Habitat Conservation for Nesting Least Terns and Piping Plovers on the Platte River, Nebraska

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ABSTRACT — We measured characteristics of the nesting habitat of least terns (*Sterna antillarum*) and piping plovers (*Charadrius melodus*) in the central and lower reaches of the Platte River during 1988. Most birds nested on the Lower Platte. Ground measurements and repetitive aerial videography indicated that birds nested in river segments that were wider and had a greater area of sparsely vegetated sandbars than segments comprising a systematic sample of the two river reaches. Wider channels and larger, higher sandbars were available on the Lower Platte than on the Central Platte. Nests on the Lower Platte had greater clearance above water at the time of nest initiation than nests on the Central Platte. The mean elevation of nests was higher than the mean elevation of sandbars used for nesting on the Lower Platte. The reverse was true on the Central Platte. The habitat differences between the two reaches probably explain the distribution of birds and suggest that habitat availability may be limiting populations on the Central Platte. We recommend creating sandbars of sufficient size and height in appropriate segments of the Central Platte, using Lower Platte nesting sites as a model, to provide suitable nesting substrate for least terns and piping plovers.

Key words: least tern, piping plover, nesting habitat, Platte River

The loss and disturbance of nesting habitat were cited as the primary threats to the interior population of the least tern and the piping plover when these birds were listed as endangered and threatened, respectively, by the U.S. Fish and Wildlife Service (USFWS) (USFWS 1985a, 1985b). Nesting habitat of both species in the northern Great Plains consists of barren or sparsely vegetated areas of sand and gravel associated with rivers (Faanes 1983, Mayer and Dryer 1988, Schwalbach 1988, Dirks 1990), ponds and lakes (Whyte 1985, Haig 1987, Prindiville-Gaines and Ryan 1988), and reservoir shorelines (Gray 1990; Mayer and Dryer 1990; Prellwitz et al. 1989; Schwalbach 1988; USFWS 1989, 1990a, 1990b, 1990c).

In the upper Missouri River Basin (Montana, North Dakota, South Dakota, Iowa, and Nebraska), least terns and piping plovers often nest close together at

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the same sites (Ducey 1981, 1982, 1989; Mayer and Dryer 1988; Schwalbach 1988; Kirsch 1990; Lingle 1988, 1989). The Platte River, a major tributary of the Missouri, supports a substantial fraction of the nesting populations of both species. About 600 least terns, comprising 13% of the population (Sidle et al. 1988, USFWS 1990c), and about 300 piping plovers, comprising 9% of the northern Great Plains population excluding Canada (USFWS 1988), nest along the Platte. Nesting occurs on sandbars in the river and on sand spoil piles associated with gravel mining operations (sand pits) near the river (Wilson 1991, Kirsch 1992, Sidle et al. 1991).

Numerous dams and water diversion canals in the upper Platte River Basin have reduced water and sediment discharge in the Platte, resulting in the transformation of wide, open channels to multiple narrow channels separated by wooded islands (Williams 1978, Eschner et al. 1981). This vegetation encroachment has eliminated much habitat for several species of birds, including least terns and piping plovers (USFWS 1981, Currier et al. 1985, Sidle et al. 1989).

The loss of open river channel has been greatest in the Upper Platte, from the confluence of the North Platte and South Platte Rivers to Lexington (Fig. 1) (Sidle et al. 1989). Least terns and piping plovers no longer nest along this reach of the river except at a few sand pits. Extensive vegetation encroachment also has occurred in the Central Platte, from Lexington to the mouth of the Loup River, but some sites are still used for nesting. Most nesting in recent years has occurred on the Lower Platte, below the mouth of the Loup River, where vegetation encroachment of the river channel is least advanced. The channel of the Lower Platte remains dynamic; the area of sandbars suitable for least tern and piping plover nesting has increased and decreased during 1949-1988 (Rodekohr and Engelbrecht 1988). High flows continue to periodically scour vegetation from sandbars along the Lower Platte (Sidle et al. in press).

Several authors have described various sandbar and river channel dimensions as important nest site characteristics of least terns and piping plovers along the Central Platte (Faanes 1983, Armbruster 1986, Carlson 1987). They noted the need for high spring flows to scour vegetation and maintain sandbars suitable for nesting, lower but continuous summer flows to ensure the availability of food items and to isolate sandbars from mammalian predators and human disturbance, and the clearing of vegetation and artificial deposition of sandbars to sustain nesting on the Central Platte.

Our objective was to assess whether the availability of suitable riverine habitat may be limiting nesting populations of least terns and piping plovers on the Central and Lower Platte River, and, if so, to formulate habitat restoration measures. We measured several habitat characteristics in a systematic sample of the Central and Lower Platte and in river segments used for nesting during 1988. We related these measurements to records of river discharge.

STUDY AREA

Our study area on the Central and Lower Platte during the 1988 breeding season (April-August) encompassed the extent of known least tern and piping plover nesting activity on the Platte in recent years. We worked in the Central

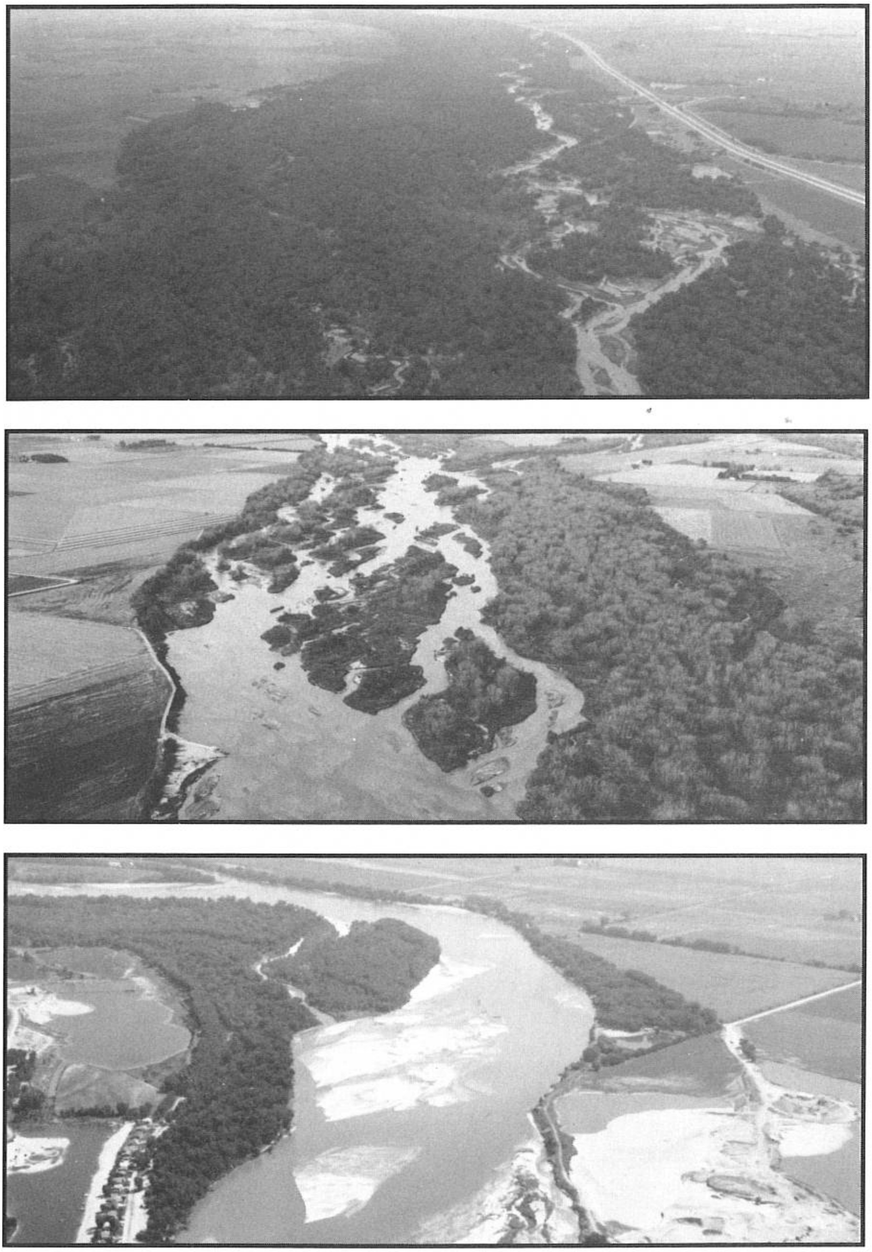

Figure 1. Aerial photographs (1989) of the Upper Platte (North Platte to Lexington) (top), Central Platte (Lexington to Columbus) (middle), and the Lower Platte (Columbus to the Platte's confluence with the Missouri River) (bottom).

Platte between Lexington (U.S. Army Corps of Engineers river mile (rm) 251) and Chapman, NE (rm 157). The reach of the Central Platte between Chapman and the mouth of the Loup River was excluded because it has not been used for nesting for about 10 years. We examined the entire Lower Platte (rm 0-101). For some analyses, the Lower Platte was divided further into the reaches above and below the mouth of the Elkhorn River (rm 33), a major tributary.

METHODS

Location of Nesting Sites

During 13-24 June, we travelled by airboat from Lexington to the mouth of the Platte locating nesting sites and marking individual nests. We located additional nests during follow-up visits to sites. We floated eggs to determine incubation stage (Hays and LeCroy 1971 as modified by Schwalbach 1988) and estimated the date of nest initiation by back-dating from the census date. We marked nests with survey flags placed 1 m north of the nest and pushed into the sand exposing 2 cm of rolled flag. Flags facilitated the relocation of nests later in the season for a variety of habitat measurements. Data collection while birds were present would have caused excessive disturbance.

Aerial Videography

We videotaped the Platte River from an aircraft on several dates to obtain areal habitat measurements during the breeding season (Sidle and Ziewitz 1990). Following the nesting season, we determined that the period 25 April-24 June had been the principal period of the birds' arrival and nest initiation. We selected six video recordings over the Lower Platte and eight over the Central Platte that represented the range of river discharges that occurred during this period because several of the habitat characteristics of interest to us varied with river discharge. We analyzed selected scenes from these recordings using image processing tools on a micro-computer (Sidle and Ziewitz 1990).

We analyzed video scenes of 26 nesting sites to measure characteristics of used sites and analyzed a systematic sample of sites to measure the same characteristics of the riverine habitat available to least terns and piping plovers. We established sample sites every three miles beginning at rm 2, which yielded 34 sites on the Lower Platte and 29 sites on the Central Platte. Three of the sites on the Lower Platte occurred at approximately the same location as nest sites. Therefore, the systematic sample of the Lower Platte was not entirely a sample of unused sites, and we included data from these three sites in both data groups. None of the Central Platte sample sites coincided with nest sites.

The object of analysis within each video scene was a 402-m (¼-mile) segment of river. Within each segment, we measured the area of total channel, permanent vegetation, and potentially suitable nesting substrate (sandbar area). Such substrate appears white or light-colored on the video. Damp areas or areas with greater than 20% vegetation cover appear darker and were not interpreted as potentially suitable nesting substrate. We calculated average channel width as the active channel area divided by the 402-m length of the segment. We defined active channel as that portion of the river bed not stabilized by permanent vegetation (area of total channel minus area of permanent vegetation). We tested the hypothesis that the means of measurements at nest sites and systematic sample sites were equal using independent-sample t-tests.

Ground Surveys

We surveyed the systematic sample sites 13 June-11 July and the nest sites 1-12 August. We measured vegetative characteristics and vertical habitat dimensions at each site on two transects crossing the river. Transects were located approximately 100 m (330 ft) upstream of the lower end of each river segment and 100 m downstream of the upper end. At nest sites, at least one of the transects passed through the nesting area. We selected points for measurements along a transect that best depicted the contours and vegetation of the river bed, i.e., major inflection points in the river cross-section and changes in vegetation along the transect. We measured horizontal and vertical dimensions using a surveyor's level and stadia rod. We visually estimated the average height of vegetation and percentage cover in a 1-m^2 area centered over each point. Currier (1982) previously described the plant species occurring on sandbars along the Platte.

We measured the characteristics of points selected along two transects within the 402-m river segments, rather than random points, to simplify the process of relating elevation measurements to the water surface elevation at the time of the survey. We believed transect sampling would better capture the range of variability in elevation and vegetation characteristics at a site than a random sampling design.

We adjusted the water-surface-elevation datum of each transect to a common elevation datum to compare the transects measured at different sites and river discharges. We selected the stages corresponding to 113 cubic meters per second (cms) (4000 cubic feet per second (cfs)) for the Lower Platte and 11.3 cms (400 cfs) for the Central Platte. Our adjustments yielded elevation measurements as if all Lower Platte data were collected at a discharge of 113 cms and all Central Platte data were collected at a discharge of 11.3 cms.

We computed the adjustments using river stages and other data collected by the Nebraska Department of Water Resources and U.S. Geological Survey at gages near Overton, Odessa, Kearney, Grand Island (Central Platte), North Bend, and Louisville (Lower Platte). Given the distance of a study site from the nearest gage and an estimate of the average velocity of flows at the time of our survey, we computed a travel time for water between the site and the gage and determined the gage height at the time of our measurements plus or minus the computed travel time, depending on whether the gage was upstream or downstream of the site. The datum adjustment computed for the site was the difference between this gage height and the gage height corresponding to 113 cms (Lower Platte) or 11.3 cms (Central Platte).

The above method of adjusting elevation measurements introduced error into these data. The adjustments were accurate only to the extent that the relationships between river stage and discharge at our study sites were similar to those at the nearest gages. The accuracy of the adjustments was also dependent upon the estimates of water travel time. Establishing stage-discharge relationships at each of our sites was a task far beyond the resources of our study, and our water travel time estimates were as precise as possible with the available data. We accepted the error inherent in our methodology as the only practical means of deriving comparable elevation data at a large number of sites.

To estimate the mean and maximum elevation of potentially suitable nesting habitat at a site, we derived a random sample from the transect data and then removed patently unsuitable points according to the following procedure. We computed the elevations of points between actual measured points at 0.3-m (1-ft) intervals by simple linear interpolation. We assigned interpolated points the vegetative characteristics of the nearest measured point, except where a measured point was expressly identified as a boundary between two vegetative cover types on the transect. Where noted, boundary points defined the assignment of vegetative characteristics to interpolated points. We randomly selected 30 points per transect from the combined set of measured and interpolated points. From these 30 points, we selected those having the vegetative cover characteristics observed at nest locations, as measured during the nest site ground survey. We computed the mean and maximum elevations of the final set of points at each site. We tested the hypothesis that the means of these measurements at nest sites and systematic sample sites were equal using independent-sample t-tests.

We measured the elevation of each nest relative to the water surface elevation. We computed the nest's elevation above the adjusted datum and its elevation above water at the time of nest initiation in the same manner that the transect elevation data were adjusted to a common datum. We tested the hypothesis that the mean elevation of nests and the mean elevation of sites were equal using paired-sample t-tests. The analysis of nest elevations involved estimating the discharge corresponding to each nest elevation; we determined the minimum, median, and maximum of these values for use as reference points in further analysis of hydrologic records.

Analysis of Hydrologic Records

From discharge records for Grand Island, North Bend, and Louisville, NE, gaging stations (U.S. Geological Survey Water Resources Data, 1959-1988) we computed mean annual hydrographs and the frequency of occurrence of discharges corresponding to nest elevations.

RESULTS

Location of Nesting Sites

We located a total of 222 least tern nests at 30 sites and 82 piping plover nests at 30 sites on the Platte River during 1988. Terns nested exclusively at three sites and plovers at three. Most nesting occurred on the Lower Platte (Figs. 2 and 3a).

We measured habitat characteristics at 177 tern nests at 26 sites and 60 piping plover nests at 26 sites. Terns nested exclusively at two of these sites and plovers at two.

We determined nest initiation dates for 155 of the 177 measured tern nests and for 46 of the 60 piping plover nests (Fig 3b). Tern nest initiation dates ranged from 19 May to 23 June and plover dates from 21 May to 25 June. The median nest initiation dates for terns and plovers were 7 June and 2 June, respectively. Both species nested earlier on the Lower Platte than the Central Platte.

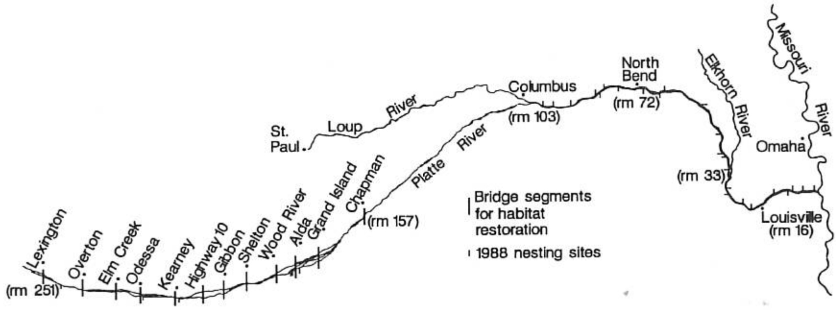

Figure 2. The Central Platte (Chapman to Lexington) and Lower Platte (Loup River confluence to the Missouri River) river segments, Nebraska where least tern and piping plover nesting habitat was studied during 1988.

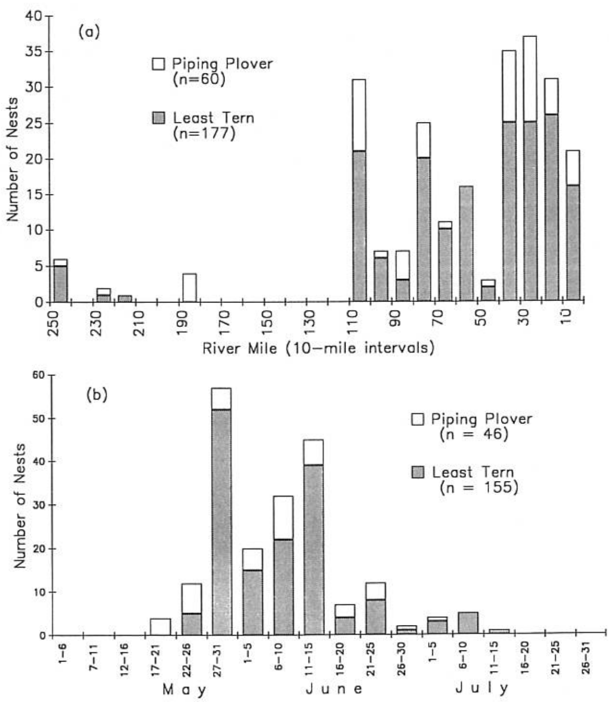

Figure 3. Distribution of nesting interior least terns and piping plovers (a) in the Platte River for which habitat characteristics were measured during 1988 and nest initiation dates (b).

Aerial Videography — Lower Platte

Nesting substrate (sandbar area) varied along the Lower Platte depending on the variable flow (Table 1 and Fig. 4). Vegetation growth during the nesting season also contributed to variation in sandbar area. Sandbar area was greatest in the reach below the mouth of the Elkhorn River.

The mean sandbar area of nest sites was 1.9 ha for the six dates examined, although nesting occurred at sites with less than 0.2 ha available (Table 1). This was significantly greater than the mean of 0.76 ha for the systematic sample sites ($t=4.75$, $P<0.001$).

The mean channel width of nest sites was 519 m, significantly greater than the mean of 430 m for the systematic sample sites ($t=3.40$, $P=0.001$). (Table 1).

Table 1. Measurements from aerial videography of 402-m (1/4 mile) systematic river segments (n=34) and river segments (n=25) centered on least tern and piping plover nesting sites on the Lower Platte River (river mile 1-101), Nebraska, 1988.

			Area of dry, sparsely vegetated sandbar (ha)						
	Channel Area (ha)	Mean Channel Width (m)	Apr 25 108 cms[1] 159 cms[2]	May 5 255 187	May 11 211 256	May 19 123 157	May 24 196 280	Jun 15 58 96	Sandbar area for all dates
Systematic Sample of River Sites									
Min.	8.5209	211.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mean	17.2908	429.8	0.9982	0.9492	0.6209	0.8932	0.5642	0.6318	0.7762
Max.	23.9383	595.0	4.8531	7.7050	3.3347	4.8898	4.1517	2.7846	7.7050
St. Dev.	4.1108	102.2	1.2506	1.5496	0.8284	1.2954	0.9498	0.8077	1.1331
Nesting Sites									
Min.	13.7742	342.4	0.2190	0.1120	0.1354	0.1397	0.1101	0.0913	0.0913
Mean	20.8786	519.0	2.4562	2.2130	1.4945	2.1612	1.4571	1.5189	1.9019
Max.	30.8530	766.9	13.1463	12.0723	12.7030	13.9372	10.5033	7.9761	13.9372
St. Dev.	3.8717	96.2	3.0572	2.9133	2.6644	3.0022	2.2902	2.0522	3.8849

[1]Average daily flows at North Bend.
[2]Average daily flows at Louisville.

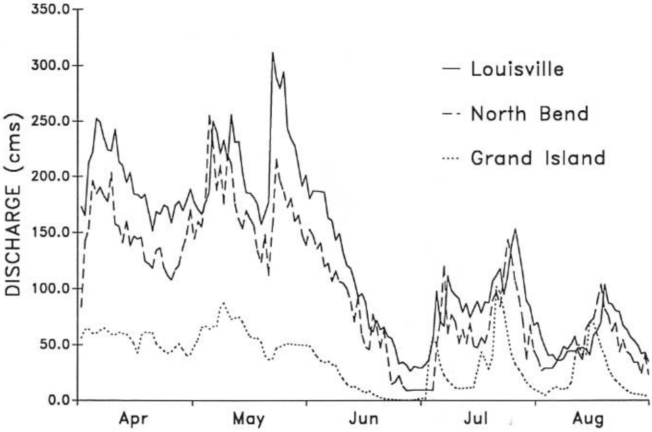

Figure 4. Flows at the U.S. Geological Survey's Grand Island, North Bend, and Louisville gages on the Platte River during April-August, 1988.

Aerial Videography — Central Platte

In the videography of the Central Platte, we commonly observed moderately vegetated sandbars and sandbars that were slightly exposed above water. We rarely observed areas that could clearly be interpreted as potentially suitable nesting substrate. The differences between the Central and Lower Platte are readily apparent (Tables 1 and 2).

River discharge at Grand Island ranged from 0.7 cms (25 cfs) to 73 cms (2570 cfs) on the eight dates of aerial videography. With one exception, we measured sandbar areas greater than 0.8 ha only on the two lowest-flow dates (15 and 24 June).

The mean sandbar area of nest sites was 0.48 ha for the eight dates examined. This was significantly greater than the mean of 0.24 ha for systematic sample sites (t=2.26, P=0.028) (Table 2). The mean channel width of nest sites was 295 m, significantly greater than the mean of 201 m for the systematic sample sites (t=2.70, P=0.011) (Table 2).

Table 2. Measurements from aerial videography of 402-m (1/4 mile) systematic river segments (n=29) and river segments centered on least tern and piping plover nesting sites (n=6) on the Central Platte River (river mile 167-251), Nebraska, 1988.

			Area of dry, sparsely vegetated sandbar (ha)								
	Channel Area (ha)	Mean Channel Width (m)	May 5 64 cms[1]	May 11 73	May 24 48	June 4 35	June 7 32	June 10 19	June 15 8	June 24 0.7	Sandbar area for all dates
					Systematic Sample of River Sites						
Min.	2.5944	64.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0585	0.0000
Mean	8.1050	201.5	0.0854	0.0911	0.0638	0.0725	0.0384	0.0945	0.5018	0.8944	0.2428
Max.	14.2251	353.6	0.6558	0.5821	0.6922	0.8047	0.3365	0.6166	2.0709	2.6486	2.6486
St. Dev.	3.0857	76.7	0.1525	0.1567	0.1430	0.1598	0.0709	0.1543	0.4440	0.6242	0.4068
					Nesting Sites						
Min.	7.2927	181.3	0.0013	0.0025	0.0000	0.0000	0.0000	0.0009	0.0205	0.3301	0.0000
Mean	11.8772	295.2	0.1667	0.1439	0.2460	0.2111	0.2295	0.3382	0.7786	1.8167	0.4856
Max.	15.3585	381.8	0.3922	0.4695	0.7867	0.7338	0.7094	1.8095	1.9478	3.8120	3.8039
St. Dev.	3.2738	81.4	0.1738	0.1982	0.3522	0.3117	0.2923	0.7217	0.7345	1.1871	0.7688

[1]Average daily flows at Grand Island.

Ground Survey

Our measurements of vegetative cover and height at nest sites were not comparable with those at systematic sample sites because we surveyed the two at different times of the breeding season to avoid disturbance to the birds. Many nests that were first observed in June as scrapes in barren sand had by August acquired a thick cover of vegetation. However, most nests (90.3%) still had less than 50% vegetative cover in the surrounding 1-m^2 area, and all had average vegetation heights less than 0.76 m. We computed the mean and maximum elevation at a site using only those points that shared these vegetative characteristics, and did not use the vegetation data to compare nest sites and systematic sample sites.

Lower Platte. — The mean elevation above the stage of 113 cms at nest sites ranged from 0.09 m to 0.82 m, with a mean of 0.3 m (Table 3). The mean elevation at the systematic sample of sites ranged from 0.0 m (no sandbar exposed at 113 cms) to 0.7 m, with a mean of 0.21 m. These means were not significantly different (t=1.51, P=0.14).

Table 3. Elevation[1] measurements from ground surveys of 402-m (1/4 mile) systematic river segments (n=34) on the Lower Platte River (river mile 1-101, Nebraska, 1988.

	Site Mean Elev.	Site Max. Elev.	# Nests	Nests Mean Elev.	Nests Max. Elev.
		Nesting Sites			
Min.	0.09	0.15	1	0.12	0.18
Mean	0.30	0.67	9.3	0.52	0.64
Max.	0.82	1.68	31	1.01	1.25
St. Dev.	0.18	0.37	7.8	0.24	0.30
		Systematic Sample of River Segments			
Min.	0.00	0.00			
Mean	0.21	0.61			
Max.	0.70	1.65			
St. Dev.	0.18	0.43			

[1]m above stage of 113 cms

The maximum elevation above the stage of 113 cms at nest sites ranged from 0.15 m to 1.68 m with a mean of 0.67 m (Table 3). The maximum elevation at the systematic sample of sites ranged from 0.0 m to 1.65 m, with a mean of 0.61 m. These means were not significantly different (t=0.71, P=0.48).

Nests were located usually on the highest sparsely vegetated ground available at a site. The mean elevation of nests above the stage of 113 cms was 0.52 m (n=224, Table 3), which was significantly higher than the mean elevation of the nest sites ($\bar{x}$=0.30, t=6.77, P<0.001) (paired sample t-test). The mean maximum elevation by site ($\bar{x}$=0.64 m) was not significantly different from the mean maximum elevation of the nest sites ($\bar{x}$=0.67 m) (t=–0.75, P=0.46).

We estimated the nest initiation date and computed the elevation above water on the nest initiation date for 188 nests of 224 surveyed ($\bar{x}$=0.49 m, range 0.03 to 1.18 m). Of these, 163 nests (86.7%) were initiated between the last two dates of videography analyzed, 24 May and 15 June. Figures 5a and 5b show the computed river stages associated with nests and the average daily river stage measured between April-July 1988.

Central Platte. — The mean elevation above the stage of 11.3 cms (400 cfs) at nest sites ranged from 0.06 m to 0.61 m, with a mean of 0.30 m (Table 4). The mean elevation at the systematic sample of sites ranged from 0.04 m to 0.54 m, with a mean of 0.13 m. These means were not significantly different (t=1.72, P=0.14).

The maximum elevation above the stage of 11.3 cms at nest sites ranged from 0.12 m to 1.34 m, with a mean of 0.81 m (Table 4). The maximum elevation at the systematic sample of sites ranged from 0.09 m to 1.13 m, with a mean of 0.42 m. These means were not significantly different (t=1.66, P=0.15).

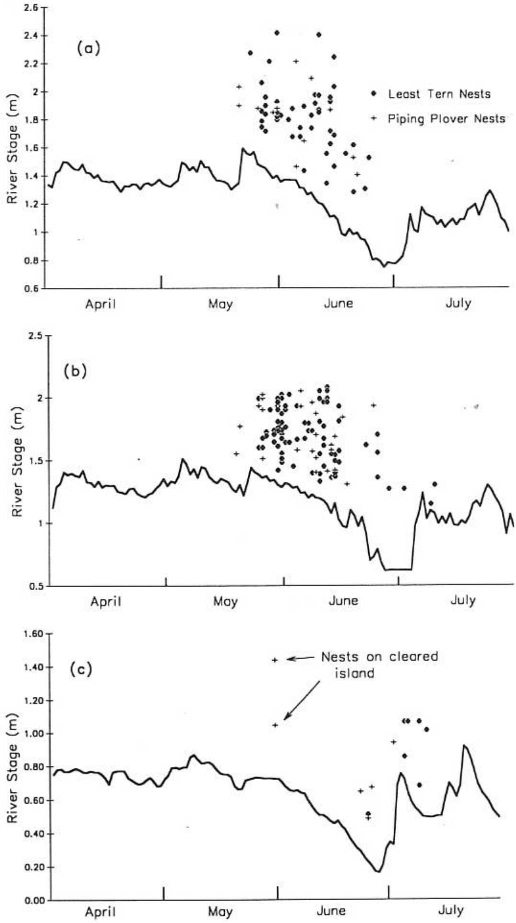

Figure 5. River stages and elevations of interior least tern and piping plover nests on the Platte River during 1988; (a) below the Elkhorn River confluence (USGS gage near Louisville); (b) below the Loup River confluence and above the Elkhorn confluence (USGS gage near North Bend); and (c) nest elevations below Lexington and above Chapman (USGS gage near Grand Island).

The mean elevation of nests above the stage of 11.3 cms was 0.34 m (Table 4). Using a paired sample t-test, this was not significantly different than the mean elevation of nest sites ($\bar{x}$=0.30 m, t=-0.13, P=0.90). The mean maximum nest elevation (0.43 m) was not significantly different from the mean maximum elevation of the nest sites ($\bar{x}$=0.81 m, t=-2.63, P=0.06).

The mean elevation above water on the nest initiation dates for the 13 nests surveyed on the Central Platte was 0.39 m (range 0.12 m to 0.70 m). Eight of these 13 nests failed due to inundation (Lingle 1988). The computed river stages associated with nests and the April-July river stages measured at the Grand Island gage are plotted in Fig. 5c.

Table 4. Elevation[1] measurements from ground surveys of 402-m (1/4 mile) systematic river segments (n=29) and river segments (n=6) centered on least tern and piping plover nesting sites on the Central Platte River (river mile 167-251), 1988.

	Site Mean Elev.	Site Max. Elev.	# Nests	Nests Mean Elev.	Nests Max. Elev.
			Nesting Sites		
Min.	0.06	0.12	1	0.09	0.15
Mean	0.30	0.81	2.6	0.34	0.43
Max.	0.61	1.34	6	0.73	0.94
St. Dev.	0.23	0.55	1.9	0.30	0.36
		Systematic Sample of River Segments			
Min.	0.04	0.09			
Mean	0.13	0.42			
Max.	0.54	1.13			
St. Dev.	0.10	0.10			

[1]m above stage of 11.3 cms

Analysis of Hydrologic Records

We examined 30 water years (1 October 1958 to 30 September 1988) of mean daily discharge records of U.S. Geological Survey gages in our study area for computing long-term statistics. The Lower Platte was continuously gaged in this period near the towns of North Bend (rm 72) and Louisville (rm 16). Largely because of contributions of the Elkhorn River (rm 33) and Salt Creek (rm 26), the mean annual volume of flow at Louisville ($6.27x10^9$ m^3) is about 50% greater than at North Bend ($4.28x10^9$ m^3). Four gages are located on the Central Platte, three of which have been operated for more than 30 years. There are no major tributaries along the Central Platte, and mean annual volumes measured are similar at all four gages (about $1.66x10^9$ m^3). We elected to repre-

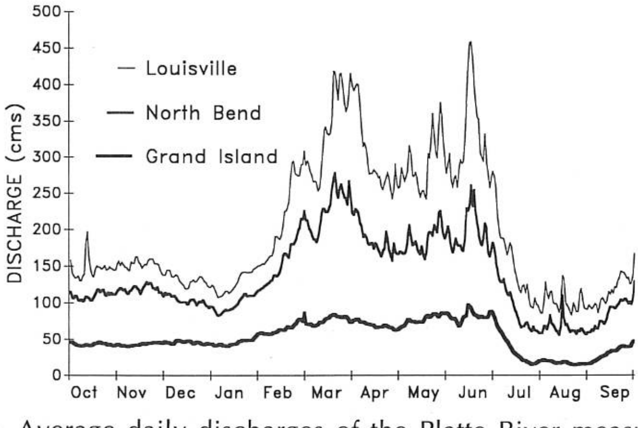

Figure 6. Average daily discharges of the Platte River measured near Grand Island, North Bend, and Louisville, Nebraska based upon U.S. Geological Survey data, 1958-1988.

sent the Central Platte by its downstream-most gage near Grand Island. Figure 6 shows mean daily flows of the Platte River during water years 1958-88 as measured at Grand Island, North Bend, and Louisville.

Table 5 shows calculations that relate our nest elevation measurements to the 30 years of daily discharge records of the nearest river gage: Grand Island, North Bend, or Louisville. We calculated the percentage of years and the percentage of days that the discharges corresponding with the minimum, median, and maximum nest elevations were exceeded. The two nests that occurred on an artificially cleared island in the Central Platte (rm 184) were excluded from this analysis. We repeated these calculations for four periods of the year: the first half of the nesting season (1 April to 15 June), the second half of the nesting season (16 June to 31 August), the non-nesting season (1 September to 31 March), and the entire year.

The discharges corresponding to the minimum, median, and maximum elevations of nests on the Central Platte were exceeded consistently more often in all three seasons of the year than those of the Lower Platte. Although nests on both the Lower and Central Platte were generally located on the highest sparsely vegetated sites available on a sandbar, these calculations suggest that such habitat is under water more often on the Central Platte.

Table 5. Frequencies that discharges associated with least tern and piping plover nest elevation measurements were exceeded in a 30-year period (October 1, 1958-September 30, 1988) at Grand Island, North Bend, and Louisville river gages along the Platte River, Nebraska.

	Nest elevations								
	Minimum			Median			Maximum		
Reach of Platte River[a]:	GI	NB	LV	GI	NB	LV	GI	NB	LV
Discharge (cms) associated with nest elevation:	9.7	89.9	149	82.0	392	524	164	677	1,550
April 1-June 15									
% days exceeded:	94.4	80.4	75.3	25.0	7.1	12.6	11.9	1.8	0.4
% years exceeded:	100.0	100.0	100.0	66.7	46.7	66.7	33.3	20.0	10.0
June 16-August 31									
% days exceeded:	54.5	33.9	32.6	11.8	3.3	4.6	5.7	1.5	0.5
% years exceeded:	100.0	100.0	100.0	60.0	50.0	56.7	33.3	20.0	16.7
September 1-March 31									
% days exceeded:	94.9	61.5	42.3	14.8	1.9	2.9	2.8	0.4	0.2
% years exceeded:	100.0	100.0	100.0	76.7	63.3	63.3	40.0	23.3	10.0
January 1-December 31									
% days exceeded:	86.3	59.6	47.1	16.3	3.3	5.3	5.3	0.9	0.3
% years exceeded:	100.0	100.0	100.0	76.7	63.3	66.7	40.0	23.3	16.7

[a]GI=Grand Island gage representing the Central Platte; 11 nest elevations measured in this reach.
NB-North Bend gage representing the Lower Platte above the confluence of the Elkhorn River; 135 nest elevations measured in this reach.
LV=Louisville gage representing the Lower Platte below the confluence of the Elkhorn River; 89 nest elevations measured in this reach.

SUMMARY AND DISCUSSION

Our comparisons of sandbar area, channel width, mean elevation, and maximum elevation of nest sites versus systematic sample sites in the Lower Platteand Central Platte study areas suggest that least terns and piping plovers use wide channels with a large area of dry, sparsely vegetated sand. By these two measures alone, habitat availability was considerably greater on the Lower Platte than on the Central Platte. Although nest sites also had higher mean and maximum elevation than systematic sample sites, these differences were not statistically significant in either river reach. On the Lower Platte, nests were located on significantly higher ground than the mean elevation of the nest sites. On the Central Platte the mean elevation of nests was less than the mean site elevation at half of the nest sites.

These differences between the nest and systematic sample sites and between the Lower and Central Platte suggest that habitat availability is limited in the river channel along the Central Platte. A greater number of least terns and piping plovers nest on sand pits than on the river along the Central Platte (Lingle 1988, 1989). This is consistent with our observation that riverine habitat is in short supply.

Nests on the Central Platte were initiated at lower elevations above water (x=0.39 m) than nests on the Lower Platte (x=0.49 m), despite the fact that 1988 nesting season flows were much greater on the Lower Platte. However, these means were not significantly different (t=1.53, p>0.1).

Low flows followed by sudden peaks in early and late July resulted in the inundation of 8 of the 13 nests surveyed at Central Platte sites. The median elevation of these nests equates to a stage of about 82.0 cms (2895 cfs) at the Grand Island gage (Table 5). Flows higher than 82.0 cms during 16 June to 31 August, the latter half of the nesting season, occurred in 18 of the 30 years from 1959 to 1988, suggesting that nest inundation is likely to be a common occurrence given present habitat conditions.

These facts coupled with the striking paucity of dry sandbar area in the videography of the Central Platte, even at low flows, suggest that those channels of the Central Platte wide enough to be attractive to terns and plovers are too flat to provide safe nesting substrate. Higher portions of the river bed that might have provided safe nesting substrate in the past have become vegetated islands.

MANAGEMENT RECOMMENDATIONS

Recovery plans for the piping plover and interior population of the least tern call for the maintenance of the distribution and range of both species, protection of essential habitat, and the restoration of nesting habitat (USFWS 1988, 1990b). Essential habitat along the Platte River refers to sandbars in the river channel. Given the degraded habitat conditions for these birds in the Central Platte, channel habitat restoration is necessary.

Habitat restoration for least terns already has been accomplished elsewhere in North America. It is the cornerstone of efforts for the recovery of the endangered California least tern (*Sterna antillarum brownii*) (USFWS 1980). Coastal least terns nest on artificial sites of dredged sand and gravel (Jernigan 1977, Buckley and McCaffrey 1978, Chaney et al. 1978, Soots and Landin 1978, Jackson and Jackson 1985). Smith and Stucky (1988) outlined a proposal for restoring habitat for least terns on the Mississippi River by dredging sand to form new nesting sandbars.

The Platte River Whooping Crane Habitat Maintenance Trust has been clearing islands of permanent woody vegetation to restore habitat in the Central Platte for cranes and other species of migratory birds (Lingle 1981, Currier 1984, Currier 1991). Least terns and piping plovers have nested on one island cleared by the Trust, but only on portions of the island that had been washed over by high flows following the clearing. Other portions of the island that were not washed over were rough and soon were covered by a thick growth of annual vegetation.

To achieve the relatively smooth and clean substrate that least terns and piping plovers are known to use, and the elevation necessary to escape inundation during the nesting season, we recommend dredging sand onto cleared islands or existing sandbars. Fig. 7 illustrates such an island constructed in 1990 between Alda and Wood River. Ten pairs of least terns and four pairs of piping plovers nested on the artificial island in 1991. An island constructed in 1990 just east of Elm Creek by the Nebraska Public Power District hosted one breeding pair of least terns and two pairs of piping plovers in 1991 (R. G. Plettner, pers. commun.). We recommend the following guidelines for habitat restoration projects in the Central Platte regarding channel dimensions, sandbar area, and sandbar height.

Figure 7. Aerial photograph of an island in the Central Platte between Alda and Wood River, Nebraska, created in 1990 by dredging sand onto an island cleared of vegetation. Least terns and piping plovers nested on the island in 1991.

Channel Dimensions

Habitat restoration in the Central Platte should be undertaken in the widest channels. Mean channel width of nest sites on the Central Platte was 295 m. Mean channel width of the 402-m (¼-mile) reaches immediately above and below the Central Platte nest sites was 275 m. Channel width was calculated as the active channel area divided by 402 m. Active channel area is the total channel area minus the area of permanent islands. We recommend undertaking habitat restoration in approximately 1200-m reaches where channel width is at least 295 m in the central 400 m and at least 275 m in the upper and lower 400 m. As in our sampling scheme for study sites, these dimensions apply to a single contiguous channel, not to multiple channels on opposite sides of long, permanent islands.

If habitat restoration proves successful in channels that meet the width and length requirements described above, similar restoration projects should be undertaken in narrower channels, because more narrow channels exist in the Central Platte. We recommend further habitat restoration in 1200-m reaches where channel width is at least 181 m, the width of the narrowest site used for nesting in 1988. Clearing vegetation from permanent islands, which does not in itself increase active channel area or channel width but does increase visibility at a site, is a third option that may provide conditions suitable for a nesting sandbar.

Sandbar Area

Within the central 400 m of a suitable 1200-m reach, one or more mid-channel sandbars should be dredged to provide a high, relatively clean, and smooth nesting substrate. Nest sites on the Lower Platte had a mean of 1.45 ha of dry, sparsely vegetated sand during the period when many nests were initiated (data from 24 May aerial videography, Table 1).

USFWS has identified 22.7 cms (800 cfs) during the summer in the Central Platte as a flow to maintain forage fish for least terns and to restrict sandbar access by mammalian predators and recreational vehicles (USFWS 1987a, 1987b; Sidle et al. 1990). Using the Lower Platte as a nearby model of better habitat conditions, we recommend that the size of the restored sandbars on the Central Platte should be at least 1.45 ha relative to a discharge of 22.7 cms. Given the apparent preference shown for greater sandbar area in the comparison of nest sites with systematic sample sites, sandbars larger than 1.45 ha should be created wherever practical. Sandbars of up to 4.04 ha located in sufficiently wide channels with adequate nesting season flows should provide suitable nest sites.

Sandbar Height

At the Grand Island river gage, a discharge of 22.7 cms is equivalent to 0.45 m above the stage of 0.0 cms (for simplicity, the stage of 0.0 cms shall be considered the lowest portion on a cross section of the river bed). At least 1.45 ha of the restored sandbar, which is the minimum size described above, should be greater than 0.45 m in height. The mean peak discharge for 15 June to 31 August during 1957-88 was 149 cms (5250 cfs), which is equivalent to a stage of 0.91 m. A sandbar of this height would have escaped inundation between 15

June and 31 August in 21 of the 32 years of that period, and would have been 0.45 m above the desired summer flow of 22.7 cms. Sandbars higher than 0.91 m would afford even greater protection from flooding. Schwalbach (1988) recommended a minimum of 0.15 m clearance between the lowest active nests and water levels. The maximum daily discharge between 15 June and 31 August in 1957-88 was 665 cms (23,500 cfs), equivalent to a stage of about 1.76 m. We recommend restoring sandbars by dredging at least 0.80 ha to a height greater than 1.06 m and at least 0.40 ha to a height greater than 1.76 m.

Number and Location of Sites

The Central Platte between Lexington and Chapman is divided into 11 reaches by important highway bridge crossings (Fig. 2). Since 1978, least terns and piping plovers have nested on the river at various locations in eight of these reaches (Lingle 1988), which still contain at least one area with a channel sufficiently wide for potential nesting sites. We recommend the restoration of sites in the eight bridge segments according to the criteria described above.

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