

INVERTEBRATE ABUNDANCE AT OCCUPIED AND POTENTIAL PIPING PLOVER NESTING BEACHES: GREAT PLAINS ALKALI WETLANDS VS. THE GREAT LAKES

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Abstract: We assessed the potential for reestablishment of endangered piping plovers (*Charadrius melodus*) at selected Great Lakes beaches by comparing invertebrate biomass and abundance with that at alkali wetland beaches occupied by breeding plovers in the Great Plains. We measured invertebrate occurrence using sticky traps secured to beach foraging substrates. Diptera (especially Chironomidae and Ephydriidae) comprised from 45 to 99% of invertebrate abundance and 24 to 53% of the biomass at six separate sites in the Great Lakes. Coleoptera (<1–17% abundance; 28–54% biomass) and Hymenoptera (<1–10% abundance; <1–9% biomass) also were frequently detected on beaches at the Great Lakes sites. At alkali wetland beaches in North Dakota, Diptera (Ephydriidae and Chironomidae) comprised 95% of the invertebrate fauna numerically and made up more than 80% of the biomass. The mean invertebrate biomass at two Great Lakes beaches (Platte Bay, MI = 0.16 g/m²/hr; Long Island, WI = 0.11 g/m²/hr) was similar ($P > 0.05$) to that at North Dakota alkali beaches (0.09 g/m²/hr) occupied by breeding piping plovers. However, at four other Great Lakes beaches, we measured 3 to 6 times less (0.01–0.02 g/m²/hr; $P < 0.01$) invertebrate biomass than at the alkali wetland beaches. Mean invertebrate abundance showed similar patterns among the sites. Food availability may limit the reestablishment of piping plovers at some Great Lakes beaches. We recommend that invertebrate abundance and biomass be measured at currently occupied piping plover nesting areas in the Great Lakes and be assessed at any sites proposed for reintroduction of piping plovers.

Key Words: alkali wetlands, *Charadrius melodus*, food availability, Great Lakes, invertebrates, piping plover, reintroduction, wetland beaches

INTRODUCTION

For migratory shorebirds, the energetic costs of breeding are high and most arrive at breeding sites with little or no stored energy (Rubbelke 1976, Howe 1983, Brown 1987). Therefore, food availability, from arrival at breeding sites through brood rearing, is critical to the reproductive success of migrant shorebirds (Howe 1983).

The piping plover (*Charadrius melodus* Ord.), a migratory shorebird, was listed for protection under the U.S. Endangered Species Act (U.S. Govt. 1985) and classified as endangered in Canada in 1985 (Haig 1985). The species breeds in 3 disjunct ranges: the northern Great Plains (ca 1,500 breeding pairs, Haig and Plissner 1992) subpopulation, which is declining (Ryan et al. 1993); the small Great Lakes subpopulation (19 pairs in 1994, Millenbah 1994); and the stable

or increasing Atlantic coast subpopulation (ca 1,050 pairs, Haig and Plissner 1992, U.S. Fish and Wildlife Service 1993).

The destruction or degradation of breeding habitat, nest predation, and human disturbance have been cited as factors contributing to the population decline of the piping plover (Flemming et al. 1988, Haig et al. 1988, Prindiville-Gaines and Ryan 1988). Habitat loss at wintering sites, pesticides, and food availability have been suggested as possible factors contributing to the decline but have been little studied. The recovery plan (Haig et al. 1988) for piping plovers calls for information regarding possible reestablishment of piping plovers in previously occupied parts of the range. Most interest in this effort has been in the Great Lakes region (e.g., Powell 1991).

Given the importance of food availability to reproductive success in shorebirds, any assessment of res-

toration potential should include data on prey abundance. Few data on the diet of piping plovers or on invertebrate abundance at plover breeding habitats are available. Along ocean beaches in Nova Scotia, Cairns (1977) observed breeding piping plovers feeding on marine worms. Coleoptera and Diptera were the most frequently detected prey in fecal samples of nesting piping plovers along marine beach habitat in Quebec (Shaffer and Laporte 1994). Whyte (1985) collected aquatic and terrestrial invertebrates at plover breeding sites on alkali wetlands in Saskatchewan, but his sampling techniques probably biased his assessment of availability to piping plovers.

As an initial step in evaluating Great Lakes beaches for piping plover reestablishment, we quantified invertebrates at selected sites during the plover breeding season. To assess the potential of the food supply to meet piping plover needs, we compared invertebrate abundance at potential restoration sites with that occurring at occupied plover breeding beaches along alkali wetlands in North Dakota.

STUDY AREAS

Great Lakes

We measured invertebrate biomass and abundance at six beaches at three National Lakeshores in the Great Lakes in 1988. Piping plovers did not occupy any of these sites in 1988. Whether this was the result of inadequate habitat conditions or the lack of plovers to occupy them is unknown. Apostle Islands National Lakeshore is on Lake Superior in Bayfield and Ashland counties, Wisconsin. We sampled invertebrates at a sand bridge connecting Long Island to Chequamegon Point (46°42'N, 90°46'W). Long Island supported nesting piping plovers until 1984 (S. Matteson, Wisconsin Department of Natural Resources, pers. comm.). At the sand bridge, a 24- to 70-m-wide sand beach was adjacent to low dunes vegetated with *Amphiphila breviligulata* Fern. A sand/mudflat area occupied the opposite shore of Long Island.

Sleeping Bear Dunes National Lakeshore is on Lake Michigan in Leelanau and Benzie counties, Michigan. We sampled invertebrates at Dimmick's Point (45°4'N, 85°58'W) on North Manitou Island and at a beach in Platte Bay (44°30'N, 86°7'W) on the mainland. Dimmick's Point was a sand and gravel spit extending about 250 m into the lake. An extensive dune system vegetated primarily with *A. breviligulata* and interspersed with ephemeral ponds separated the spit from hardwood forest. Piping plovers nested on Dimmick's Point until 1988 (Nordstrom 1990); reasons for their absence were unknown. The Platte Bay beach was a 34-m-wide gravel and sand beach adjacent to low

dunes covered with *A. breviligulata* succeeding to shrubs and hardwoods toward the upland.

We quantified invertebrate occurrence at three beaches at Pictured Rocks National Lakeshore on Lake Superior in Alger County, Michigan. Sevenmile Creek beach (46°37'N, 86°14'W) was a 31-m-wide sand and gravel beach backed by a 8-m-high bank and upland hardwood forest. Twelvemile beach (46°16'N, 86°16'W) was a 30-m-wide beach with primarily gravel near the shore and sand covering the upper beach. Erosion along the bank at the back of the beach had caused trees to fall onto the upper beach area. Sullivan Creek beach (46°39'N, 86°11'W) was approximately 35 m wide with substantial gravel cover near the water and sand on the upper beach. The back beach abutted a steep, eroding bank topped by hardwood forest. See Nordstrom (1990) for a detailed description of all sites.

North Dakota

We sampled invertebrates at beach habitat adjacent to alkali wetlands at the John E. Williams Nature Preserve (JWMNP), McLean County, North Dakota (47°32'N, 100°48'W). This site supported 90 breeding pairs of piping plovers in 1988 ($\bar{x}$ = 94 from 1984–1995). These wetlands were highly saline (15–39 dSm/m, 1986, North Dakota State Water Commission, unpubl. data) with no emergent vegetation. Beaches were salt-encrusted mud, sand, and gravel with little vegetation (primarily *Salicornia rubra* A. Nels.). Uplands adjacent to beaches were dominated by *Puccinella nuttalliana* Hitchc. and *Distichlis stricta* Rydb. See Prindiville (1986) and Mayer (1991) for detailed descriptions of this study area.

METHODS

We tested sampling techniques at all sites in 1987 and quantified invertebrate presence at the same sites in 1988. Piping plovers forage visually, using a run-and-peck method (Cairns 1977, Allan 1986, Beckerman 1988) to capture prey on or <1 cm beneath the surface. At breeding sites, plovers usually forage along the shoreline and on the open beach and only infrequently in the water or in upland vegetation (Lambert and Nol 1978, Allan 1986, Brown 1987, Beckerman 1988). Therefore, we confined our sampling of invertebrates to the former areas.

In 1987, we sampled subsurface invertebrates at JWMNP (late May) and at Long Island (early June). We took ten, 5-cm-deep cores (405 cm³) spaced 10 m apart along the beach in the area washed by waves at both sites. We washed each core through a #30 sieve. In 150 samples, we collected only 9 invertebrates (Oligochaete worms) and therefore did not repeat this sam-

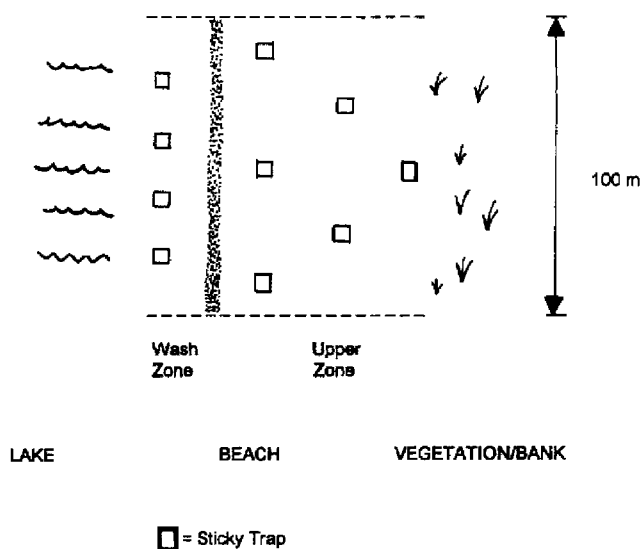


Figure 1. Placement of invertebrate sticky traps on occupied or potential nesting beaches of piping plovers along the Great Lakes or alkali wetlands in North Dakota.

pling in 1988. In 1988, we only sampled invertebrates occurring on beach substrates. We secured sticky traps (0.09 m², 4 mil, clear plastic sheets; Southwood 1966, MacLean and Pitelka 1971), to beach substrates with roofer's nails. We coated each sheet with "Stickem Special" (Seabrite Enterprises, Emeryville, CA 94608) and covered it with a box-shaped enclosure (0.1 m² × 5 cm) of 2.54-cm-mesh wire. The enclosures prevented vertebrates from becoming entangled or from taking invertebrates off the traps.

We placed ten sticky traps in randomly selected, 100-m lengths of each beach. We placed four traps 20 m apart on the beach area overwashed by waves and the remaining six traps in the upper beach as shown in Figure 1. We exposed traps for 4-hour intervals distributed temporally among three diurnal periods: dawn–1000 hr; 1000 hr–1600; 1600–dusk, except at Sevenmile Creek where the midday period was not sampled. We limited trap exposure to 4-hour intervals to reduce problems associated with windblown sand or overwashing by storm waves, which we encountered in 1987 presamples. For these reasons we excluded from analyses one trap from North Dakota and two from Long Island. We did not sample during heavy rainfall. We covered each sticky trap with plastic wrap upon collection for transport to the laboratory. We used mineral spirits to dilute the "Stickem Special" and removed invertebrates with forceps. We preserved invertebrates in 70% ethanol.

We sampled invertebrates during the piping plover breeding season. We collected data at JWMNP (20–31 May), Dimmick's Point (14–19 May), Platte Bay (21–24 May), and Sullivan Creek (28 May–1 June)

during the approximate egg-laying and incubation period for plovers in these regions; at Long Island (5 June–6 July) during the approximate incubation and brood-rearing interval; and at the three Pictured Rocks Lakeshore beaches (Sullivan Creek: 19 July–3 August; Twelve-mile Creek: 21–28 July; Seven-mile Creek: 20–21 July) during the approximate brood-rearing interval (Haig et al. 1988).

We counted and identified invertebrates to family, or in a few cases superfamily or suborder, using standard keys (Borror and White 1970, Borror et al. 1989). We dried invertebrates for 24 hours at 60 °C and determined dry weight for each taxa and total dry weight for each sample. Removal with mineral spirits, alcohol preservation, and any "Stickem Special" remaining on invertebrates may have affected weights, but we stored, processed, and handled all samples similarly to control for bias in weight change among samples. We compared untransformed biomass and abundance data among sites using ANOVA with LS means comparisons (SAS 1985). Beaches were the experimental units for statistical comparison with individual traps pooled by beach for analyses. For ease of future comparison, we converted biomass and abundance from g or no./4hr/0.09m² to g or no./hr/m² for presentation in tables.

RESULTS

We collected 70 taxa from the Great Lakes beaches ($\bar{x} = 32.8 \pm 8.3$ SE, $n = 6$) and 37 taxa from alkali wetland beaches in North Dakota (Table 1). Dipterans (especially Chironomidae, Ephydriidae, Muscidae, and Dolichopodidae) were numerically the most common taxa at all sites. In the Great Lakes, Coleoptera, Diptera, and Hymenoptera contributed most of the biomass. At alkali wetlands, Diptera (primarily Ephydriidae and Dolichopodidae) comprised over 80% of the biomass.

Mean total biomass at each of two Great Lakes beaches (Platte Bay, MI and Long Island, WI) was similar ($P > 0.05$) to that detected at alkali wetland beaches occupied by nesting piping plovers (Table 2). Nearly 45% of the biomass at Platte Bay was attributed to nine June beetles (Scarabaeidae, Coleoptera). We detected 3 to 6 times less ($P < 0.01$) invertebrate biomass at the remaining four Great Lakes beaches than at the plover nesting beaches at alkali wetlands (Table 2). Numerically, the Platte Bay and North Dakota sites were similar ($P > 0.05$), whereas the remaining Great Lakes beaches had fewer ($P < 0.01$) invertebrates than the alkali beaches (Table 2).

Most of the invertebrate biomass at all sites was concentrated in the washover zone and, therefore, reflected the same pattern of differences among sites as total biomass (Table 3). At the three sites with highest

Table 1. Percent total numerical abundance and biomass of dominant invertebrate taxa collected at occupied piping plover nesting beaches along alkali wetlands in North Dakota and Great Lakes' beaches with potential for reestablishment of piping plovers.

Wetland Beach	Invertebrate Taxon ¹	Nu-mer-ical Abun-dance	Bio-mass
Long Island, WI (n = 222) ²	O. Diptera	80	24
	Chironomidae	62	8
	Dolichopodidae	8	8
	Muscidae	4	5
	18 other families	5	4
	O. Coleoptera	10	28
	Tenebrionidae	8	2
	Cicindelidae	1	17
	Scarabaeidae	<1	5
	10 other families	2	4
	O. Hymenoptera	6	8
	Pompilidae	3	5
	11 other families	3	3
	O. Homoptera	2	39
	Membracidae	1	39
	4 other families	1	<1
	O. Hemiptera	1	<1
	8 families		
Dimmick's Point, MI (n = 48)	O. Diptera	92	46
	Chironomidae	61	9
	Muscidae	21	35
	4 other families	10	2
	O. Coleoptera	5	46
	Scarabaeidae	1	38
	4 other families	4	7
	O. Hymenoptera	3	6
	4 families		
Platte Bay, MI (n = 30)	O. Diptera	99	53
	Chironomidae	99	49
	9 other families	<1	4
	O. Coleoptera	<1	46
	Scarabaeidae	<1	45
	8 other families	<1	1
	5 other taxa	<1	<1
Sullivan Creek, MI (n = 120)	O. Diptera	45	35
	Chironomidae	19	2
	Muscidae	7	10
	Ephydriidae	7	1
	Tipulidae	1	9
	12 other families	11	13
	O. Hymenoptera	25	19
	Proctotrupidae	17	9
	6 other families	8	9
	O. Coleoptera	17	36
	Histeridae	7	11
	Tenebrionidae	6	2
	Carabidae	3	7

Table 1. Continued.

Wetland Beach	Invertebrate Taxon ¹	Nu-mer-ical Abun-dance	Bio-mass
Sevenmile Creek, MI (n = 20)	Cicindelidae	1	14
	3 other families	1	2
	O. Hemiptera	6	3
	Lygaeidae	5	2
	4 other families	1	1
	7 other taxa	7	7
	O. Diptera	78	30
	Chironomidae	63	18
	Ephydriidae	8	3
	6 other families	7	9
Twelvemile, MI (n = 40)	O. Coleoptera	14	54
	Carabidae	8	34
	Histeridae	5	18
	O. Hymenoptera	3	9
	5 families		
	5 other taxa	5	7
	O. Diptera	77	50
	Ephydriidae	34	8
	Chironomidae	23	5
	Dolichopodidae	15	25
JWMNP, ND (n = 99)	Calliphoridae	1	7
	5 other families	5	5
	O. Hymenoptera	10	9
	Proctotrupidae	9	7
	3 other families	1	2
	O. Coleoptera	8	33
	Carabidae	4	12
	Cicindelidae	1	15
	3 other families	3	6
	8 other taxa	5	8
	O. Diptera	95	83
	Ephydriidae	73	36
	Chironomidae	11	4
	Dolichopodidae	9	33
	Muscidae	<1	6
	O. Hymenoptera	3	2
	6 families		
	O. Orthoptera	<1	9
	1 family		
	20 other families	1	6

¹ Taxa listed are those comprising >5% of numerical abundance or biomass.

² Number of 0.09 m² traps exposed.

biomass, we collected more than twice the biomass in the washover zone compared to the upper beach ($P < 0.01$ in all comparisons). We detected no differences among sites in biomass present in the upper beach zone (Table 3). Invertebrate abundance was concentrated in the washover zones of the three sites with

Table 2. Invertebrate biomass (g/m²/hr) and abundance (number/m²/hr) from the washover and upper beach zones combined at occupied piping plover nesting beaches along alkali wetlands in North Dakota and Great Lakes beaches with potential for reestablishment of piping plovers.

Wetland Beach	n ¹	Biomass		Abundance	
		Mean	S.E.	Mean	S.E.
Platte Bay, MI	30	0.163 A ²	0.65	414.7 A	75.6
Long Island, WI	222	0.105 A	0.36	70.3 B	4.8
JWMNP, ND	99	0.087 A	0.33	223.6 A	64.7
Twelvemile, MI	40	0.024 B	0.04	34.0 B	5.9
Sullivan Creek, MI	120	0.021 B	0.05	13.3 C	1.1
Sevenmile Creek, MI	20	0.021 B	0.04	36.2 B	5.2
Dimmick's Point, MI	48	0.013 B	0.01	10.5 C	2.7

¹ Number of 0.09 m² traps exposed.

² Means with the different letters were different ($P < 0.01$).

greatest abundance and biomass (all comparisons $P < 0.05$), but at the remaining sites abundance was equally distributed between the two zones ($P > 0.05$; Table 3).

DISCUSSION

At the Great Lakes beaches we sampled, the most abundant invertebrates were dipterans, but coleopterans often comprised a larger proportion of the biomass. Hymenopterans were of secondary importance at those sites. Without direct observation of piping plover food habits, no inferences regarding which invertebrates present are truly available can be made.

Dipterans, primarily Ephydriidae, Dolichopodidae, Chironomidae, and Muscidae were the dominant invertebrate fauna at alkali wetland beaches occupied by nesting piping plovers in North Dakota. Hymenopterans were substantially less common, and coleopterans were only rarely collected there. On piping plover

breeding beaches at an alkali lake in Saskatchewan, Whyte (1985) collected Corixidae (O. Hemiptera) and Dytiscidae (O. Coleoptera) most frequently, followed by Diptera (Chironomidae and Ephydriidae). Whyte (1985) sampled aquatic invertebrates with a sweep net and collected terrestrial invertebrates by hand, probably biasing his assessment of invertebrates available to plovers.

We detected more invertebrates and greater biomass in the washover zone than upland beach at sites with high overall invertebrate abundance and biomass. In North Dakota, at the same wetlands we studied, Beckerman (1988) reported that piping plovers spent 45% of their foraging time in the upper beach area and 42% in the washover zone. However, prey capture attempts were three times more frequent in the washover zone (Beckerman 1988). In Michigan, piping plovers foraged most often in the upper beach but foraged more intensively and made more captures along the shoreline, especially where detritus had accumulated (Brown 1987). Whyte (1985) observed almost 70% of piping plover foraging within 5 m of the water's edge. Cairns (1977) and Whyte (1985) noted that piping plover chicks fed in the upper beach more than did adults.

Invertebrate biomass was similar to that at occupied piping plover nesting sites along alkali wetlands at only two of six Great Lakes beaches. At one of those two sites, almost half of the biomass was attributable to nine beetles. Invertebrate abundance at only one Great Lakes beach was similar to that at the North Dakota site. However, one of the sites with low invertebrate abundance and biomass, Dimmick's Point, had been occupied by nesting piping plovers until 1988 and was used again in 1994 (National Park Service, unpubl. data). Data on success of nesting attempts at this site were unavailable. Our sampling effort at Dimmick's Point was of short duration and occurred prior

Table 3. Invertebrate biomass (g/m²/hr) and abundance (number/m²/hr) in the washover and upper beach zones at occupied piping plover nesting beaches along alkali wetlands in North Dakota and Great Lakes beaches with potential for reestablishment of piping plovers.

Wetland Beach	n ¹	Washover Zone				Upper Beach Zone			
		Biomass		Abundance		Biomass		Abundance	
		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Platte Bay, MI	12	0.301 A ²	0.093	757.7 A	116.3	18	0.054 A	185.8 A	51.9
Long Island, WI	90	0.194 A	0.059	96.0 B	9.2	132	0.043 A	52.6 B	4.5
JWMNP, ND	40	0.180 A	0.083	407.4 AB	156.7	59	0.025 A	104.2 AB	23.6
Sullivan Creek, MI	48	0.027 B	0.008	13.6 C	1.5	72	0.016 A	13.2 C	1.5
Twelvemile, MI	16	0.027 B	0.003	32.6 BC	7.2	24	0.020 A	34.9 BC	8.7
Sevenmile Creek, MI	8	0.024 B	0.003	27.1 BC	6.1	12	0.019 A	42.4 BC	7.3
Dimmick's Point, MI	20	0.008 B	0.016	12.4 C	6.0	28	0.016 A	9.1 C	2.0

¹ Number of 0.09 m² traps exposed.

² Means with the different letters were different ($P < 0.01$).

to the typical piping plover brood-rearing period. We could have missed peak invertebrate abundance at a critical time for piping plovers.

We measured invertebrate abundance and biomass at most sites during only a portion of the total piping plover breeding season. Thus, the data do not measure likely temporal variation in invertebrate occurrence. Invertebrate abundance or biomass can fluctuate substantially at a given site (e.g., Maxson and Oring 1980). It is possible that we missed peaks of invertebrate abundance and biomass at some sites. Although the most common invertebrate taxa (family level) were surprisingly similar between North Dakota and the Great Lakes, the wetlands we compared are substantially different. Therefore, caution must be used in interpreting the results. We cannot conclude that habitat quality is unsuitable for plovers at any of the sites we monitored. Samples from Sullivan Creek and Twelvemile Creek, however, were of sufficient length during the probable chick-rearing period to suggest that concern about habitat quality for piping plovers may be warranted.

Griffith et al. (1989) noted that the success rate for endangered species releases have been <50% and that high habitat quality is a prerequisite for increasing the probability of success. Our data suggest that low invertebrate occurrence could limit successful reestablishment of piping plovers at some sites in the Great Lakes.

CONCLUSIONS AND RECOMMENDATIONS

There is a need for further research on invertebrate abundance at occupied piping plover habitats, especially in the Great Lakes. Studies of invertebrate abundance over the entirety of the plover breeding season are needed, as are attempts to link piping plover foraging behavior to invertebrate abundance and the presence of specific taxa.

We recommend that any sites in the Great Lakes targeted for piping plover reestablishment be intensively surveyed for invertebrate abundance and biomass throughout at least two breeding seasons prior to any restoration effort. Long-term monitoring of invertebrate abundance and biomass at currently occupied or at restoration sites would be useful for piping plover conservation planning. Because of the potentially high cost and low success rate of reestablishment efforts, only sites with invertebrate abundance and biomass equal to or greater than that detected at occupied piping plover sites should be used for restoration attempts.

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