Predation on Adult Piping Plovers at Predator Exclosure Cages

ROBERT K. MURPHY[1], ISABELLE M. G. MICHAUD[2,3], DAVID R. C. PRESCOTT[2,4], JACOB S. IVAN[5], BEVERLY J. ANDERSON[5,6] AND MARLANEA L. FRENCH-POMBIER[7,8]

[1]US. Fish and Wildlife Service, Des Lacs National Wildlife Refuge Complex
8315 Hwy 8, Kenmare, ND 58746, USA
Internet: bob_murphy@fws.gov

[2]Alberta Conservation Association, 6909 116th Street, Edmonton, AB T6H 4P2, Canada

[3]Present address: Box 40027 Baker Centre Postal Outlet, Edmonton, AB T5K 2M4, Canada

[4]Present address: Alberta Sustainable Resource Development, 4911 51st Street, Red Deer, AB T4N 6V4, Canada

[5]The Nature Conservancy, 8315 Hwy 8, Kenmare, ND 58501, USA

[6]Present address: Rookery Bay National Estuarine Research Reserve, 300 Tower Road, Naples, FL 34113, USA

[7]U.S. Geological Survey-Biological Resources Division, Northern Prairie Wildlife Research Center
8711 37th Street SE, Jamestown, ND 58401, USA

[8]Present address: Ottawa National Forest, 990 Lalley Road, Iron River, MI 49935, USA

Abstract.—To boost productivity in the Piping Plovers (*Charadrius melodus*) breeding in the northern Great Plains, predator exclosure "cages" constructed of wire mesh fence were placed over 1,355 plover nests on alkali lake beaches in Alberta, Saskatchewan, North Dakota, and Montana during 1993-2002. Nesting plovers were killed, apparently by raptors, near cages at 68 (5%) of the nests. In contrast, no losses of adult plovers were detected at 420 nests that were not covered by cages. The predation was greatest (up to 48% of applications) when small (1-1.7 m) diameter cages with wire mesh tops were used at sites with low (mean, 4%) or moderate (15%) tree cover within two km. In areas with low tree cover, predation decreased to 0.7% of applications/year when large (3-4 m) diameter cages with soft netting tops replaced other designs. No predation was recorded in 393 applications of small cages at plover nests along the relatively treeless North Dakota-Montana border. Predator exclosure cages should be used cautiously for protecting eggs of endangered shorebirds. In some situations, enhanced productivity from use of the cages is outweighed by risks to adult birds. *Received 13 May 2002, accepted 8 January 2003.*

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Predators can be deterred from taking eggs of endangered shorebirds by large wire mesh exclosures (cages) placed over individual nests, which still allow access for the incubating adult. On the U.S. Atlantic coast, for example, reproductive output of the Piping Plover (*Charadrius melodus*) has improved through the use of cages topped with strings or netting (Rimmer and Deblinger 1990; Melvin *et al.* 1992). Likewise, resource managers in the northern Great Plains used cages to boost Piping Plover productivity; up to 392 cages were applied annually during 1998-2002 (this paper; C. Kruse and G. Pavelka, pers. comm.). However, predation by raptors on adult Piping Plovers at cages has emerged as a significant problem on alkali lakes in the Great Plains. Here we describe this problem and efforts to resolve it, to alert resource managers and help prevent similar problems with management of endangered shorebirds elsewhere. Johnson and Oring (2002) recently called attention to this general problem, stemming from experiences with predation by mustelids on Killdeer (*C. vociferous*) nesting within exclosure cages in California.

STUDY AREAS AND METHODS

Our data were collected from alkali lakes in the northern Great Plains during 1993-2002, in five areas from Alberta to North Dakota (Fig. 1). Plover nesting beaches were sparsely vegetated by Alkali Grass (*Puccinellia nutalliana*), Inland Saltgrass (*Distichilis spicata*),

Figure 1. Alkali lake areas in the northern Great Plains where predator exclosure cages were used to protect Piping Plover nests during 1993-2002: Hanna (cages used on 3 lakes, 1998-2000); Reflex Lakes (10 lakes, 1995-2000); Stateline (15 lakes, 1995-2002); Lostwood (15 lakes, 1993-2002); Williams Preserve (7 lakes, 1995 and 1997-2002).

and Saltwort (*Salicornia rubra*) (see Prindiville Gaines and Ryan 1988, Murphy *et al.* 2000). Landscapes within two km of the lakes mainly were rolling uplands dominated by grazed and idle native prairie and farmland. Trees, which harbor predators in the region (Sargeant *et al.* 1993), were nearly absent at the Stateline area. Planted farm shelterbelts and Quaking Aspen (*Populus tremuloides*) woodland covered an average of 4% of landscapes within two km of lakes at the Hanna, Lostwood and Williams Preserve areas, and Quaking Aspen woodland covered 15% of the landscape around lakes at the Reflex Lakes area. Potential predators of adult plovers in the study areas included Coyote (*Canis latrans*), Red Fox (*Vulpes vulpes*), Raccoon (*Procyon lotor*; North Dakota and Montana only), American Badger (*Taxidea taxus*), Striped Skunk (*Mephitis mephitis*), gulls (*Larus* spp.), Northern Harrier (*Circus cyaneus*), Merlin (*Falco columbarius*; Hanna and Reflex Lakes only), Red-tailed Hawk (*Buteo jamaicensis*), Swainson's Hawk (*B. swainsonii*), Great Horned Owl (*Bubo virginianus*), and American Crow (*Corvus brachyrhynchos*).

Plover nesting beaches were surveyed weekly during May and June to identify territorial pairs and locate nests, using standard methods (Murphy *et al.* 1999). During laying or early incubation, cages were placed over most nests to protect them from predators. Cages initially were constructed of 5-cm wide mesh wire and were small (1-1.7 m) in diameter. In areas where adult plovers were killed by predators at these cages, the small cages were replaced in following years by large (3-4 m) diameter cages. Subsequently, the wire mesh tops of the large cages were replaced by fruit-tree netting to discourage perching by avian predators (U.S. Fish and Wildlife Service 1996), in an attempt to further avoid predation. All cages were about one m tall. Cages were secured to the ground with iron stakes and fiberglass rods; no attempt was made to bury bottom edges. At Williams Preserve, Lostwood, and Stateline areas, 1.1-m tall electric fences were sometimes used to bar mammalian predators from entire nesting beaches where cages also were employed (Larson *et al.* 2002).

After nests were located, each plover territory was monitored one to three times weekly until a pair failed in its nesting attempt and abandoned its territory, or reared chicks to near fledging age (18-20 days [Murphy *et al.* 1999]). To avoid disturbance to nesting plovers, each territory was observed from 30-200 m with 10 × 50 binoculars or a 15-60× spotting scope. Nests were investigated closely if no adults were seen. At least one adult Piping Plover was assumed killed at a cage when remains were found (i.e., ranging from blood and plucked feathers, to a partially plucked and consumed carcass) less than 1 m from the cage. We classified predation events as episodic if losses at three or more cages within one km of each other were involved, and coincided within a week. This distinction, which suggested rapid associative learning by an individual predator, was important because losses of multiple adults clearly were of greater concern than an isolated, infrequent predation event. During several such episodes, the disappearance of a breeding pair of plovers from an intact clutch within a cage coincided with obvious predation of adult plovers at other cages on the same beaches. Again, we assumed one adult plover was killed in such situations. This assumption seemed reasonable because Piping Plovers rarely abandon their nests on alkali lake beaches (about 1% of nests; Murphy *et al.* 2000; D. Prescott, unpublished), especially when mild weather prevails and incubation is advanced, as in these cases; we believe evidence of predation (i.e., plucked feathers) had blown away, or entire carcasses had been carried away by predators. No attempts were made to remove predators except in 1996 when a Great Horned Owl which preyed on adult plovers at cages in the Lostwood area was captured and removed.

Analyses of data from this unplanned assessment were limited by confounding factors: lack of independence, changes in cage design within and among areas, occasional use of electric fence, and the removal of an owl. Thus, only descriptive summary statistics were used.

RESULTS

Cages were used to cover 1,355 Piping Plover nests during 1993-2002 (Table 1). At least 73 adult plovers were killed by predators at 68 (5%) of these nests. During this same period, no adult plover mortality was detected at 420 nests not covered with cages in the study areas. At least 40 adult plovers were killed in 1999, the year in which most (319) cages were used.

The incidence of predation varied by area and cage size and covering type (Tables 1 and 2; Fig. 2). No losses were detected in

Table 1. Predation on adult Piping Plovers at predator exclosure cages at alkali lakes in five areas across the northern Great Plains during 1993-2002: number of applications of cages at which plovers were killed (N_d) and total number of applications of cages (N_{tot}).

	Hanna		Reflex Lakes		Stateline		Lostwood		Williams Preserve	
Year	N_d	N_{tot}	N_d	N_{tot}	N_d	N_{tot}	N_d	N_{tot}	N_d	N_{tot}
1993							0	8		
1994							0	9		
1995			1	20	0	2	0	30	0	9
1996			0	17	0	21	10	51		
1997			1	15	0	35	0	46	3	15
1998	0	12	3	28	0	44	0	114	6	34
1999	13	27	14	41	0	103	11	125	0	23
2000	0	4	4	35	0	40	0	56	0	25
2001					0	75	1	78	0	44
2002					0	73	1	56	0	40
Total	13	43	23	156	0	393	23	573	9	190
%	30		15		0		4		5	

eight years of applications of small cages on the nearly treeless Stateline area. However, adult plovers were preyed on in areas with trees, especially when small cages were used. For example, adult plovers were killed at 48% of small cages in the Hanna and Reflex Lakes areas. Conversely, losses in areas with trees were less likely when large cages with netting tops were used. After small cages were replaced by large cages with netting at Reflex Lakes, the proportion of cages at which adult plovers were killed was reduced from 34% to 11% (Table 1: 1999 versus 2000). In other areas, losses occurred at only 0.7% of applications of large cages with netting tops (N = 303), despite widespread predation at cages with wire tops in these areas in previous years. For example, when 71 large cages with netting tops were used at Lostwood and Williams Preserve areas in 2000, no mortality was detected among adult plovers, even though predation had occurred at 7.5% of 134 large cages with wire tops in these areas in 1999.

Most (81%) predation occurred as episodes (N = 9) that involved losses at 3-16 cages ($\bar{x}$ = 6.2, SD ± 2.7) over 2-10 days. An episode occurred at the same lake at Williams Preserve in successive years, 1997 (three cages) and 1998 (five cages). An episode also occurred in each of 1999 and 2000 at the same lake at Reflex Lakes (eleven and four cages), following three isolated predation events in 1998.

Evidence suggested that adult Piping Plovers were killed by raptors at 78% (53 of 68) of cages where plover losses were recorded. Adult losses at eleven other cages were indicated by nest abandonments that coincided with local episodes and may also have been raptor-caused mortality. Predation was as-

Table 2. Number of applications of predator exclosure cages at which adult Piping Plovers were killed (N_d) and total number of applications (N_{tot}) for two sizes of cages used to protect plover nests at alkali lakes in the northern Great Plains during 1993-2002.

	Small cages[a]		Large cages[b,c]	
Year	N_d	N_{to}	N_d	N_{tot}
1993	0	8		
1994	0	9		
1995	0	41	1	20
1996	10	89		
1997	4	111		
1998	9	122	0	110
1999	27	198	11	121
2000	0	44	4	116
2001	0	75	1	122
2002	0	73	1	96
Total	50	770	18	585
%	6.5		3.1	

[a]1-1.7m diameter.
[b]3-4m diameter.
[c]Changed from wire mesh top to netting top in 2000.

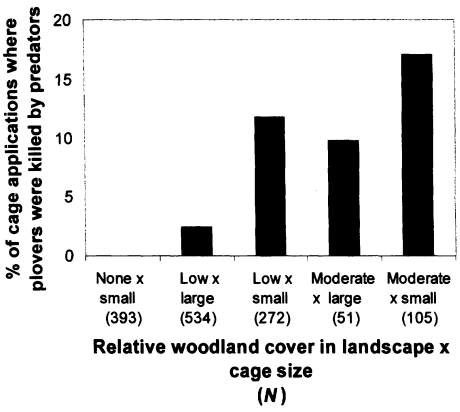

Figure 2. Frequency of predation on adult Piping Plovers at predator exclosure cages as a function of surrounding woodland cover (none: <1% of landscape wooded within 2 km; low: 4%; moderate: 15%) and cage size (small: 1- to 1.7-m diameter; large: 3- to 4-m diameter), at five alkali lake areas in the northern Great Plains during 1993-2002. Numbers of applications are indicated parenthetically.

cribed to raptors based on evidence at nest sites and observation of individual raptors. For example, among predation events at Lostwood National Wildlife Refuge in 1996, numerous (12-20) plucked contour feathers were noted, some flecked with blood, within 15 cm of each cage. There was no evidence of digging or damage to wire mesh exclosures, nor of tracks of potential predators along nearby shorelines. All nests were intact. Distal parts of a pair of plover wings remained at two kill sites. A Great Horned Owl or sign (contour feathers, urates) of the owl was observed at beaches where plovers had been taken. After capture and removal of the owl, no additional plover mortality was recorded on the refuge.

At Reflex Lakes, Hanna, and Williams Preserve, remains of adult plovers typically consisted of partially to thoroughly plucked, decapitated, partial carcasses, with breast and leg musculature delicately removed from bones, diagnostic of raptor predation (Weidensaul 2000:166). At least one of the adult plovers at Williams Preserve had been killed at mid-day (indicated by a moist, discarded gastrointestinal tract when discovered in mid-afternoon), suggesting a diurnal raptor. Some plovers killed at Reflex Lakes and Hanna were represented merely by a few contour feathers, although partial or complete heads of decapitated plovers were found at about a quarter of the cages. At the end of a spate of plover deaths at Reflex Lakes in 1999, a Merlin in flight was observed striking the side of a cage, then catching the adult plover on the cage edge as the plover departed. Merlin predation on plovers at Reflex Lakes, presumably the same individual raptor, continued during the following year, despite replacement of small cages by large cages. Most (91%) plover nests at which adults were killed at Hanna, Reflex Lakes, and Williams Preserve were intact and no damage to the cages was found. Finally, 39% of 31 cages where plovers were killed at Lostwood and Williams Preserve were within electrified fences that barred mammalian predators, supporting other evidence that losses were due mainly to avian predators.

DISCUSSION

We noted appreciable mortality among adult Piping Plovers at predator exclosure cages and strong evidence indicated that this was caused mainly by raptors. Losses were greatest at small cages, except no predation was detected in 393 small cages used at the Stateline area where trees were scarce, suggesting losses were caused by tree-associated raptors (e.g., Red-tailed Hawk, Great Horned Owl) (Sargeant *et al.* 1993). This suggests that the species makeup of local predator communities influences the security of adult Piping Plovers nesting within predator exclosure cages. At areas other than Stateline, predation on adult plovers seemed less at large cages than at small cages, and even less when netting tops were used, which apparently were too unstable to afford perching by raptors. Indeed, predation ended almost entirely at Lostwood and Williams Preserve when large cages with netting tops replaced other cages. We believe there were no major changes in the composition of the predator community in these areas. However at Reflex Lakes, adult plovers

continued to be killed at large cages, perhaps by the same Merlin.

Predator exclosure cages can play an important role in reversing declines of Piping Plovers (Larson *et al.* 2002) and other shorebird species, but only if managers devise and employ cages which avoid losses of adults. The breeding season normally is a safe period for adult plovers; we recorded no adult mortality at nests not covered with cages. Adult survival rates are important because in the Piping Plover population viability is particularly sensitive to changes in adult survival (Larson *et al.* 2000). Using the following estimates, the increased production needed can be estimated: (1) a recently published estimate of adult survival (0.74) derived from eleven years of re-sightings of plovers marked at Williams Preserve, plus a crude but reasonable estimate of juvenile survival (0.50) (Larson *et al.* 2000); (2) a mean production level of 1.3 fledglings (i.e., 2.5-week-old chicks)/pair for plover pairs managed by cages (Larson *et al.* 2002); and (3) an assumption that a mean of 1.5 adults is killed per application where predation occurs. To offset a loss of adult plovers at 0.7% of cage applications (i.e., the loss rate observed at large cages with netting tops in most areas in this study), the mean production per pair must increase by about 2%. Such an increase seems possible, but increasingly greater levels of production do not. To offset our observed overall loss of adult plovers at 5% of cage applications, production must be increased 15-25%, to 1.5-1.6 fledglings/pair, a level difficult to achieve with current management. Thus, progress towards reversing a steady decline in the plover's northern Great Plains population seems unlikely if adults are killed in 5% of cage applications, and greater levels of loss probably contribute to the decline.

Large cage size has been recommended for managing Piping Plovers on the Atlantic coast (U.S. Fish and Wildlife Service 1996) mainly to reduce chances of entanglement in cage tops, but it may also provide a critical escape distance (i.e., raptors perched on small cages have short distances to move to capture emerging plovers). Tops of cages should be designed to discourage bird perching, by combining flexible coverings such as plastic fruit tree netting ($\leq 2 \times 2$-cm square mesh; U.S. Fish and Wildlife Service 1996) with stiff wires projecting 8-10 cm vertically around the cage rim. Initially, reports of adult plover mortality due to entanglement in netting tops on the Atlantic coast prompted resource managers in the Great Plains to avoid this material and adopt wire tops instead. Losses of Atlantic coast plovers due to entanglements in mesh netting are relatively rare (<0.5% of applications; A. Hecht, pers. comm.), compared to predation losses we recorded at cages with mesh wire tops.

Resource managers should closely monitor cages placed over shorebird nests for signs of predation or other problems. Evidence of predation may be scant and persist only one to two days. Such losses could be overlooked (e.g., we observed seven instances of lone adult plovers successfully hatching eggs and rearing chicks after their mates had been killed at cages), or misinterpreted as nest abandonment. Based on our observations, twelve or more adult plovers were killed at cages over 2-3 km^2 in only two to four days. The onset of this mortality may not be recognized if monitoring occurred weekly. Cages should be checked at least every two to three days in areas of moderate to high nesting density (>4 breeding pairs/km^2). Cages within three km should be removed at the first signs of predation, to protect the remaining adults. Last, resource managers should locally assess the baseline productivity of species of concern and the makeup of predator communities, to help determine whether and what type of predator exclusion is warranted for managing endangered shorebirds (Johnson and Oring 2002).

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