6-2008

Endangered Species Responses to Natural Habitat Declines: Nebraska's Interior Least Terns (*Sternula antillarum athalassos*) and Piping Plovers (*Charadrius melodus*) Nesting in a Human-Created Habitat

Mary Bomberger Brown
Tern and Plover Conservation Partnership, mbrown9@unl.edu

Joel G. Jorgensen
Nebraska Game and Parks Commission, joel.jorgensen@nebraska.gov

Sarah E. Rehme

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Mary Bomberger Brown [1, 4], Joel G. Jorgensen [2], and Sarah E. Rehme [2, 3]

[1] Tern and Plover Conservation Partnership
153 Hardin Hall
3310 Holdrege Street
Lincoln, NE 68583
mbrown9@unl.edu

[2] Nebraska Game and Parks Commission
2200 North 33rd Street
Lincoln, NE 68503
joel.jorgensen@nebraska.gov

[3] Current address: School of Natural Resources
244 Hardin Hall
3310 Holdrege Street
Lincoln, NE 68583
srehme@neb.rr.com

[4] Corresponding author

Formerly, state and federally endangered Interior Least Terns (*Sternula antillarum athalassos*) and state and federally threatened Piping Plovers (*Charadrius melodus*) nested on sandbars in rivers, as well as on other sandy beach habitat (Hardy 1957; Haig 1992; Kirsch 1992; Ziewitz et al. 1992; Thompson et al. 1997). In Nebraska, the birds primarily used sandbars in the Platte, Loup, Elkhorn, Niobrara, and Missouri rivers (Sharpe et al. 2001). These sandbars were created and maintained by river flow and regular flooding events. Despite the frequent scouring, reshaping and relocation of the sandbars, nesting habitat was consistently available to the birds in these river systems. With recent human-caused modifications to annual river flow, river bed and bank structure, and emergent vegetation, the number of river sandbars that are suitable for nesting has been greatly reduced (Haig 1992; Ziewitz et al. 1992; Wilson et al. 1993; Thompson et al. 1997; NRC 2005).

In recent decades, Least Terns and Piping Plovers have used human-created habitats for nesting, although they still use river sandbars when they are available (Haig 1992; Thompson et al. 1997). During the last several decades, the birds have nested on human-created sites such as sand spill piles at sand and gravel mines, fly-ash piles at electrical power-generating plants, gravel and tar rooftops, and lakeshore-sandy beach housing developments (Ducey 1982; Haig 1992; Kirsch 1992; Ziewitz et al. 1992; Wilson et al.1993; Thompson et al. 1997; Forys and Borboen-Abrams 2006). In eastern Nebraska, economic growth near human population centers has increased the attractiveness of lakeshore housing developments to investors. In the past, retired sand and gravel mines were converted into lakeshore housing developments. Recently, however, developers have bypassed the mine stage and are excavating the lakes directly for housing developments.

As terns and plovers use human-created and human-dominated habitats with increasing frequency, the importance of these areas to conservation and management becomes more critical. Threats to nests, chicks, and adults may be quite different at these sites than at river nesting sites or sand and gravel mines because of different human uses. Reliable nesting data are essential for the development of effective protocols to secure and recover the populations of these two protected species. Here we report the results of one nesting season at a human-created site along the lower Platte River.

Methods

The study site is located adjacent to the Platte River, near North Bend, Dodge County, Nebraska. It consists of a human-created sandpit lake surrounded by an expanse of sparsely vegetated and bare sand. Houses and other structures, in various stages of completion, are distributed around the lake with extensive areas of open sand between the structures (see Figure 1). The Tern and Plover Conservation Partnership (Partnership) worked cooperatively with lot owners and the developer to limit conflicts between these two protected species and people. Partnership personnel located nests, marked nest clusters with signs, and occasionally roped off areas so that people would not disturb nesting birds.

The study site was visited every 1–4 days from 12 June through 1 August 2007. The entire area was surveyed, and we attempted to locate all Least Tern and Piping Plover nests. During each visit, Partnership personnel also assessed the effectiveness of protection measures and whether any nests had been disturbed. The GPS coordinates of each nest were recorded. Eggs were floated when each nest was first located to determine the date of nest initiation (Hays and LeCroy 1971). Nests were otherwise undisturbed during incubation. Clutch size, defined as the maximum number of eggs found in the nest, was recorded.

Least Terns typically lay three eggs and incubate for 25 days (Thompson et al. 1997). Piping Plovers typically lay four eggs and incubate for 28 days (Haig 1992). The expected hatching date was extrapolated from the nest initiation date. All of the following analyses use the expected hatching date rather than the actual hatching date. Nests were observed on the expected hatching date to determine the hatching success. Hatching success was inferred by the presence of unhatched eggs, egg shells, or nestlings in the nest. Hatching success was defined as the number of eggs or the percentage of the clutch that hatched. After hatching began, the study site was surveyed to locate broods being attended by adults and dependent juveniles. We were not able accurately to assess the number of fledglings produced from the site due to logistical and methodological limitations.

To analyze nesting synchrony or how closely in time eggs within and between clusters hatched, the standard deviation (SD) of the modal hatching date for all tern nests at the study site was calculated. Each nest was then assigned, based on its hatching date, as within ± 1 SD, within ± 2 SD, etc. If more nests hatch near the modal hatching date or within ± 1 SD of the mode, it implies more synchronous nesting (see Brown and Brown 1996: 35–36 for additional details on this technique for describing synchrony).

Most of the following analysis and discussion is focused on the Least Tern nesting data. Due to a very small sample size (five nests), our Piping Plover data analyses are largely anecdotal.

Using GPS coordinates, nest nearest-neighbor distance was calculated using ArcGIS 9.2 (ESRI 2006). All statistics were calculated using Prism 3.02 (GraphPad Prism 2000). Due to small sample sizes, all statistical tests were non-parametric. Statistical significance was set at $P < 0.05$.

We analyzed our data using correlation. This statistic provides a measure of how associated two variables are. Correlation is represented by the term r_s and ranges from -1 to +1. If the association is weak, r_s will be near 0. As the association becomes stronger r_s will diverge from 0; r_s values of -1 and +1 represent perfect association. Positive values of r_s occur when both variables in the association increase. Negative values of r_s occur when one value in the association increases while the other decreases. A statistically significant value of r_s refers to the closeness of the association. P is the significance level and represents our confidence in the association. N is the sample size and indicates how many values were used in the calculation. SE is the standard error of the mean and provides us with a confidence interval around the mean.

No birds were handled and no nests or eggs were damaged or destroyed by Partnership or Nebraska Game and Parks Commission (NGPC) personnel as a consequence of data collection.

Results

A total of 67 Least Tern and five Piping Plover nests was found at the study site. The nests were distributed around the lake in eight clusters. The clusters were separated by water, roads, buildings, elevation, or vegetation. The clusters ranged in size from 2–18 nests (Table 1). One Piping Plover nest was located in each of four clusters (3, 17, 7, 7 Least Tern nests). One Piping Plover nest was isolated from all other nests (Table 2). One Killdeer (*Charadrius vociferus*) nest was located in one cluster (13 Least Tern nests). Three clusters consisted of Least Terns only (10, 2, 8 Least Tern nests). At least 9 incidents of human disturbance within nest clusters were noted, including two incidents of vehicles having been driven into nesting areas. The death of one Least Tern chick, caused by human encroachment into a nesting area, was noted. Incidents of human disturbance were reported to U.S. Fish and Wildlife Service Law Enforcement.

Table 1. Least Tern variables at a housing development near North Bend, Dodge County, Nebraska, 2007.

	Modal Hatch Date	Clutch Size[a]	Number Hatched[a]	Percent Hatched[a]	Nearest Neighbor[b]	Total Eggs	Total Hatched	Number of Nests	Mean Hatch Date[c]	Hatch Date Range[d]
Cluster 1	20-Jun	2.5 ± 0.2	1.7 ± 0.2	71.6 ± 10.0	15.7± 3.4	25	17	10	53.6 ± 2.2	25
Cluster 2	23-Jun	2.7 ± 0.3	1.0 ± 1.0	33.3 ± 33.3	34.2 ± 14.2	8	3	3	58.3 ± 5.9	20
Cluster 3	19-Jun	2.8 ± 0.1	1.9 ± 0.3	67.6 ± 10.2	14.5 ± 1.8	48	33	17	52.8 ± 2.1	27
Cluster 4	19-Jun	2.7 ± 1.3	1.4 ± 0.3	52.6 ± 11.6	13.4 ± 1.2	35	18	13	52.3 ± 2.4	34
Cluster 5	24-Jun	2.6 ± 0.2	0.9 ± 0.5	35.7 ± 18.0	16.8 ± 2.4	18	6	7	59.0 ± 6.5	42
Cluster 6	5-Jul	3.0 ± 0.0	3.0 ± 0.0	100.0 ± 0.0	43.0 ± 0.0	6	6	2	65.5 ± 0.5	2
Cluster 7	25-Jun	2.1 ± 0.3	1.3 ± 0.5	45.3 ± 17.3	29.3 ± 4.7	15	9	7	56.0 ± 2.1	14
Cluster 8	20-Jun	2.6 ± 0.2	1.8 ± 0.5	62.5 ± 18.3	14.3 ± 1.7	21	14	8	54.3 ± 3.0	20
Total	24-Jun	2.6 ± 0.1	1.6 ± 0.2	58.5 ± 5.3	17.9 ± 1.4	176	106	67	54.6 ± 1.2	42

[a] = mean ± 1SE

[b] = mean ± 1SE, meters

[c] = mean ± 1SE, 1 May = 001, 1 June = 032, 1 July = 062

[d] = number of days between first and last egg hatching

Based on egg-floating nest age estimates, all Least Tern nests at the study site were initiated between 20 May and 18 June. Eight nests did not hatch due to predation or abandonment by the adults. The remaining tern nests hatched between 12 June and 24 July, a span of 42 days. Of the 67 tern nests located, 48 (72%) hatched at least one egg and 19 (28%) did not hatch. Thirty-four of the 48 (71%) tern nests hatched during the first 12 days of the hatching period. The remaining 14 nests (29%) hatched over the following 30 days. Within the eight clusters, hatching spanned 2–42 days.

Among all tern nests, there was no statistically significant correlation between hatch dates and clutch size (r_s= -0.137, P = 0.275, N = 66), number of eggs hatched (r_s = -0.038, P = 0.762, N = 66) or percent of the clutch hatched (r_s = -0.039, P = 0.759, N = 66). This suggests that clutches initiated later in the season, which may be second nesting attempts by adults possibly in poorer condition, are not smaller in size nor are the eggs less fertile.

Hatching synchrony for terns across all clusters, as measured by modal hatch date SD was not correlated with clutch size (r_s = -0.016, P = 0.217, N = 67), number of eggs hatched (r_s = -0.084, P = 0.498, N = 67), or percent of clutch hatched (r_s = -0.078, P = 0.532, N = 67). This suggests that hatching in temporal proximity to others was not necessarily advantageous to the birds.

Nest density within the tern clusters, as reflected by nearest-neighbor distance, was not correlated with clutch size (r_s = 0.022, P = 0.858, N = 67), number of eggs

Table 2. Piping Plover nest variables at a housing development near North Bend, Dodge County, Nebraska, 2007.

	Hatch Date	Clutch Size	Number Hatched	Percent Hatched	Nearest Neighbor[a]	Cluster Size[b]
Solitary	25-Jun	4	4	100.0	N/A	0
Cluster 2	12-Jun	4	0	0.0	27.4	3
Cluster 3	26-Jun	4	4	100.0	11	17
Cluster 5	6-Jul	4	0	0.0	33.4	7
Cluster 7	22-Jun	4	4	100.0	20	7

[a] = meters, measured to nearest Least Tern nest

[b] = number of Least Tern nests

hatched (r_s =-0.009, P = 0.944, N = 67), or percent of clutch hatched (r_s = -0.061, P = 0.623, N = 67). This suggests that the proximity of other active nests does not influence the success of a specific nest or the success of the cluster as a whole. Nearest-neighbor distance and hatch date were positively correlated (r_s = 0.468, P < 0.0001, N = 67). Nests initiated later in the season, which may be second nesting attempts, begin after broods in nearby nests have left the immediate area so the nests, by necessity, are spaced more widely.

The number of tern nests in each cluster was not significantly correlated with clutch size (r_s = -0.311, P = 0.462, N = 8), number of eggs hatched (r_s = 0.192, P =0.665, N = 8), or the percent of clutch hatched (r_s = 0.204, P = 0.619, N = 8). This suggests that the presence of other nests in close proximity does not affect the success of a nest. There was a significant negative correlation between the number of nests in each cluster and the nearest-neighbor distance (r_s = -0.874, P = 0.007, N = 8). When the number of nests in an area seen as suitable for nesting by the birds increases, the nearest neighbor distance decreases.

The correlation between Least Tern nest hatching date and Piping Plover hatching date, for the four clusters with plovers present, was not significant (r_s = -0.675, P > 0.05, N = 4). This suggests that the terns and plovers initiated nesting independently. The number of terns in the four clusters with plovers was not significantly correlated with the plovers' hatching date (r_s = 0.000, P = 1.05, N = 5), the plovers' clutch size (r_s = 0.7071, P = 0.233, N = 5) or the number of plover eggs hatched (r_s = -0.408, P = 0.5167, N = 5). This suggests that the presence of terns does not influence the nesting success of the plovers.

Discussion

Birds are generally thought to aggregate their nests, either to avoid predation via increased vigilance and deterrence of predators by conspecifics, to increase foraging efficiency, or to exploit a limited habitat (Alexander 1974; Brown and Brown 2001). Even though our analyses are based on only one study site for one nesting season with small sample sizes, several patterns are apparent. It appears that the number of conspecifics nesting nearby (in the same nest cluster) does not affect the nesting success of Least Terns, at least to the egg-hatching stage. Our analyses did not include actual fledging data, so there may be a conspecific effect after broods leave the nest area that we did not detect. One might expect that birds nesting in larger groups or in close proximity to others would be more successful due to the presence of more individuals watching for predators. This increase in nesting success was seen in a large (500-nest) Least Tern colony in Connecticut (Brunton 1997). At our study site, terns nesting in smaller clusters or less densely packed clusters were not more or less successful than terns nesting in larger or more densely paced clusters. The colony size and cluster sizes at our study site may have been too small for the anti-predator effect to be apparent. Kirsch (1992) reported that nesting success varies widely between nesting sites in the lower Platte River. This suggests that the effects of nest clustering may also vary. Further research is needed to clarify this issue. It has been suggested that the less aggressive plovers nest in close proximity to the terns, presumably for the advantage of increased predator avoidance and deterrence (Haig 1992). The small number of plover nests at our study site did not allow us to address this question.

Our data suggest, but do not demonstrate conclusively, that terns aggregate their nests due to limited habitat availability. Burger (1984) predicts that the loss of suitable nesting habitat will result in a decrease in the number of Least Tern colonies and an increase in the size of those colonies. Parham's (2007) analysis of suitable sandbar nesting habitat in the lower Platte River (1954–2004) showed that the availability of such habitat has declined above the confluence with the Elkhorn River, particularly in the last 10 years (1996–2005). Nesting on river sandbars in this area is now infrequent, with nesting recorded in only three years from 1996–2005, and there are no records from the past four years (Dinan 2005, Jorgensen 2006, 2007; Parham 2007; NPGC unpubl. data). During 2007, no sandbar nesting habitat was available to the birds within the lower Platte River during late May and June because all sandbars were submerged by high water flow (approximately 12,000 cfs, 13 June 2007 at North Bend USGS gauge). Parham (2007) estimated that optimum habitat forming flows are 38,170 cfs. Flows of this magnitude or greater have not occurred in this reach of the lower Platte River since 1999 (http://waterdata.usgs.gov). The long-term reduction of river habitat coupled with short-term high water flows very likely contributed to the increase in the number of birds nesting on off-river sites, such as the lakeshore housing development near North Bend.

Figure 1. Piping Plover nest at a lakeshore housing development in eastern Nebraska, 2007. Image shows close proximity of a threatened species to human activity. Note the nest with protective caging to the left, a "do not enter" sign, a rope cordoning off the nesting area, and a house with construction workers in the background.

The consequences of more birds nesting in fewer but larger groups are unknown but likely to be negative. Large numbers of adults, eggs, and chicks may be lost simultaneously due to disease, predation, human disturbance, or stochastic events. Even though our visits were limited and we were present only for short periods of time, high rates of human disturbance, including direct chick mortality, were observed, despite knowledgeable residents and marking nest clusters with signs. Clearly, making suitable nesting habitat available for these two vulnerable species is critically important (Ziewitz et al. 1992). Unfortunately, human-created nesting sites are ephemeral for the birds. In time, structures will occupy most available space at housing developments, and sand spill piles at mines may become overgrown with vegetation (Wilson et al. 1993).

Maintaining water flow adequate to create and maintain river sandbars must be included in any management plan for these two species (Thompson et al. 1997). Unless more usable river sandbars are made available to the birds for nesting, they will be forced to continue nesting at these man-made sites, with uncertain consequences for their survival.

Acknowledgements

Funding was provided by The Nebraska Environmental Trust (grant 05-164) and the Nebraska Game and Parks Commission. We thank Charles R. Brown, Stephen J. Dinsmore, Alice Heckman, Paul A. Johnsgard, Martha Tacha, and Chris Thody for useful comments on the manuscript. We thank Bob Virgl, Glenn Baumert, and the members of the homeowner's association for their assistance and cooperation. We also thank Robin Smith for assistance in the field.

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