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Comparison of Piping Plover Foraging Habitat on Artificial and Natural Sandbars on the Missouri River

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ABSTRACT The presence of food close to nesting habitat is essential for piping plover (*Charadrius melodus*) reproductive output. Since 2004, the U.S. Army Corps of Engineers has been engineering artificial nesting and brood-rearing habitat for piping plovers on the Missouri River. We compared arthropod abundance indices from artificial and natural sandbars as part of an evaluation of foraging habitat. The artificial sandbars had fewer and different arthropods than natural sandbars. The arthropod indices, however, need to be considered in light of total area of foraging habitat. Although there were fewer arthropods on artificial sandbars, the abundance of foraging habitat and relatively low plover densities after construction may have alleviated pressures associated with a more limited food supply. The amount of foraging habitat on artificial sandbars decreased with time while the number of arthropods remained stable, suggesting that food could become an issue on older artificial sandbars, particularly with higher nesting densities. Our results suggest that if artificial sandbars are used, care should be taken to ensure that ample foraging habitat is created.

KEY WORDS Arthropod prey, *Charadrius melodus*, foraging habitat, Missouri River, piping plover, sandbar

Abundance of food within a territory can have a significant impact on piping plover (*Charadrius melodus*) nesting density and reproductive output (Loegering and Fraser 1995, Goldin and Regosin 1998, Elias et al. 2000, Le Fer et al. 2008*a*, Cohen et al. 2009). In particular, wet substrates protected from high-energy wave or current action (such as edges of bays, inlets, and backwater areas) have the greatest arthropod abundances (Loegering and Fraser 1995, Elias et al. 2000, Le Fer et al. 2008*b*); both adults and young plovers have previously been shown to select these habitats for foraging (Le Fer et al. 2008*b*).

Although plover foraging habitat has been well-studied on the Atlantic Coast (Loegering and Fraser 1995, Elias et al. 2000, Cohen et al. 2009), comparatively little was known about this feature for river nesting birds on the Great Plains until 2001 (Le Fer et al. 2008*a*, 2008*b*). On the Missouri River, high-quality foraging habitats are found on the off-channel side of sandbars where the water temperature is higher and the current is slower than areas exposed to the channel (Le Fer et al. 2008*b*). Abundance of arthropods also is associated with the characteristics of the releases from the upstream dams, such that there were fewer arthropods below a cold-water, hydro-peaking dam than below a dam that releases warm water with little diel fluctuation (Le Fer et al. 2008*b*).

Piping plovers nest primarily on the unvegetated portions of sandbars in the Missouri River that have foraging habitats attached to them (Elliott-Smith and Haig 2004, Catlin et al. 2011*b*). However, water management, including reduction of high flows by dams, has resulted in fewer sandbars, more vegetation on those sandbars, and more erosion of foraging habitat than existed before a series of dams were built in the mid-twentieth century. In response to this habitat loss, in 2004 the United States Army Corps of Engineers (USACE) began engineering artificial sandbars to provide breeding and foraging habitat (Catlin et al. 2011*b*). The primary objective of our study was to compare arthropod abundance indices among naturally and artificially created foraging habitats to determine the feasibility of artificially creating piping plover foraging habitat.

METHODS

Study Area

We collected arthropod samples on sandbars on the Missouri National Recreational River downstream of the Gavins Point Dam (42° 51′ N, 97° 29′ W; ca. 95 km of river) in 2005–2009 (Fig. 1). These sandbars were part of a concurrent study of plover population dynamics (Catlin 2009, Catlin et al. 2011*a*, 2011*b*). The Gavins Reach downstream from the dam is one of the last free-flowing, unchannelized portions of the Missouri River. Much of the ‘naturally’ occurring habitat available for piping plovers resulted from sand deposited in relatively high flows during the 1990s. The size and composition of sandbars varied widely. Some were low unvegetated mud and sandflats, while others were high sandbars dominated in some areas by cottonwood (*Populus* sp.) and willow (*Salix* sp.) saplings (hereafter 'natural sandbars'; Catlin et al. 2011*b*). Throughout the breeding season, herbaceous plants grew along the shorelines of most sandbars (Catlin et al. 2011*b*). Beginning in 2004, the USACE engineered artificial sandbar complexes using a mixture of dredging and other

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mechanical methods (hereafter 'artificial sandbars'; Catlin et al. 2011*b*). In 2007, the USACE also began building sandbars on Lewis and Clark Lake, the reservoir upstream from the Gavins Dam (Catlin et al. 2011*b*).

Field Methods

We sampled arthropods in plover foraging habitat by coating paint-stirrers in Tanglefoot Insect Trap Coating (The Tanglefoot Company, Grand Rapids, MI, USA; hereafter sticky traps; Loegering and Fraser 1995, Le Fer et al. 2008*a*, 2008*b*, Anteau and Sherfy 2010) approximately every two weeks during the June–August chick-rearing period (Catlin et al. 2011*a*). We used a random number as the distance (in meters) from the downstream end to the place along the shoreline where the first transect began. Each transect extended perpendicular to the river flow through the sandbar to the other shoreline. We placed a second transect parallel to the first and 50 m upstream. We sampled in two wet substrate cover types: damp sand and mud, and saturated sand and mud, (cf. Le Fer et al. 2008*a*, 2008*b*). The two transects had two to four samples each (1–2 for each cover type on transect) depending on the presence of moist habitat. At the center of each cover type on the transect, we placed two paint-stirrers, one placed vertically (catch area: 129 cm^2) in the sand and another placed horizontally (catch area: 64.5 cm^2), for 30 minutes before we collected the sticks, and subsequently identified organisms to broad taxonomic categories (no lower than Order). To prevent bird injury, we placed chicken-wire cages around the sticky traps (Le Fer et al. 2008*a*, 2008*b*). From 2005 to 2009, we sampled arthropod abundance on all artificial sandbars on the Gavins Reach and Lewis and Clark Lake and several natural sandbars on the Gavins Reach (Table 1).

We also collected four core samples (10-cm diameter × 2-cm depth) during each of the sampling periods at each sandbar. We collected core samples at each of the sampling locations for the sticky traps on the first transect. If there were not four sampling locations on the first transect, we collected the remaining cores from the second transect. We inserted a PVC pipe into the sediment and used a paint scraper to dig out the pipe and transfer the sediment to a plastic container. We preserved samples in 95% EtOH, and counted organisms by taxon in the laboratory.

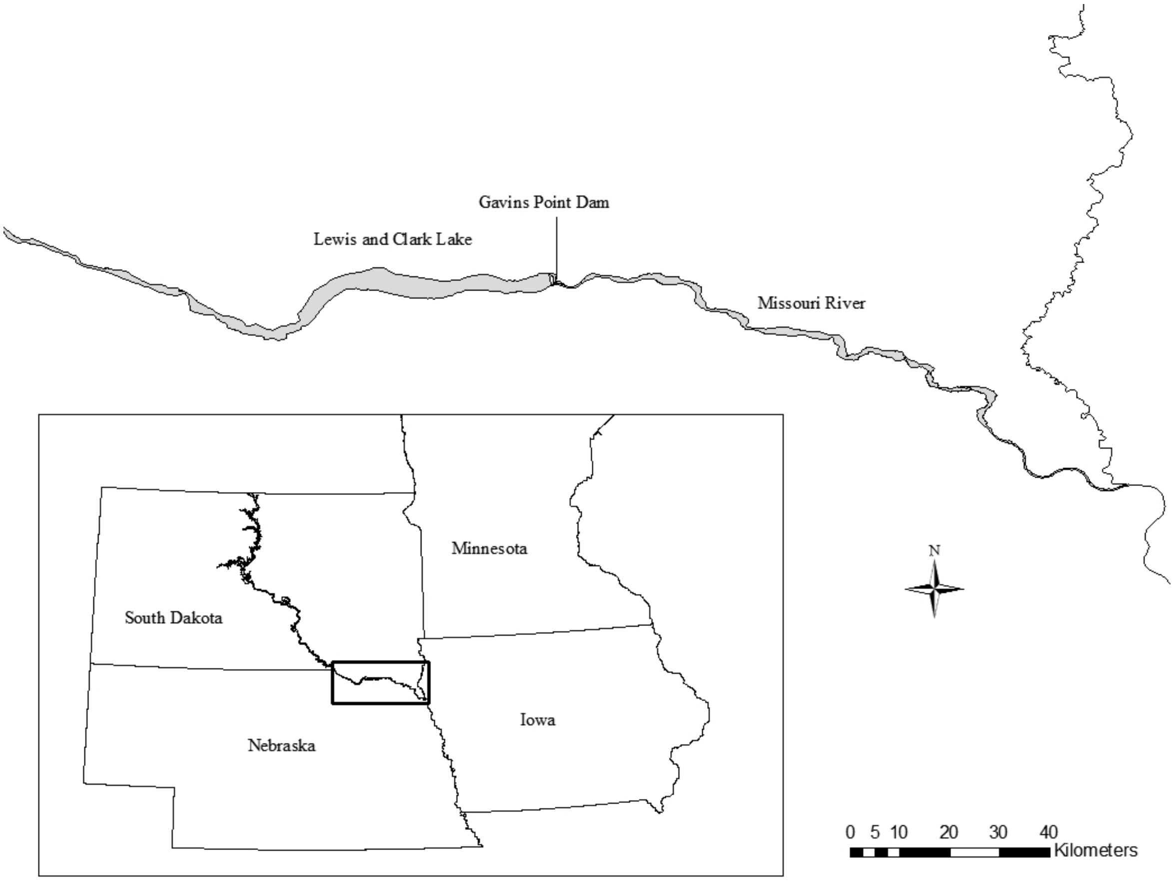

Figure 1. Piping plover (*Charadrius melodus*) foraging habitat study area showing the location of the Missouri River and Lewis and Clark Lake regionally (inset) and in relation to the Gavins Point Dam, 2005–2009.

Table 1. Mean (± 1 SE) piping plover foraging habitat[a] on natural and artificial sandbars of various ages on the Missouri River, 2005–2009.

Sandbar type	Sandbar age (yrs)	*N*[b]	Mean foraging area (ha)
Natural	ca. 8–12	47	3.89 ± 0.77
Artificial	0	10	11.62 ± 2.16
	1	8	4.62 ± 1.85
	2	5	4.81 ± 3.10
	3	4	3.62 ± 2.30
	4	3	2.16 ± 1.09
	5	1	0.09

[a] Foraging area is open or sparsely vegetated wet sand; [b] The sampling unit for this study was sandbar within year.

Analytical Methods

We tested for a difference in arthropod indices between natural and artificial sandbars, and among ages within artificial sandbars, using negative binomial regression (SAS 2011). Habitat age was treated as a nested effect such that it only affected artificial sandbars; natural sandbars were considered homogenous with respect to age because they were created during a high water event in 1998 and natural sandbars' age was confounded with sandbar type. The data collected from sticky traps and cores were analyzed separately. In addition to comparing artificial sandbars to natural ones, we used covariates to control for the potential effects of date, temperature, wind speed, calendar year, location (river or lake) and time of day when we analyzed the data from the sticky traps, and for date, calendar year, and location when we analyzed data from core samples.

We included a random effect for a sandbar×year interaction in all of our models under the assumption that arthropod abundance samples on the same sandbar in the same year may not be independent of other such samples. This effect controlled for the potential lack of independence among samples. We assessed goodness of fit for the model with all parameters except the random effect, and used the Pearson Chi-squared value divided by the degrees of freedom to control for over-dispersion in the analysis (correction for sticks: 2.44, cores: 2.61). We used Akaike's information criteria, corrected for small sample sizes and overdispersion ($QAIC_c$) to rank models and create model-averaged parameter estimates (Burnham and Anderson 2002). We tested overall hypotheses of year and hour effects using the global (all variables) model. If the overall tests were significant, we ran a series of means separation tests and used a Bonferroni correction to account for multiple comparisons (Zar 1999).

We used a Chi-squared test of equal proportions to compare abundances of arthropod orders between artificial and natural sandbars. We performed these tests separately for data collected on sticky traps and data collected in core samples.

To measure habitat availability (e.g., total area), we used land classification coverages collected during the 2005–2009 breeding seasons (L. Strong, United States Geological Survey [USGS], unpublished data). The USACE collected pan-sharpened multispectral QuickBird satellite imagery (DigitalGlobe Inc., Longmont, CO, USA) each year between April and October and classified it using Definens Developer Software (Definens, Munich, Germany; L. Strong, USGS, unpublished data). We multiplied the predicted arthropod abundance by the average amount of foraging habitat to compare any differences in arthropod catch rate at the sandbar scale and to examine the relationship between quality and quantity of prey and foraging habitat. We calculated the standard error of this measurement using the delta method for calculating variance (Powell 2007).

RESULTS

Arthropod Abundance

The sticky trap sampling indicated there were more arthropods on natural sandbars than on artificial sandbars (Table 2, 3; $\beta_{\text{artificial}}$ −0.498, 95% CI: −0.995–−0.001). This difference in abundance did not increase on artificial sandbars as the sandbars aged (Tables 2, 3; $\beta_{\text{age(artificial)}}$ 0.013, 95% CI: −0.064–0.090). There was a significant overall effect of year ($F_{4,\ 77} = 2.59$, $P = 0.043$); there were more arthropods in 2007 than in 2005 ($\beta = 0.780$, 95% CI: 0.250–1.310) but the confidence intervals for the other comparisons included 0. There was no effect of time of day ($F_{3,77} = 0.89$, $P = 0.449$), but the control variables temperature, date, and wind speed did have a significant effect on the arthropod catch rate (Table 3).

Arthropod abundance measured in core samples did not show a difference between artificial and natural sandbars (Table 2; $\beta_{\text{artificial}}$ −0.364, 95% CI: −1.084–0.357), nor did abundance change on artificial sandbars as the sandbars aged (Table 2; $\beta_{age(artificial)}$ −0.030, 95% CI: −0.160–0.100). The number of arthropods in the soil cores increased with increasing date (Table 1, 2; β_{date} 0.016, 95% CI: 0.010–0.022). There was a significant overall effect of year ($F_{4,77}$ = 8.57, $P < 0.001$). Among-year comparisons indicated arthropod abundance from core samples was lower in 2005 and 2006 than in 2007–2009 (all $P \leq 0.01$). There was no difference between 2005 and 2006 ($P = 0.096$) or among 2007–2009 (all $P \geq 0.348$).

Table 2. Mean (± 1 SE) number of arthropods collected during the chick-rearing period (June–August) in piping plover foraging habitats on natural sandbars and artificial sandbars of various ages on the Missouri River, 2005–2009. We present data separately for arthropods collected on sticks and arthropods collected in core samples.

	Natural	Artificial (age in yrs)					
Sample type	ca. 8–12 yrs.	0	1	2	3	4	5
Sticky traps	5.75 ± 0.65	2.93 ± 0.58	3.13 ± 0.45	3.35 ± 0.47	3.58 ± 0.69	3.83 ± 1.03	4.09 ± 1.45
Core samples	20.40 ± 4.00	13.04 ± 4.21	11.86 ± 2.84	10.79 ± 2.55	9.81 ± 3.08	8.93 ± 3.84	8.12 ± 4.57

Arthropod Composition

The composition of the arthropod samples differed (χ^2_{54} = 2901.6, $P < 0.001$) between natural and artificial sandbars. The proportion of Diptera was higher on artificial sandbars than on natural sandbars (Table 4), and the other categories generally had lower representation on artificial sandbars than on natural sandbars.

For the core samples annelids and dipterans comprised the majority of samples on both types of sandbar. As with the sticky traps, dipterans were more numerous on artificial sandbars than on natural sandbars, but this difference appeared after the first year (χ^2_{36} = 1790.8, $P < 0.001$; Table 5).

Habitat Availability

Artificial sandbars contained more foraging habitat than natural sandbars in the first year after building, and at least as much as natural sandbars in subsequent years (Table 1). The interaction between predicted catch and the amount of foraging habitat available also was greater for artificial sandbars than natural sandbars in the first year after building, but it appeared to decline during subsequent years (Fig. 2).

Table 3. Model averaged parameter estimates of the effects of variables on the number of arthropods captured on sticky traps in piping plover foraging habitat on the Missouri River, 2005–2009.

	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept	−0.918	0.475	−1.850	0.014
Artificial	−0.498	0.254	−0.995	−0.001
Lake	0.052	0.166	−0.273	0.378
Artificial age	0.013	0.039	−0.064	0.090
Date	0.010	0.002	0.006	0.013
Temperature	0.036	0.006	0.025	0.048
Wind speed	−0.025	0.007	−0.039	−0.011

DISCUSSION

Our results indicated that there were fewer arthropods on artificial sandbars than on natural ones. Specifically, the number of Orthoptera and Collembola on natural sandbars constituted much of the difference between natural and artificial sandbars. Overall, Dipterans dominated the arthropod communities on artificial sandbars, where other taxa had greater representation on natural sandbars. However, the "natural" sandbars in this study were all approximately 8–12 years old, compared to the artificial sandbars that were all ≤ 6 years old. A better test of similarities and differences between artificial and natural sandbars would be to sample arthropods on natural sandbars in early age classes, but unfortunately none were available during our study.

As the amount of available foraging habitat decreased on sandbars, nesting density increased; this increase has been associated with lowered chick survival (Catlin 2009). Although predation is a major cause of chick mortality on the Missouri River (Kruse et al. 2001, Le Fer et al. 2008*a*, Catlin et al. 2011*a*), predator removal from artificial sandbars was effective in increasing chick survival only in some years (Catlin et al. 2011*a*). This result suggested that either predator removal had a variable effect on chick survival, or, as in other studies, factors such as food availability may have contributed to lower chick survival (Loegering and Fraser 1995, Goldin and Regosin 1998, Elias et al. 2000).

Table 4. Number (%)[a] of arthropods collected on sticky traps in piping plover foraging habitat (natural and artificial sandbars) on the Missouri River, 2005– 2009[b].

	Natural	Artificial (age in yrs)					
	ca 8–12	0	1	2	3	4	5
Araneae	158 (0.9)	11 (0.4)	15 (0.4)	11 (0.6)	14 (1.4)	11 (1.2)	0 (0.0)
Coleoptera	207 (1.2)	47 (1.8)	51 (1.4)	64 (3.5)	16 (1.6)	8 (0.9)	3 (3.1)
Diptera	10,272 (58.3)	2,353 (89.8)	3,242 (86.7)	1,340 (73.9)	788 (79.7)	815 (89.9)	87 (89.7)
Hemiptera	603 (3.4)	72 (2.7)	59 (1.6)	65 (3.6)	20 (2.0)	37 (4.1)	0 (0.0)
Homoptera	589 (3.3)	44 (1.7)	52 (1.4)	23 (1.3)	28 (2.8)	2 (0.2)	0 (0.0)
Hymenoptera	273 (1.6)	30 (1.1)	29 (0.8)	19 (1.0)	12 (1.2)	5 (0.6)	4 (4.1)
Orthoptera	1,677 (9.5)	13 (0.5)	18 (0.5)	24 (1.3)	52 (5.3)	6 (0.7)	0 (0.0)
Collembola	3,007 (17.1)	10 (0.4)	238 (6.4)	252 (13.9)	44 (4.4)	5 (0.6)	0 (0.0)
Unknown	806 (4.6)	22 (0.8)	32 (0.9)	13 (0.7)	15 (1.5)	18 (2.0)	2 (2.1)
Other	16 (0.1)	18 (0.7)	4 (0.1)	3 (0.2)	0 (0.0)	0 (0.0)	1 (1.0)
Total	17,608	2,620	3,740	1,814	989	907	97

[a] Percent of total individuals collected per sandbar type and age; [b] Chi-square test of equal proportions: $\chi^2_{54} = 2901.6$, $P < 0.001$.

Table 5. Number (%)[a] of arthropods collected in sediment cores in piping plover foraging habitat (natural and artificial) on the Missouri River, 2005 – 2009[b].

	Natural	Artificial (age in yrs)					
	ca 8–12	0	1	2	3	4	5
Annelids	6,001 (23.0)	1,008 (24.8)	692 (12.5)	445 (13.4)	102 (9.9)	107 (6.8)	13 (4.3)
Coleoptera	1,565 (6.0)	155 (3.8)	474 (8.6)	264 (7.9)	111 (10.8)	60 (3.8)	14 (3.8)
Diptera	14,916 (57.2)	2369 (58.2)	3993 (72.0)	2181 (65.6)	686 (66.9)	1,323 (84.4)	235 (78.3)
Eggs	902 (3.4)	180 (4.4)	118 (2.1)	68 (2.0)	41 (4.0)	13 (0.8)	0 (0.0)
Mollusca	259 (1.0)	87 (2.1)	20 (0.4)	3 (0.0)	2 (0.2)	8 (0.5)	1 (0.3)
Copepods	90 (0.3)	46 (1.1)	68 (1.2)	30 (0.9)	0 (0.0)	9 (0.6)	13 (4.3)
Other	2,323 (8.9)	224 (5.5)	177 (3.2)	330 (9.9)	84 (8.2)	47 (3.0)	24 (8.0)
Total	26,057	4,068	5,542	3,321	1,026	1,567	300

[a] Percent of total individuals collected per sandbar type and age; [b] Chi-square test of equal proportions: $\chi^2_{36} = 1790.8$; $P < 0.001$.

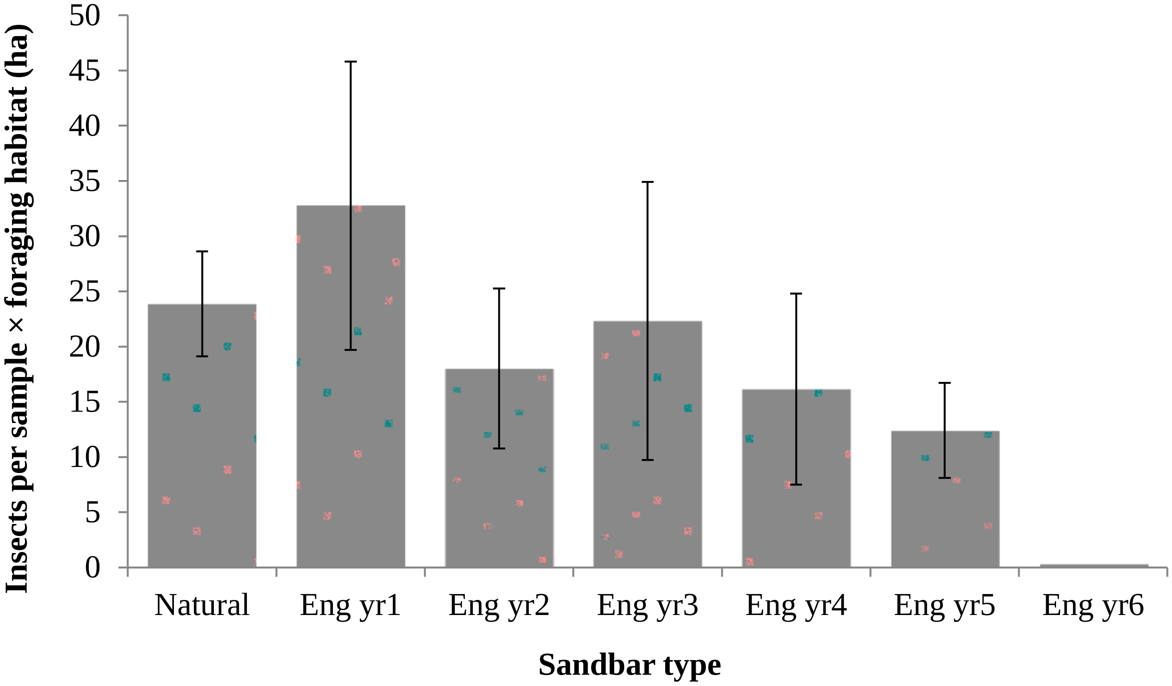

Figure 2. Predicted number of arthropods sampled on Missouri River sandbars times the average amount of foraging habitat available on artificial and natural sandbars, 2005–2009. Error bars represent 1 SE, calculated using the Delta Method (Powell 2007).

Although the artificial habitat yielded fewer arthropods per sample in the first year after building, these sandbars had more foraging habitat than natural. Moreover, the presence and abundance of Coleopterans, Dipterans, and Hymenopterans suggested that artificial sandbars produced adequate replacement foraging habitat in the short term. These Orders were the most common prey items in fecal analyses of chick diets from Atlantic Canada (Shaffer and Laporte 1994) and in gizzard contents from chicks on the Great Lakes (Cuthbert et al. 1999).

MANAGEMENT IMPLICATIONS

Our results indicated that care should be taken to ensure that enough quality foraging habitat is associated with artificial habitats created for piping plovers. Although there were fewer arthropods on artificial sandbars, we were comparing these relatively young sandbars to older natural sandbars. Comparisons to naturally created sandbars of comparable age will be needed to determine if this effect is unique to the artificial sandbars.

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