

Piping Plover Foraging-Site Selection on the Missouri River

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Abstract.—Selection of a foraging site entails costs and benefits which are reflected in survival and reproductive success. We studied Piping Plover (*Charadrius melodus*) foraging-site selection during the breeding season (2001–2003) on the Missouri River and examined the relationship between site selection and invertebrate abundance indices within habitats. Foraging adult plovers selected protected shoreline (inter-sandbar channels, inlets, and backwater areas) more often than expected based on availability (use: $92\% \pm 3\%$; availability: $58\% \pm 5\%$). Invertebrate biomass and numbers along exposed shoreline did not differ among reaches. Along the protected shoreline, invertebrate biomass and numbers were higher below a dam with an epilimnetic release and a relatively constant release rate (epilimnetic reach) than at the other two reaches. On the epilimnetic river reach, invertebrate biomass and numbers were higher along the protected shoreline than on the main channel shoreline. On a reach below a dam with a hypolimnetic release and diel flow pulse (hypolimnetic reach) and a cold water reservoir, invertebrate indices were similar on the protected and exposed shoreline. Invertebrate numbers were higher in saturated and moist habitats than in vegetated and dry habitats ($P < 0.05$). At the epilimnetic and hypolimnetic reaches, foraging Piping Plover chicks used saturated and moist habitats more than vegetated and dry habitats, based on availability. On the Missouri River, protected shorelines were important foraging sites for Piping Plovers during the breeding season, and sandbars with low-lying moist habitat were important to foraging chicks. Piping Plovers will benefit from increased availability of these habitats on managed or created sandbars on the Missouri River. Received 9 September 2007, accepted 1 June 2008.

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Habitat selection entails choices that balance the costs (e.g., predation risk and competition) and benefits (e.g., prey availability) of using a given site (Jones 2001), and can affect survival and reproduction and thus fitness. In coastal locations, whether wintering or breeding, foraging Piping Plovers (*Charadrius melodus*) appear to prefer high nutrient, low energy sites (Patterson 1988; Nicholls and Baldassarre 1990; Loegering and Fraser 1995; Elias *et al.* 2000; Zonick 2000; Drake *et al.* 2001). Such sites have greater food availability and in some cases higher chick survival than sites with higher wave energy (Loegering and Fraser 1995; Elias *et al.* 2000). Despite the large number of Piping Plovers nesting on the Missouri River (>1,000, Haig *et al.* 2005) there has been little study of plover foraging habitat selection in this system.

Piping Plovers nest on sandbars and shoreline of the Missouri River from Nebraska to Montana, USA. They must select loca-

tions with suitable nesting sites for adults and foraging sites for both adults and chicks. Some sandbar shoreline is exposed to rapidly moving water in a relatively deep channel while other shoreline is adjacent to inlets, inter-sandbar channels and backwater areas with warmer slower-moving water (hereafter protected shoreline). We hypothesized that these protected areas were the functional equivalent of coastal bay intertidal flats, as they likely offered greater invertebrate abundance than other habitats.

Backwater areas may have higher invertebrate numbers in part due to lower invertebrate drift, the downstream movement of invertebrates, which is high downstream of hydro-peaking dams with diel flow pulses (Troelstrup and Hergenrader 1990; Moog 1993). In the Mississippi River, total macroinvertebrate densities were greater in backwater areas than in the main channel, and shallow water with high light penetration in backwater areas supported nutrient-rich macro-

phyte beds (Anderson and Day 1986; Sheaffer and Nickum 1986). Furthermore, macro-invertebrate densities in the Mississippi River were highest in low-velocity, high silt areas and lowest in higher-velocity, sand substrates (Anderson and Day 1986).

We studied Piping Plover foraging habitat selection on the Missouri River to determine whether protected shorelines were used more than exposed shorelines, and, if so, whether this use appeared to be driven by differences in food availability. We also tested whether Piping Plover chicks foraged preferentially in the moist and saturated substrate at the sandbar's edge.

METHODS

Study Area

Piping Plovers were studied on two riverine segments and one reservoir segment of the Missouri River. Study sites on the Missouri River included the Gavins Reach in South Dakota, downstream of the Gavins Point Dam (Gavins; 42°78'N, 97°15'W); the Garrison Reach downstream of the Garrison Dam (Garrison; 47°28'N, 101°09'W); and Lake Sakakawea upstream of the Garrison Dam in North Dakota (47°59'N, 101°34'W). The water is released from the bottom of the Garrison Dam (hypolimnetic, penstock 55 m below full pond), resulting in cold water (June temperature ~11°C, USGS 2006) in the Garrison Reach, while the water is released near the top of the Gavins Dam (epilimnetic, penstock nine m below full pond), resulting in warmer water (June temperature ~22°C, USGS 2006) in the Gavins Reach. Garrison is a hydro-peaking dam characterized by substantial daily variation in the amount of water released.

Field Procedures

Sandbars on the epilimnetic and hypolimnetic river reaches and the shoreline of the reservoir were surveyed during the pre-chick period (plovers selecting territories, laying, and incubating eggs, late April to late May) and the chick-rearing period (early July to late July). The shoreline was walked with a GPS unit, measuring the length of protected shoreline (inter-sandbar channels, inlets, pools) and exposed shoreline (facing the main river channel or open lake). The number of adult Piping Plovers foraging within ten m of the shoreline were counted in each shoreline type.

Four habitat categories were identified in the study. Saturated habitats were adjacent to the water's edge, retained a wet sheen, and water appeared at the surface when pressure was applied to the soil. Moist habitats had dark, moist, but not saturated, sand. Dry sand was light in color. The vegetated habitat consisted of dry sand with ≥10% plant cover.

Chicks were located every four d from hatching to age 22 d. Two-min behavioral observations were conducted on each chick within a brood, recording chick behavior and habitat occupied at the start of the obser-

vation period, and then at ten-s intervals. If the chick disappeared from view during an observation, the clock was stopped. The observation was resumed if the chick was spotted in less than five min. After five min, if the chick was not seen, the observation was deleted. All observations were 120 s. The mean proportion of observations in which broods were foraging in different habitats (saturated, moist, dry, vegetation) were calculated.

The amount (m) of available habitat (saturated, moist, dry, vegetation) intersecting a 50-m transect perpendicular to the shoreline at the location where the chick was first seen was measured at the end of time budget observations. Sandbar width ranged from less than 100 m to over 500 m, and some sandbars were densely vegetated in the center. Since transects were 50 m long, they did not cover the whole width of the sandbar, and, since dry sand and vegetation were located in more inland parts of these islands, in some cases underestimated the amount of these habitats. This could lead to overestimates of chick use of dry and vegetated habitats. However, chicks used these habitats very little. Values of zero for use and availability were assigned a proportion of 0.01 (Aitchison 1986; Aebischer *et al.* 1993).

Invertebrate indices were obtained at chicks' foraging sites every eight d (two or three sets per brood), and the location was identified as exposed or protected shoreline. Piping Plovers feed predominately on surface invertebrates, particularly beetles and flies (Shaffer and Laporte 1994; Cuthbert *et al.* 1999). Paint stirrers coated with Tanglefoot Insect Trap Coating (the Tanglefoot Company, Grand Rapids, Michigan) were placed in each habitat along transects on each territory. Transects were started at the water's edge nearest the chick location at the start of the first ten-s observation. Transects were conducted immediately after behavioral observations. Stirrers were placed in pairs, one vertically in the sand (with tanglefoot on both sides) and one horizontally on the ground (tanglefoot on one side), five cm apart, for 30 min. The catch area for the traps was 64.5 cm² (21.5 cm × 3 cm) for the horizontal stick and 129 cm² for the vertical stick. Data from vertical and horizontal sticks were combined. Chicken wire cages (diameter = 0.5 m, height = 0.6 m, mesh size: 2.5 cm) were placed around each set of traps to prevent bird injury. Invertebrates were sampled in saturated, moist, dry and vegetated habitats, and counted, measured and identified to order. Invertebrate catch rates (number of invertebrates per half hour), and estimated biomass (mg dry weight per half hour) were calculated. Invertebrate length measurements were used to calculate biomass based on an equation developed with data from a range of invertebrate orders (Dry Weight (mg) = (0.0305) (Length (mm))^{2.62}; Rogers *et al.* 1976).

Statistical Analyses

The ratio of adult use to availability among reaches, years, and breeding periods (pre-chick and chick-rearing period) were compared with an analysis of variance. Differences between the percent use of shoreline type and percent availability were tested with a two-tailed paired *t*-test.

The proportion of time the chicks spent foraging in a habitat (proportion of ten-s observations in the habitat) was compared to the proportion of available habitat measured, using compositional analysis (Aebischer *et al.*

1993). Invertebrate indices at exposed and protected shorelines and among habitat types were compared with an ANOVA on ranks followed by a Fisher's LSD for significant effects ($P \leq 0.05$). The statistical analysis software (SAS) for analyses (SAS 2004) was used for the analyses. Means are reported \pm SE.

RESULTS

Adult Shoreline Selection

During the pre-chick period, sandbars on the epilimnetic reach were surveyed on 28 April-29 April 2002 (three sandbars), and 29 May-1 June 2003 (three sandbars) and the hypolimnetic reach on 17 May-24 May 2002 (three sandbars), and 24 May 2003 (one sandbar). During the chick-rearing period, sandbars on the epilimnetic reach were surveyed on 10 July-11 July 2001 (three sandbars), 18 July-19 July 2003 (three sandbars) and the hypolimnetic reach on 17 July-18 July 2001 (three sandbars), 28 July 2002 (two sandbars) and 24 July 2003 (one sandbar).

There was no difference in the ratio of adult plover use of protected shoreline to availability for reach ($F_{1,21} = 0.9, P = 0.36$), year ($F_{2,21} = 0.9, P = 0.42$) or breeding period ($F_{1,21} = 1.3, P = 0.27$). Most foraging adult plovers ($92\% \pm 3\%$) were observed on protected shoreline but such shoreline accounted for

only $58\% \pm 5\%$ of the available shoreline (paired t -test: $t_{21} = -5.4, P < 0.001$).

Chick Habitat Selection

At both the epilimnetic and hypolimnetic reaches, saturated and moist habitats were selected more than dry habitats and vegetation based on availability (epilimnetic: Wilks' $\lambda = 0.44, F_{3,18} = 7.7, P = 0.002$; hypolimnetic: Wilks' $\lambda = 0.19, F_{3,11} = 15.8, P < 0.001$, Table 1). Chicks used habitats in proportion to their availability at the reservoir site (Wilks' $\lambda = 0.69, F_{3,7} = 1.0, P = 0.43$; Table 1).

Invertebrate Indices

Predominately beetles (Coleoptera) and flies (Diptera) were caught in traps (Le Fer 2006). Invertebrate biomass was higher in the saturated than in the other habitats in the epilimnetic reach and the reservoir (Table 2). In the hypolimnetic reach, biomass was low in all habitats and lowest in the dry sand. At the epilimnetic reach, invertebrate numbers were higher in the saturated than in the dry and vegetation. At the reservoir, numbers were highest in the saturated, followed by moist habitats, and lowest in the dry habitat and vegetation (Table 2).

Table 1. Piping Plover chick habitat use (% time chicks spent in each habitat) availability (% transect in each habitat type), and preference based on compositional analysis, on three Missouri River reaches in North and South Dakota, 2001-2003. Preferences for habitats followed by the same letter were similar ($\alpha \geq 0.05$). n.s. indicates $P \geq 0.05$. N = number of broods.

Habitat type	% Use	SD	% Availability	SD	Habitat preference
Hypolimnetic reach (N = 15)					
Saturated	41	41	30	22	21
Moist	51	51	33	30	23
Dry	4	4	8	29	35
Vegetation	1	1	2	5	6
Epilimnetic reach (N = 21)					
Saturated	26	26	33	7	9
Moist	47	47	35	61	28
Dry	0	0	0	6	10
Vegetation	3	3	7	19	23
Reservoir (N = 10)					
Saturated	22	22	25	4	3
Moist	27	27	26	35	28
Dry	25	25	39	15	13
Vegetation	19	19	24	47	32

Table 2. Invertebrate abundance and biomass (mean mg dry weight per set) \pm SE in habitats during chick-rearing period in North Dakota and South Dakota, 2001-2003. Results of ANOVA on ranks followed by Fisher's LSD for significant effects ($P \leq 0.05$). Habitats with the same letters are not significantly different. N = Number of brood foraging sites.

Habitat	N	Biomass ^a			Numbers ^b		
		Mean \pm SE	F ₃	P	Mean \pm SE	F ₃	P
Hypolimnetic							
Saturated	24	4.2 \pm 1.2 A	4.6	0.005	4.1 \pm 0.6 BC	5.3	0.003
Moist	24	4.5 \pm 1.0 A			7.6 \pm 1.1 A		
Dry	20	2.1 \pm 0.7 B			3.1 \pm 0.6 C		
Vegetation	17	4.5 \pm 1.0 A			6.5 \pm 1.0 AB		
Epilimnetic							
Saturated	28	24.8 \pm 3.8 A	11.4	< 0.001	14.9 \pm 3.5 A	11.4	< 0.001
Moist	28	7.9 \pm 1.6 B			7.4 \pm 0.9 AB		
Dry	16	10.6 \pm 5.1 B			3.0 \pm 1.0 C		
Vegetation	24	6.5 \pm 1.4 B			5.2 \pm 0.7 B		
Reservoir							
Saturated	21	10.9 \pm 2.3 A	14.8	< 0.001	11.5 \pm 1.7 A	21.1	< 0.001
Moist	20	2.9 \pm 0.7 B			5.1 \pm 0.7 B		
Dry	16	1.7 \pm 0.5 B			2.6 \pm 0.6 C		
Vegetation	21	2.2 \pm 0.8 B			2.3 \pm 0.3 C		

^aTwo Way ANOVA on ranks: habitat: $F_{3,247} = 22.8$, $P < 0.001$; reach: $F_{2,247} = 3.1$, $P = 0.05$; habitat x reach: $F_{6,247} = 7.5$, $P < 0.001$.

^bTwo Way ANOVA on ranks: habitat: $F_{3,247} = 23.1$, $P < 0.001$; reach: $F_{2,247} = 12.1$, $P < 0.001$; habitat x reach: $F_{6,247} = 5.1$, $P < 0.001$.

At the epilimnetic reach, mean invertebrate biomass and number in the saturated and moist habitats were higher along the protected shoreline than the exposed shoreline (Table 3). At the hypolimnetic reach and the reservoir, there was no difference in invertebrate biomass and abundance between the protected and exposed shoreline (Table 3).

Invertebrate biomass and numbers along exposed shoreline did not differ among reaches (biomass: $F_{2,42} = 0.9$, $P = 0.42$; numbers: $F_{2,42} = 1.4$, $P = 0.27$). Invertebrate biomass and numbers were higher along the protected shoreline on the epilimnetic reach than at the other two reaches (biomass: $F_{2,42} = 20.3$, $P < 0.001$; numbers: $F_{2,42} = 6.4$, $P = 0.003$).

DISCUSSION

Plover selection of protected shoreline over exposed shoreline on the Missouri River is similar to results for breeding Piping Plovers on the East Coast (Loevinger and Fraser 1995; Elias *et al.* 2000) and for coastal

wintering Piping Plovers, which used bay-shore tidal flats more than ocean shoreline (Nicholls and Baldassarre 1990; Zonick 2000). At the epilimnetic reach, disproportionate selection of protected shorelines was likely driven by higher invertebrate numbers and biomass. The higher invertebrate indices in backwater areas of the epilimnetic reach may have been due to lower invertebrate drift or stranding (Troelstrup and Hergenrader 1990; Moog 1993), or higher temperatures (Saltviet *et al.* 1994). At the hypolimnetic reach, the low invertebrate indices at both the protected and exposed areas were perhaps due to low water temperature or effects of the hypolimnetic (colder water, released from lower depths of reservoir) hydropeaking (diel water fluctuations) release (Cushman 1985; Moog 1993; Saltviet *et al.* 1994). Plovers preferred protected shorelines at the hypolimnetic reach even though invertebrate indices were not higher. These areas might be attractive for other reasons, including lower inter- or intra-specific competition or predation risk. In this study we measured only prey availability. The more

Table 3. Invertebrate biomass (Mean mg dry weight per set), and number in saturated and moist habitats, along protected and exposed shoreline at the three Missouri River reaches in North and South Dakota, during the chick-rearing period, 2001-2003. Results of ANOVA on ranks comparing exposed and protected shoreline.

Reach	N	Biomass				Number			
		Mean ± SE	Mean Rank	F ₁	P	Mean ± SE	Mean Rank	F ₁	P
Epilimnetic									
Protected	24	19.5 ± 3.7	23.6	4.2	0.05	13.1 ± 2.1	24.9	11.9	0.002
Exposed	12	11.2 ± 3.7 6.1 ± 1.7	15.8 12.8						
Hypolimnetic									
Protected	16	4.3 ± 1	17.3	0.03	0.87	6 ± 0.8	17.0	0	1.0
Exposed	17	3.7 ± 0.7	16.7			6.1 ± 0.9	17.0		
Reservoir									
Protected	12	4.9 ± 1	13.5	0.3	0.6	7.5 ± 1.3	14.6	0	0.99
Exposed	14	8.8 ± 3.2	15.2			9.2 ± 2.3	14.6		

gradually sloping protected shoreline might offer more foraging area as the water recedes, compared to exposed shoreline which drops off more abruptly.

On the Missouri River, protected shorelines, which include backwater areas, inlets, inter-sandbar channels and ephemeral pools, are important foraging sites for Piping Plovers during the breeding season. Flow management on the Missouri River should incorporate processes that create these shorelines. High water in the 1990s created dissected sandbars with this habitat type. If allowing natural processes to create sandbars is not feasible, artificial sandbars should incorporate inlets and pools as suitable habitat and should slope gently into the water. Water levels should be managed to maintain availability of these moist and saturated shoreline habitats throughout the Piping Plover breeding season.

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