

PREDATOR EXCLOSURES: A TECHNIQUE TO REDUCE PREDATION AT PIPING PLOVER NESTS

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Federal listing of the piping plover as endangered and threatened (Federal Register 1985) has prompted intensive management to reduce impacts of predation and other factors limiting piping plover productivity (Dyer et al. 1988, Haig et al. 1988, Melvin et al. 1991). While studying piping plover breeding biology at 6 sites on Cape Cod, Massachusetts, during 1985-1987, we determined that at least 79 of 126 (63%) piping plover nests were destroyed by red foxes (*Vulpes vulpes*), striped skunks (*Mephitis mephitis*), American crows (*Corvus brachyrhynchos*), and gulls (*Larus* spp.) (MacIvor 1990). These results led us to investigate the use of predator exclosures (Nol and Brooks 1982, Post and Greenlaw 1989, Rimmer and Deblinger 1990) to reduce predation of piping plover nests. We first used an exclosure to protect a piping plover nest at Coast Guard Beach on Cape Cod in 1987. Although foxes destroyed 5 previous clutches laid by that pair of plovers that summer, the protected nest hatched successfully and 1 chick fledged. We describe the construction, installation, and success of circular, wire predator exclosures that we placed around individual piping plover nests in Massachusetts in 1988 and 1989.

STUDY AREA AND METHODS

We examined effects of predator exclosures on piping plover productivity at 6 nesting beaches on outer

Cape Cod: Race Point Beach in Provincetown, Jeremy Point and Marconi Beach in Wellfleet, Coast Guard Beach in Eastham, and South Beach Island and Monomoy National Wildlife Refuge (NWR) in Chatham. Piping plovers nested at these beaches on upper berms, primary and secondary dunes, and overwash areas. Red foxes and American crows were present at all sites except Monomoy NWR; skunks were present at Race Point Beach, Coast Guard Beach, and South Beach Island; and gulls were present at all sites.

Each exclosure consisted of a 1- × 10-m piece of 5- × 10-cm (2- × 4-inch) galvanized wire mesh fencing placed in a 3.2-m-diameter circle around the nest (Fig. 1). Fencing was stapled to 5, 2.5- × 12.5-cm or 5.0- × 5.0-cm sharpened, evenly spaced wooden posts 150 cm tall. Tops of posts were positioned 5 cm below the top of the wire mesh to discourage perching by avian predators. Plovers could walk through the mesh, but mammalian predators could not. Total cost for each exclosure was approximately \$15 U.S., and most materials could be reused.

Two to 5 people (usually 3 or 4) installed exclosures using a sledgehammer, needle-nose pliers, and shovel. Fencing with wooden stakes attached was unrolled at least 60 m from nests to minimize disturbance to plovers. One person directed installation of the exclosure to avoid breaking eggs. Fencing was placed upright in a 5- to 8-cm deep trench dug around the nest. The ends were wired together, and support posts were pounded approximately 0.8 m into the sand so that the fence bottom was buried about 9 cm. Sand was smoothed around the outside of exclosures with a shovel or by hand to provide easy access for plovers and to reduce accretion of windblown sand. We installed exclosures on days with <32 km/hour wind velocity, 10-25 C air temperatures, and no rain. We preferred to install exclosures in early morning when the fewest people were on the beach. Portions of beaches where exclosures were used were cordoned off with symbolic fencing (twine stretched between posts with warning signs) to discourage people from approaching and disturbing incubating plovers.

Data collected at time of installation were: clutch age, time to install exclosures, time from completion of installation until incubation was resumed, and total duration of incubation interruption. We observed fenced nests for up to 30 minutes following installation to

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Fig. 1. Circular predator enclosure around a piping plover nest, Cape Cod, Massachusetts, 1988.

determine if both members of a pair would accept the presence of an enclosure and continue to share incubation duties. Sex of adults was determined from courtship displays and plumage differences (Cairns 1982, Haig and Oring 1988). Enclosures were removed after eggs hatched and chicks had left the immediate vicinity of the nest.

We protected 12 nests in 1988 and 17 nests in 1989 with enclosures. We left unprotected as controls 17 nests in 1988 and 7 in 1989. Excluded from these totals are 2 protected nests that were lost to overwash by high tides and 3 unprotected nests lost to overwash (2) and drifting sand. Selection of nests to be protected in 1988 was partly haphazard although we sought to maintain nearly equal sample sizes of protected and unprotected nests at each beach and for all beaches combined. Our sample of unprotected (control) nests was smaller in 1989 because we attempted to enclose a majority of nests to boost productivity. To reduce chances of abandonment, all but 2 enclosures were erected after clutches had been completed. In 1988, we installed enclosures around 2 incomplete clutches of 3 eggs each at 2 beaches where eggs were being depredated before clutches were complete. Unprotected nests depredated during egg-laying ($n = 8$) were included in the control sample.

Protected and unprotected nests were checked daily (1988) or every other day (1989) at Coast Guard, Marconi, and Race Point Beaches, and 1–3 times each week at other beaches. During each visit, we determined if an adult was incubating or if the nest had been abandoned or depredated. We removed seaweed or other debris caught in the wire and smoothed sand as needed.

We used the Mayfield method (Mayfield 1961, 1975) to calculate daily survival rates of protected and unprotected nests based on number of days nests were exposed to predation. We considered a nest successful if at least 1 egg hatched. We defined hatching success as percentage of eggs laid that survived to hatching and productivity as number of chicks fledged/pair. We based calculations of hatching success and productivity for protected and unprotected nests in 1988–1989 only on eggs that survived to incubation. We assumed a

7-day egg-laying period and 27-day incubation period. A chick was considered fledged if it reached 25 days of age or was observed in flight for ≥ 15 m. Mayfield (1961, 1975) suggested that observed hatching rates are usually overestimates of true rates because eggs that are destroyed and never found are excluded from calculations. In our study, we believe that the number of eggs not found was negligible because of the high frequency of visits to most of our sites, intensive nest searches and observations of marked birds, and the fact that most nests were found during the egg-laying period.

We used contingency table analysis (Zar 1984:64) to compare nest success, nest survival rates, and hatching success between unprotected and protected nests; in all cases, we considered unprotected nests to be controls and protected nests to be treatments. Although we recognize that presence of potential predator species varied among beaches, we used contingency table analysis to test nest survival rates rather than an ANOVA block design. This is because of our small sample size, the high probability of potential predation of plover nests at all beaches, the difficulty of calculating a standard error for survival estimates calculated by the Mayfield method, and the overwhelming results of the contingency table analysis. We used t -tests and ANOVA to compare productivity between protected and unprotected nests. The following data were pooled over years because we could not detect significant between-year differences: success of protected nests in 1988 and 1989 ($\chi^2 = 0.10$, 1 df, $P = 0.75$); mean number of young fledged/pair in 1985, 1986, and 1987 (ANOVA, $F = 1.71$; 2,60 df; $P = 0.41$); and mean number of young fledged/pair in 1988 and 1989 ($t = 1.56$, 37 df, $P = 0.13$).

RESULTS AND DISCUSSION

Twenty-six of 29 nests (90%) protected by enclosures in 1988 and 1989 hatched at least 1 egg (Table 1). In contrast, only 4 of 24 nests (17%) unprotected by enclosures hatched eggs. Daily survival rate for protected nests (0.994) was higher than for unprotected nests (0.930) ($\chi^2 = 26.64$, 1 df, $P < 0.001$). Of the 3 protected nests that failed, 2 were destroyed, probably by a skunk that tunneled under the enclosure and by an avian predator. The third was abandoned for unknown reasons 3 days after enclosure installation. Unprotected nests were destroyed by red fox (14 nests), gull (3), crow (1), and unknown (2).

Hatching success for eggs that survived to incubation was 74% (77/104 eggs) for protected nests ($n = 27$) compared to only 19%

Table 1. Number of protected ($n = 29$) and unprotected ($n = 24$) piping plover nests that hatched ≥ 1 egg or failed at 6 beaches on outer Cape Cod, Massachusetts, 1988–1989.

Location	Protected		Unprotected	
	Hatched	Failed	Hatched	Failed
Race Point	6	2	1	6
Jeremy Point	1	0	1	0
Marconi Beach	4	0	0	1
Coast Guard Beach	5	1	0	6
South Beach Island	3	0	1	4
Monomoy NWR	7	0	1	3
Totals ^a	26	3	4	20

^a Number of hatched and failed nests differed ($\chi^2 = 25.59$, 1 df, $P < 0.001$) between protected and unprotected nests.

(11/59 eggs) for unprotected nests ($n = 16$) ($\chi^2 = 44.24$, 1 df, $P < 0.001$). Mean number of chicks fledged/pair was 1.96 for protected nests compared to 0.12 for unprotected nests ($t = 5.11$, 41 df, $P < 0.001$). Overall productivity at all 6 sites increased from a mean of 0.60 chicks fledged/pair during 1985–1987 (prior to exclosure use) to 1.41 chicks fledged/pair during 1988–1989 when 29 of 53 nests (55%) were protected with exclosures ($t = 5.74$, 100 df, $P < 0.001$).

Our estimate of nest success was biased because 8 nests destroyed during egg-laying were classified as controls (unprotected), whereas only 2 of 29 protected nests were exclosed during egg-laying. The protection provided by exclosures may have been overestimated because control nests were exposed to predation for longer periods than treatment nests. This bias resulted from our decision to place exclosures, with 2 exceptions, around only nests with complete clutches. However, this does not change our conclusion that exclosures were effective in reducing nest loss to predation, given the highly significant differences that we observed in nest success and survival. The fact that 8 of 24 unprotected nests were destroyed during egg-laying further demonstrates the severity of predation at our study beaches and

stands in contrast to the high success of nests protected by exclosures during incubation.

We installed exclosures between 14 May and 3 July in 1988 and between 4 May and 22 June in 1989, 6–20 days after egg-laying began ($\bar{x} = 10.7$, SE = 1.1). Installation time averaged 9.5 minutes (SE = 0.8, range = 4.3–20.0, $n = 31$). Installation time with 3 people ($\bar{x} = 11.1$ min, SE = 1.9, $n = 8$) was not significantly longer than with 4 people ($\bar{x} = 8.2$ min, SE = 0.8, $n = 17$) ($t = 1.65$, 23 df, $P = 0.12$). Time between completion of exclosure installation and when plovers returned to eggs was recorded at 24 nests and averaged 8.5 minutes (SE = 1.8, range = 2.1–43.5); at 17 of 24 nests (71%) plovers resumed incubation <10 minutes after installation was completed. Total time that plovers spent off nests (from initial flush until resumption of incubation) averaged 17.3 minutes (SE = 1.9, range = 6.5–51.3, $n = 24$) and was <20 minutes at 18 of 24 nests (75%). We recorded incubation exchanges at 12 of 30 nests (40%) within 30 minutes after exclosures were installed.

In both instances where we placed exclosures around incomplete clutches of 3 eggs, the pairs accepted the exclosures and laid the fourth egg of the clutch within 24 hours. Both nests hatched 2 of 4 eggs.

Plovers usually left and returned to nests within exclosures by walking or running through the wire mesh. On 4 occasions, plovers left by flying up and out of exclosures; all of these were at nests in dense vegetation that likely obscured approach by investigators. Two pairs did not tolerate exclosures around their nests and resumed incubation only after exclosures were removed 1–2 hours after installation. These nests were classified as unprotected in calculations of nest success. The first pair had been captured with a wire box trap and banded the previous day and may have been especially wary. The second pair nested on Monomoy NWR where incubating plovers encounter less human disturbance, seem less habituated to people than at other sites, and

often do not return to nests when people are nearby. Both nests of these intolerant pairs were preyed upon within 2 weeks after exclosures were removed. Abandonment of another nest 3 days after exclosure installation did not appear to result from failure of plovers to accept the structure because both members of the pair were observed incubating after exclosure installation.

On 6 occasions, we observed people cross over symbolic fencing and walk up to exclosures, causing the incubating plovers to leave. In all cases, the birds returned and resumed incubation after the people left. Seaweed and trash occasionally accumulated on exclosures and had to be removed but was never sufficient to block access by the plovers. Likewise, sand often accumulated along 1 side of exclosures but did not block access.

Rimmer and Deblinger (1990) reported similar success using larger (30.5-m-perimeter), triangular wire-mesh exclosures to protect piping plover nests (24 of 26 [92%] protected nests hatched, 18 of 24 [75%] unprotected nests failed). Their design was more expensive (\$50/exclosure) and took longer to install (≤ 30 min) than ours but maintained a wider buffer area between the centered nest and the edge of the exclosure. They used twine or monofilament line over tops of exclosures to discourage avian predators, especially crows. Our uncovered design seemed to protect piping plover nests from gull predation on Monomoy NWR, where $> 19,000$ pairs of herring gulls (*Larus argentatus*) and great black-backed gulls (*L. marinus*) nest (U.S. Fish and Wildl. Serv. 1988).

Nol and Brooks (1982) had less success using 1-m² wire exclosures with 7- × 12-cm openings cut in the sides to protect killdeer (*Charadrius vociferus*) nests from predators. These exclosures reduced gull predation but not mammalian predation apparently because mammals could enter or reach through the side openings. As with Rimmer and Deblinger (1990), our use of larger exclosures with smaller openings apparently solved this problem.

MANAGEMENT RECOMMENDATIONS

We recommend use of predator exclosures to protect piping plover nests only at sites where nest predation has been documented as a consistent and significant limiting factor (Dyer et al. 1988:45) and where species of nest predators have been identified. Use 3–4 people to install exclosures. One person should direct others in placing the exclosure around the nest to prevent stepping on eggs. Damage to eggs may also be avoided by placing a hat or other clearly visible object over or near the nest. Minimize installation time to reduce the time adult plovers are off the nest. If avian predators are nearby, postpone installation to avoid alerting crows or gulls to the location of plover nests (MacInnes and Misra 1972, Picozzi 1975). Place symbolic fencing ≥ 50 m outside exclosures, if possible, to minimize human disturbance near exclosures. Symbolic fencing, combined with public education efforts and effective enforcement, may be especially important on relatively narrow beaches, where people walking along the water's edge may be attracted to nearby exclosures that are clearly visible.

Behavior of nesting plovers should be monitored to ensure that 1 adult returns to incubate eggs ≤ 1 hour after installation and that the other adult is seen incubating ≤ 24 hours after installation. Exclosures should be removed if these conditions are not met. For the duration of incubation, nests should be checked at least every other day from a distance with binoculars or spotting scope (MacIvor et al. 1990) to increase the chances of determining causes of nest loss and to ensure prompt removal of debris that might accumulate and block access. If a protected nest is destroyed, a thorough search should be conducted to determine the cause. Exclosures should be removed as soon as chicks have hatched and left the immediate area to reduce the potential that predators may habituate to fencing.

If mammalian predators dig under or jump over exclosures, modifications may be needed.

These could include burying exclosures deeper or installing a wire-mesh apron laterally from the exclosure base to discourage predators from digging under. Angling the top of exclosures outward or extending the height of exclosures may discourage predators from jumping over. Black seiner's twine or monofilament line stretched over the top of exclosures has discouraged avian predators from flying into exclosures (Rimmer and Deblinger 1990). However, because we observed piping plovers flying up and out of exclosures when disturbed, especially at nests in dense vegetation, we recommend that exclosures be covered with twine only at sites where avian predation has been documented.

At beaches where predation is so severe that eggs may be eaten soon after they are laid, it may be necessary to install exclosures around incomplete clutches. In this case, plover behavior should be monitored closely to ensure that exclosures are accepted. Some foxes regularly visit nesting colonies of least terns (*Sterna antillarum*) (E. M. Hoopes, C. R. Griffin, S. M. Melvin, and M. J. Croonquist, Univ. Massachusetts, Amherst, unpubl. rep., 1989), and plovers often nest within or on the peripheries of these colonies. We suggest enclosing plover nests separately from tern nests to reduce the potential of predation on plover nests associated with tern colonies. If a tern nest is near a plover nest, placing the exclosure around both nests may be necessary. In this situation, string should not be placed over the top because it may impede terns attempting to fly to and from their nests.

SUMMARY

Circular, 3.2-m-diameter wire-mesh exclosures significantly reduced predation on piping plover nests at 6 beaches on Cape Cod, Massachusetts. Ninety percent of nests protected by exclosures in 1988 and 1989 hatched at least 1 egg compared to 17% of unprotected nests in those years. Hatching success was 74% for

nests protected by exclosures compared to only 19% for unprotected nests. Mean number of chicks fledged/pair in 1988–1989 was 1.96 for protected nests compared to 0.12 for unprotected nests. Mean productivity at all sites increased from 0.60 chicks fledged/pair during 1985–1987 (before exclosure use) to 1.41 chicks/pair during 1988–1989 when 29 of 53 nests (55%) were protected with exclosures. Installation time averaged 9.5 minutes/exclosure, and incubating plovers were kept off nests an average of 17.3 minutes. Cost/exclosure was \$15 U.S.

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LITERATURE CITED

- CAIRNS, W. E. 1982. Biology and behaviour of breeding piping plovers. *Wilson Bull.* 94:531–545.
DYER, R. W., A. HECHT, S. MELVIN, C. RAITHEL, AND

- K. TERWILLIGER. 1988. Atlantic coast piping plover recovery plan. U.S. Fish and Wildl. Serv., Newton Corner, Mass. 77pp.
- FEDERAL REGISTER. 1985. 50(238):50,726-50,734.
- HAIG, S. M., AND L. W. ORING. 1988. Mate, site, and territory fidelity in piping plovers. *Auk* 105:268-277.
- , W. HARRISON, R. LOCK, L. PFANNMULLER, E. PIKE, M. RYAN, AND J. SIDLE. 1988. Great Lakes and northern Great Plains piping plover recovery plan. U.S. Fish and Wildl. Serv., Twin Cities, Minn. 160pp.
- MACINNES, C. D., AND R. K. MISRA. 1972. Predation on Canada goose nests at McConnell River, Northwest Territories. *J. Wildl. Manage.* 36:414-422.
- MACIVOR, L. H. 1990. Population dynamics, breeding ecology, and management of piping plovers on outer Cape Cod, Massachusetts. M.S. Thesis, Univ. Massachusetts, Amherst. 100pp.
- , S. M. MELVIN, AND C. R. GRIFFIN. 1990. Effects of research activity on piping plover nest predation. *J. Wildl. Manage.* 54:443-447.
- MAYFIELD, H. F. 1961. Nesting success calculated from exposure. *Wilson Bull.* 73:255-261.
- . 1975. Suggestions for calculating nest success. *Wilson Bull.* 87:456-466.
- MELVIN, S. M., C. R. GRIFFIN, AND L. H. MACIVOR. 1991. Recovery strategies for piping plovers in managed coastal landscapes. *Coastal Manage.* 19:21-34.
- NOL, E., AND R. J. BROOKS. 1982. Effects of predator closures on nesting success of killdeer. *J. Field Ornithol.* 53:263-268.
- PICOZZI, N. 1975. Crow predation on marked nests. *J. Wildl. Manage.* 42:471-476.
- POST, W., AND J. S. GREENLAW. 1989. Metal barriers protect near-ground nests from predators. *J. Field Ornithol.* 60:102-103.
- RIMMER, D. W., AND R. D. DEBLINGER. 1990. Use of predator closures to protect piping plover nests. *J. Field Ornithol.* 61:217-223.
- U.S. FISH AND WILDLIFE SERVICE. 1988. Final environmental assessment. Monomoy National Wildlife Refuge master plan. U.S. Fish and Wildl. Serv., Newton Corner, Mass. 186pp.
- ZAR, J. H. 1984. *Biostatistical analysis*. Second ed. Prentice-Hall, Inc., Englewood Cliffs, N.J. 718pp.

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POTENTIAL INDICES OF MALLARD AND WOOD DUCK ABUNDANCE IN FORESTED WETLANDS DURING WINTER

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Mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*) have been the most heavily harvested species of ducks in the Mississippi and Atlantic flyways since the 1960's (Bellrose and Heister 1987, Gamble 1990, Serie and Chasko 1990). Forested wetlands, especially

red oak (subgenus *Erythrobalanus*) bottomlands, are important migrational and wintering habitats for both species (Bellrose 1976:194, 235; Fredrickson and Heitmeyer 1988; Thompson and Baldassarre 1988; Reinecke et al. 1989; Heitmeyer and Fredrickson 1990). However, estimating abundance of these birds in forested wetlands can be difficult, variable, and costly. Hence, only a few attempts have

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