 0.6 | 8 | 6 | 2 | 24 | |
| ≥21 days old | | | | | | | | | | |
| Foraging | | | | 76 | 19 | 3 | 59 | 9 | 18 | 0.420 |
| Locomotion | | | | 12 | 8 | 3 | 12 | 3 | 18 | |
| Preening | | | | 0 | 0 | 3 | 3 | 1 | 18 | |
| Alert | | | | 13 | 13 | 3 | 14 | 5 | 18 | |
| Resting | | | | 0 | 0 | 3 | 11 | 6 | 18 | |
| Disturbed | | | | 0 | 0 | 3 | 8 | 2 | 18 | |

^a Kruskal-Wallis test comparing behavior among bay beach, island interior, and ocean beach.

hatched chicks. Predation undoubtedly occurs, but evidence that predation causes lower survival on ocean beach is inconclusive. Ghost crab burrows occurred mostly on the ocean beach, and we noted 1 chick depredated by a ghost crab (Loegering et al. 1995). Red fox trails, however, were most numerous on the island interior,

where chick survival was the highest, and ocean beach, where chick survival was lowest. Lower chick masses on ocean beach suggest it is unlikely that predation alone is responsible for lower chick survival on ocean beach. Hypotheses identifying specific sources of predation are difficult to test.

Table 5. Terrestrial arthropod abundance (no./30 min sample) on Assateague Island National Seashore, Maryland, 1988–90.

| Habitat | Piping plover brood-rearing transects | | | Random transects | | | P ^a |
|-----------------|---------------------------------------|-------|----|------------------|-------|----|----------------|
| | \bar{x} | SE | n | \bar{x} | SE | n | |
| 1988 | | | | | | | |
| Bay beach | 21.0 | 5.9 | 5 | 34.8 | 23.7 | 5 | 0.875 |
| Ocean beach | 0.4 | 0.4 | 5 | 0.7 | 0.3 | 5 | |
| P ^b | | 0.001 | | | 0.007 | | |
| 1989 | | | | | | | |
| Bay beach | 8.0A ^c | 2.1 | 5 | 3.8A | 0.7 | 5 | 0.125 |
| Island interior | 6.3B | 3.0 | 8 | 4.4A | 1.8 | 8 | |
| Ocean beach | 1.8C | 0.9 | 12 | 4.5A | 2.1 | 11 | |
| P | | 0.036 | | | 0.615 | | |
| 1990 | | | | | | | |
| Bay beach | 6.4A | 1.6 | 5 | 16.6A | 8.4 | 7 | 0.313 |
| Island interior | 13.1A | 7.3 | 15 | 5.9A | 2.6 | 15 | |
| Ocean beach | 1.3B | 0.5 | 15 | 1.9B | 1.1 | 14 | |
| P | | 0.002 | | | 0.009 | | |

^a Wilcoxon signed-rank on the differences between brood-rearing transects and random transects paired by each week of collection.

^b Wilcoxon rank sum and Kruskal-Wallis tests comparing the bay beach, island interior, and ocean beach.

^c Within years, column means with the same letters are not different ($P > 0.05$).

Table 7. Number of animal or human trails per linear 100 m on Assateague Island National Seashore, Maryland, 1988–90.

| Habitat | Predators | | | | | | | | | | Total trails ^b | | | | | |
|-----------------|-------------------------|-----|---------------------|----|-----------|----|---------|----|---------|----|---------------------------|----|--------|----|---------|------|
| | Ghost crab ^a | | Boat-tailed grackle | | Gull spp. | | Red fox | | Raccoon | | Nonpredators | | Humans | | x̄ | SE |
| | x̄ | SE | x̄ | SE | x̄ | SE | x̄ | SE | x̄ | SE | x̄ | SE | x̄ | SE | | |
| Bay beach | 27 | 1.2 | 1.1 | | | | | | | | | | | | 64.4 | 12.7 |
| Island interior | 45 | 0.4 | 0.1 | | | | | | | | | | | | 52.2 | 6.0 |
| Ocean beach | 70 | 5.2 | 0.7 | | | | | | | | | | | | 33.6 | 2.5 |
| P ^c | <0.001* | | | | | | | | | | | | | | 0.013** | |

^a No. of ghost crab burrows/100 m².

^b Total trails include ghost crabs, boat-tailed grackles, gulls, egrets, red foxes, raccoons, dogs, feral ponies, sika deer, fiddler crabs, American oystercatchers, willets, turtles, ducks, and humans.

^c Chi-square test (*) on the presence or absence of trails or Kruskal-Wallis test (**) on the number of trails.

dation, especially if adequate food resources were not available. While this disturbance hypothesis is consistent with lower chick masses on ocean beach, it does not explain the differences in foraging rates and the time spent foraging during the day. If chicks on ocean beach were disturbed at night and consequently had higher energy expenditures, we would predict that these chicks would compensate for this energy deficit by foraging longer or more intensely during the day when disturbance rates are low. However, chicks on ocean beach foraged at a lower rate and spent less time foraging than chicks in other habitats.

Foraging Hypothesis

Our data are consistent with the hypothesis that starvation, or starvation-induced weakness, led to lower piping plover chick survival on ocean beach. Ocean beach had fewer insects, and chicks there foraged at a lower rate, weighed less, and had higher mortality than chicks elsewhere.

Chick growth rates and mass gains are affected by food supplies in shearwaters (*Puffinus therminier*), puffins (*Fratercula arctica*) (Harris 1969, 1978), and terns (*Sterna* spp.) (LeCroy and Collins 1972), and mass gains have been used as a measure of growth rates in many species. A lack of food resources may slow or limit development (O'Connor 1977) to the point that chicks that fail to gain mass above certain thresholds do not survive (e.g., brown pelicans [*Pelecanus occidentalis*], Schreiber 1976; house wrens [*Troglodytes aedon*], Ricklefs 1983). Initially, precocial chicks devote most of their energy to maintenance and survival (Ricklefs 1973). At 10–25% of adult mass, the metabolic rate and energy demand are greatest (Ricklefs 1974:246). This corresponds to piping plover chick masses of 5–13 g; the same range of masses in chicks

4–5 days old. Therefore, differences in relative masses of plover chicks may reflect the chicks' ability to survive and increase their body mass on available resources.

At 4–5 days of age, masses of piping plover chicks that ultimately survived were greater than the masses of chicks that did not survive. This is consistent with our hypothesis that poor food supply contributes to chick mortality on AINS. Cairns (1982) also reported that chicks that did not fledge had lower body masses in the first 10 days than did chicks that survived.

Invertebrate Prey

Bay beach and island interior habitats were superior to ocean beaches with respect to terrestrial prey available to piping plover chicks. Ocean beaches had greater substrate invertebrate densities than did other habitats; however, these may have been unavailable to young chicks. Amphipods composed most of these samples, showed the greatest differences among habitats, and were responsible for differences we observed. Most of these organisms live in the saturated zone of the intertidal area (Loegering 1992:180) and migrate up and down the beach with the tide (Vader 1964). On AINS, chicks <10 days old seldom used this area and restricted their foraging to the wet zone and wrack line. Chicks >20 days old and adults, however, used the saturated zone often. This pattern of use may be unique to AINS or the southern Atlantic coast. Elsewhere along the Atlantic Coast, piping plover chicks feed primarily in ocean beach habitat and have higher survival rates (e.g., MacIvor 1990), but it is unclear whether these chicks are feeding on insect prey associated with wrack or amphipods. Goldin (1993) and Hoopes (1993) reported piping plover chicks preferred wrack habitats; however,

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