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CHANNEL WIDTH AND LEAST TERN AND PIPING PLOVER NESTING INCIDENCE ON THE LOWER PLATTE RIVER, NEBRASKA

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ABSTRACT—Endangered interior least terns (*Sternula antillarum athalassos*) and threatened northern Great Plains piping plovers (*Charadrius melodus*) nest together on midstream sandbars in large rivers in the interior of North America. We investigated the relationship between river channel width and tern and plover nesting incidence on the lower Platte River, Nebraska, using a model-based logistic regression analysis. Multiple channel width measurements and a long-term nesting data set were used in the analysis. Nesting incidence was positively associated with increasing river channel width proximal to the nesting site. At a greater distance, up to 802 m away from the nesting site, there was no relationship with channel width. Managers and regulators should use these results to aid decisions pertaining to habitat creation and assessing impacts of future projects. Future research should address whether relationships exist between river channel width and nest counts and reproductive rates of interior least tern and piping plovers on the lower Platte River.

Key Words: channel width, *Charadrius melodus*, interior least tern, lower Platte River, piping plover, *Sternula antillarum athalassos*

INTRODUCTION

Effective management of threatened and endangered species occupying human-altered ecosystems in the Great Plains often relies on the creation, renovation, and preservation of habitats that are critical to their survival. Because broad-scale restoration of ecosystems is often physically or economically impractical, habitat managers are now being challenged to replicate components of complex and dynamic natural ecosystems within limits and constraints and at small geographic scales. They are further challenged to do their work with incomplete information on important relationships between species and their habitats. For threatened and endangered species management efforts to be successful, it is critical to develop and refine information about species–habitat relationships and make it available to conservation practitioners and habitat managers.

Nearly all midcontinental river systems in North America have been altered by human activities such as

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dam construction, channelization, bank stabilization, and water diversion (National Research Council 2002, 2005). These alterations serve human interests by providing services such as irrigation, navigation, and flood control, but they often disrupt ecosystem services and hydrological and geomorphological processes. The consequence of these alterations can be substantial loss of habitat for riverine-dependent species, which in turn may put certain species at risk of extinction. The endangered interior least terns (*Sternula antillarum athalassos*) and threatened northern Great Plains piping plovers (*Charadrius melodus*) are two such species whose decline in the United States is largely attributed to nesting habitat loss (US Fish and Wildlife Service 1988, 1990). For both species, the critically important nesting habitat includes midstream macroform sandbars and sandbar complexes in large sediment-rich rivers (Thompson et al. 1997; Elliott-Smith and Haig 2004). A recent rangewide survey showed that approximately 90% of all interior least tern nests (Lott 2006) and 21% of all piping plover nests (Elliott-Smith et al. 2009) located in the Great Plains in 2006 were found on river sandbars.

While full restoration of human-altered river systems is generally not a politically viable or economically feasible option, water project managers and users in the United States must comply with the Endangered Species Act. For example, they may be required to mitigate for the negative environmental impacts resulting from their projects and provide necessary habitat for threatened and endangered species. The comprehensive scope of mitigation necessary to meet recovery objectives in these human-altered rivers has led to the development of two major programs in the central Great Plains that are focused on the mechanical creation of nesting habitat: the US Army Corps of Engineers Emergent Sandbar Habitat program on the Missouri River (US Fish and Wildlife Service 2003) and the three-state Platte River Recovery Program on the central Platte River in Nebraska (Nebraska, Colorado, and Kansas; Platte River Recovery Implementation Program 2006).

As recovery of tern and plover populations in the Great Plains is increasingly dependent on targeted habitat projects, a critical aspect is determining where habitat construction projects will be most effective. Tern and plover nesting habitat appears, superficially, to be easily created, as it consists of expanses of sparsely vegetated sand located near water (Thompson et al. 1997; Elliott-Smith and Haig 2004). However, nesting habitat selection by terns and plovers is complex, and key species–habitat relationships are poorly understood. Terns and plovers may choose not to use sandbars that are created as part of these habitat projects or, even worse, they may be drawn into unsuitable nesting habitat that become population sinks (Pulliam 1988; Battin 2004).

The width of the river active channel (channel width) is a variable known to influence tern and plover nest site selection. Two studies on the Platte River, Nebraska, showed that mean channel width at tern and plover nesting sites was greater than the mean width of the channel at unused sites (Kirsch 1992; Ziewitz et al. 1992). These studies made important contributions to our understanding of tern and plover habitat relationships; however, both are limited in usefulness for habitat projects. The studies only showed that mean channel width differed between used and unused nesting sites; neither study provided insight on how nesting incidence changed as channel width changed. Both studies also used only one measure of channel width, that at the nesting site. However, we know that nesting habitat use by terns and plovers may be influenced by habitat variables at multiple scales (Orians and Wittenberger 1991; Pribil and Picman 1997).

The goal of this study was to expand upon earlier studies that examined the relationship between channel width and interior least tern and piping plover nesting incidence and to provide information that has practical applications to habitat projects. We addressed this by using a model-based logistic regression approach to estimate the probability of nesting incidence across a set of channel width measurements, using a long-term (ten-year) data set of tern and plover nesting habitat selection, and evaluating habitat use on the lower Platte River. Compared to other large rivers in the Great Plains, such as the Missouri and central Platte, the lower Platte River is relatively dynamic and physically unmodified.

METHODS

The Platte River drainage covers approximately 223,000 km^2 in Colorado, Wyoming, and Nebraska (National Research Council 2005). The lower Platte River extends from the Loup–Platte River confluence (near Columbus, Platte County) 166 km downstream to where it joins the Missouri River (near Plattsmouth, Cass County; Fig. 1). The lower Platte River is distinct from the portion upstream of the Loup–Platte River confluence, generally referred to as the central Platte River, because of contributions to the river flow from the Loup River (Schaepe and Alexander 2011). The lower Platte River is a dynamic, braided river system characterized by broad channels, anabranches (sections of the river that divert from and

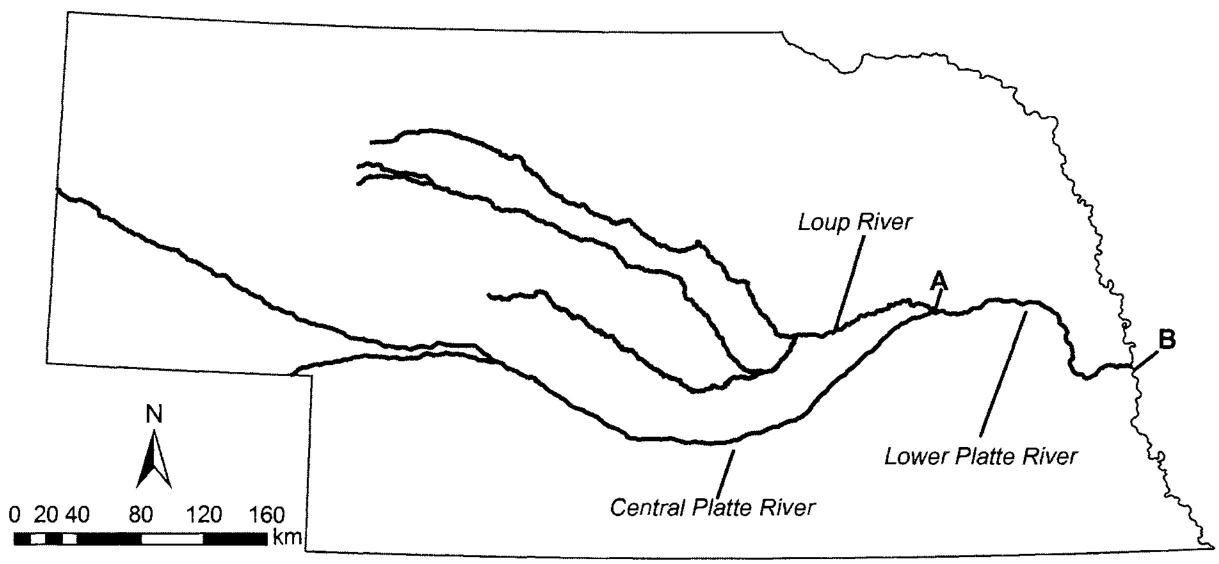

Figure 1. Lower Platte River, Nebraska, extending from the Loup–Platte River confluence near Columbus, Platte County (A) to the Platte–Missouri River confluence near Plattsmouth, Cass County (B).

rejoin the main channel in areas where river flows were divided by stabilized islands), sandbars, islands, a high sediment load of sand and gravel, and erodible banks (Blodgett and Stanley 1980). The amount and availability of sandbar tern and plover nesting habitat is variable from year to year.

We measured active channel width for 1999, 2003, and 2006 using digital ortho-photo quadrangle aerial photographs from the Farm Service Agency's National Agricultural Imagery Program. Our working definitions and analytical approach of defining the channel boundary was similar to that of Elliot et al. (2009). We defined active channel width as the unstabilized riverbed that possesses geomorphic features such as moving water and sandbars lying between stabilized steep banks that confine stream flow. Active channel width remains stable under variable water discharge and flow regimes. Ephemeral sandbars are considered part of the active channel because they lie between the stabilized banks, and river flows frequently reshape these features. Islands stabilized by early-successional or gallery forests are not considered part of the active channel. We measured both main channels and anabranches. Channel width measurements did not vary among the three years for which we had aerial photographs.

We used the aerial photographs to digitize polylines, here referred to as individual channel measurements, in ArcGIS (ESRI Inc. 2006, Version 9.2, Redlands, CA, www.esri.com). Individual channel measurements were drawn perpendicular to the active channel every 402 m beginning at the mouth of the Platte (river mile 0) and moving upstream to the Platte–Loup River confluence (near river mile 102). We followed the methods of Ziewitz et al. (1992) in using 402 m so that results of the two studies would be comparable. We used an ArcMap utility to estimate the length of each polyline.

We assessed multiple active channel width measurements by creating a series of 1,206-m-long segments consisting of four consecutive channel width measurements (Fig. 2). We refer to each unit as a unique river segment. Each unique river segment consists of three areas or sections between channel width measurements. From the middle section, measures of channel width are located immediately upstream and downstream and also 804 m upstream and downstream of the middle section (Fig. 2). The 804-m-long channel widths were included to assess not only channel width in the immediate vicinity of the sandbar but also the relationship between channel widths located some distance away. We labeled the four channel width measurements by their relative location to the middle section, thus the labels were distal upstream, proximal upstream, proximal downstream, and distal downstream. We started at the downstream terminal channel width measurement; we then moved upstream 402 m and repeated the process, creating another unique river segment. In this way, each 402-m-long segment of

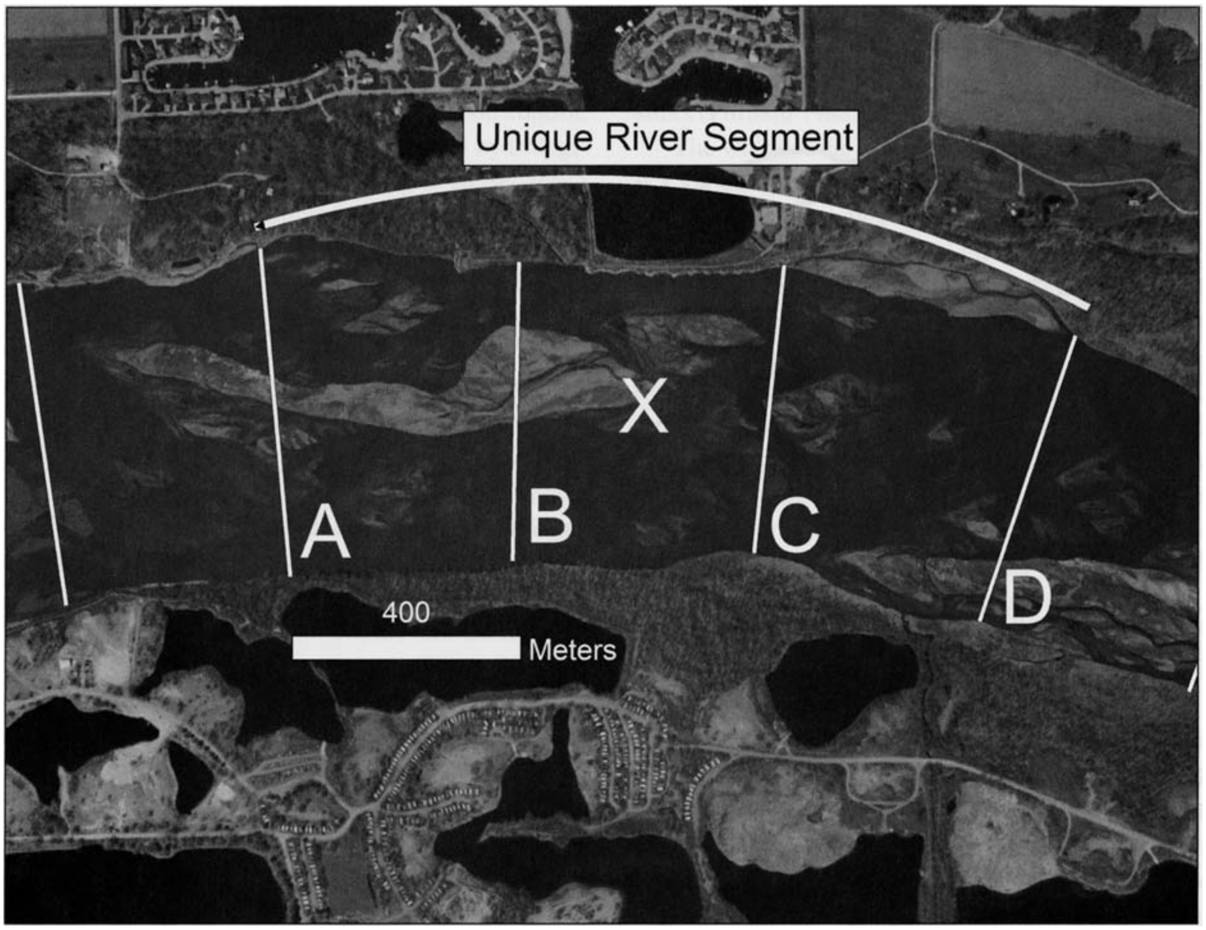

Figure 2. Relative locations of channel width measurements that comprise a unique river segment: distal upstream (A), proximal upstream (B), proximal downstream (C), and distal downstream (D). Success or failure in logistic regression models was determined by whether a nest was present in the area between the locations of the proximal channel measurements (location denoted by "X").

the river was associated with four channel width measurements. In areas of divided flow, we created multiple unique river segments.

To identify nesting sites, we used nest location data collected during annual Nebraska Game and Parks Commission tern and plover surveys from 1999 to 2008. Terns and plovers commonly nest together in loose aggregations (*sensu* Alexander 1974). Annual surveys were conducted by airboat or canoe at least once during the nesting season and covered the entire lower Platte River. All sandbars were surveyed for tern and plover presence and nesting activity. Sandbars where birds were detected were inspected on foot and nests were counted. We define a nesting site as a location in which one or more interior least tern or piping plover nests were found. We considered nesting incidence (presence or absence) rather than number of nests because survey effort was unbalanced among all river segments and among years. We used data across all years to account for extremes in nesting habitat variation and availability. A location was considered a nesting site if nesting occurred there at least once during the ten-year period.

We used logistic regression in a generalized linear model that uses binary response data (here, success or failure) to predict the probability of nesting incidence (Hilbe 2009) and to model the relationship between nesting incidence and the four channel-width measurements for each unique river segment. We also included nest site location on the lower Platte River, identified by river mile, in candidate models. In our analysis, the presence of a nesting site in the middle section of a sandbar, between the proximal downstream and proximal upstream channel widths, was scored as a success for each unique river segment. Absence of nesting at this location was scored as a failure. We rescaled channel width values by subtracting the mean channel width and dividing by 100 (Draper and Smith 1998). This analytical approach allowed us to interpret the intercept of the top model as representing the average probability of nesting at a site and each unit increase in the model coefficient as the increase in the odds (log scale) of nesting at a site for every 100 m increase in channel width.

Adjacent channel widths are not independent, because the width measurements overlap, that is, the proximal upstream width for a given river segment is the proximal downstream width for the next river segment. Prior to conducting the analyses, we determined whether individual channel width measurements were correlated. We used correlation analysis to determine relationships among the four measurements in each unique river segment. If two variables were strongly correlated ($r_S > 0.80$; Franzblau 1958), only one of the correlated variables would be included in subsequent analyses.

We used Akaike's information criterion (AIC) and model weights (w_i) to select the best-fitting model(s) (Burnham and Anderson 1998). We used *t*-statistics to determine whether the maximum likelihood parameter estimates for the top model differed from zero. Unless otherwise noted, means are presented ±1 SE. All statistical analyses were performed in Program R 2.9.2 (R Development Core Team 2009).

RESULTS

We identified 589 individual channel measurements and 610 unique river segments. Of the 610 unique river segments, 420 were classified as main channel segments and 190 were classified as anabranches. Individual channel widths varied from 21 to 743 m (mean = 327.4 ± 6.1 m). From 1999 to 2008, 82 tern and plover nesting sites were recorded on the lower Platte River in 64 unique river segments. All nesting areas were located in main channel segments.

Several channel width measurements were correlated. Channel width measurements adjacent to one another were moderately correlated (r_S = 0.57–0.60, *P*-values < 0.01). Nonadjacent channel width measurements were less strongly correlated ($r_S < 0.40$, *P*-values < 0.01). Channel width measurements were weakly correlated with river mile ($r_S < 0.25$, *P*-values < 0.01). Based on these correlation coefficients (see "Methods"), all variables were included in the analysis.

Our model selection procedure indicated little support for the simplest models that included two or fewer parameters or complex models that included interaction terms (Table 1). A model that included only proximal upstream and proximal downstream channel widths had the lowest AIC (306.5; see Table 1) and had the highest model weight (0.49). Models that included the interaction between proximal upstream and proximal downstream channel widths or river miles were not markedly better than the top model. The three best-fitting models had a total of 87% support, and the point estimates and standard error for parameters were very similar.

Nesting incidence increased with proximal upstream and proximal downstream channel widths (see Table 2). Parameter estimates from the top model, which showed the relationship between increased nesting incidence and both proximal upstream and proximal downstream channel widths, are shown in Figure 3. Our model shows that nesting incidence is rare (<0.03) when values of both proximal upstream and proximal downstream channel widths are equal to or less than the mean channel width (327 m) of the study area.

DISCUSSION

Our results show a strong relationship between interior least tern and piping plover nesting incidence and channel width on the lower Platte River. Nesting incidence increased sharply with increased channel width; wide river channels are more attractive to nesting terns and plovers. Channel width at the smaller spatial scales (proximal upstream and proximal downstream to nesting areas) was the best predictor of colony incidence. These two imperiled species avoid nesting in narrow channels and anabranches.

These results have implications for the lower Platte River, which, being largely unregulated, remains a relatively dynamic system. The lower Platte River currently creates and maintains sandbar habitat that support nesting interior least terns and piping plovers. There is increasing pressure from economic interests and policy makers to develop river infrastructure, such as bank stabilization structures and levees, to protect private and industrial property and investments. Agencies responsible for the protection of threatened and endangered species have raised concerns about impacts to terns and plovers resulting from these developments. Decision makers charged with evaluating these developments have been hindered by limited information on the consequences of these developments for protected species. Several studies have been commissioned recently to provide this information and help rectify this problem (Ginting et al. 2008; Elliot et al. 2009; Schaepe and Alexander 2011). However, these studies are largely descriptive in nature and have not established and quantified specific species–habitat relationships. By explicitly quantifying the species–habitat relationship

TABLE 1
MODEL SELECTION SUMMARY OF INTERIOR LEAST TERN AND NORTHERN GREAT PLAINS PIPING PLOVER NESTING INCIDENCE AS A FUNCTION OF CHANNEL WIDTH AND LOCATION ON THE LOWER PLATTE RIVER

Model	Deviance	K	ΔAIC*	w_i
Intercept	409.6	1	105.1	0.00
Location	388.8	2	86.3	0.00
Distal downstream	386.4	2	83.8	0.00
Proximal downstream	328.9	2	26.4	0.00
Proximal upstream	331.6	2	29.1	0.00
Distal upstream	382.4	2	79.9	0.00
Distal downstream × location	373.4	4	74.8	0.00
Proximal downstream × location	321.9	4	23.3	0.00
Proximal upstream × location	326.2	4	27.6	0.00
Distal upstream × location	371.2	4	72.7	0.00
Distal downstream + proximal downstream	328.9	3	28.4	0.00
Distal upstream + proximal upstream	331.2	3	30.7	0.00
Proximal downstream + proximal upstream	300.5	3	0.0	0.49
Proximal downstream × proximal upstream	300.4	4	1.9	0.19
Distal downstream × distal upstream	365.4	3	64.9	0.00
Distal downstream + proximal downstream × location	321.6	5	25.1	0.00
Distal upstream + proximal upstream × location	324.6	5	28.0	0.00
Proximal downstream + proximal upstream × location	298.5	5	1.9	0.19
Distal downstream + distal downstream × location	359.3	5	62.7	0.00
Distal downstream + proximal downstream + proximal upstream + distal upstream	300.4	5	3.8	0.07
Distal downstream + proximal downstream + proximal upstream + distal upstream + location	298.8	6	4.4	0.09
(Distal downstream + proximal downstream + proximal upstream + distal upstream + location)^2	290.1	16	15.5	0.00
Distal downstream × proximal downstream × proximal upstream × distal upstream × location	283.9	32	41.3	0.00

*Akaike's information criterion (AIC) for the best-fitting model was 306.5.

TABLE 2
ESTIMATES (LOGIT SCALE) OF MAXIMUM-LIKELIHOOD PARAMETERS AND SIGNIFICANT DEVIATION FROM 0 FOR THE BEST-FITTING MODEL DESCRIBING THE PROBABILITY OF NESTING ON SANDBARS

Parameter	Estimate ± SE	*z*-value	*P* > Z
Intercept	−3.28 ± 0.27	−12.06	<0.001
Proximal downstream	0.75 ± 0.15	4.99	<0.001
Proximal upstream	0.72 ± 0.15	4.75	<0.001

Note: Values were rescaled prior to analysis.

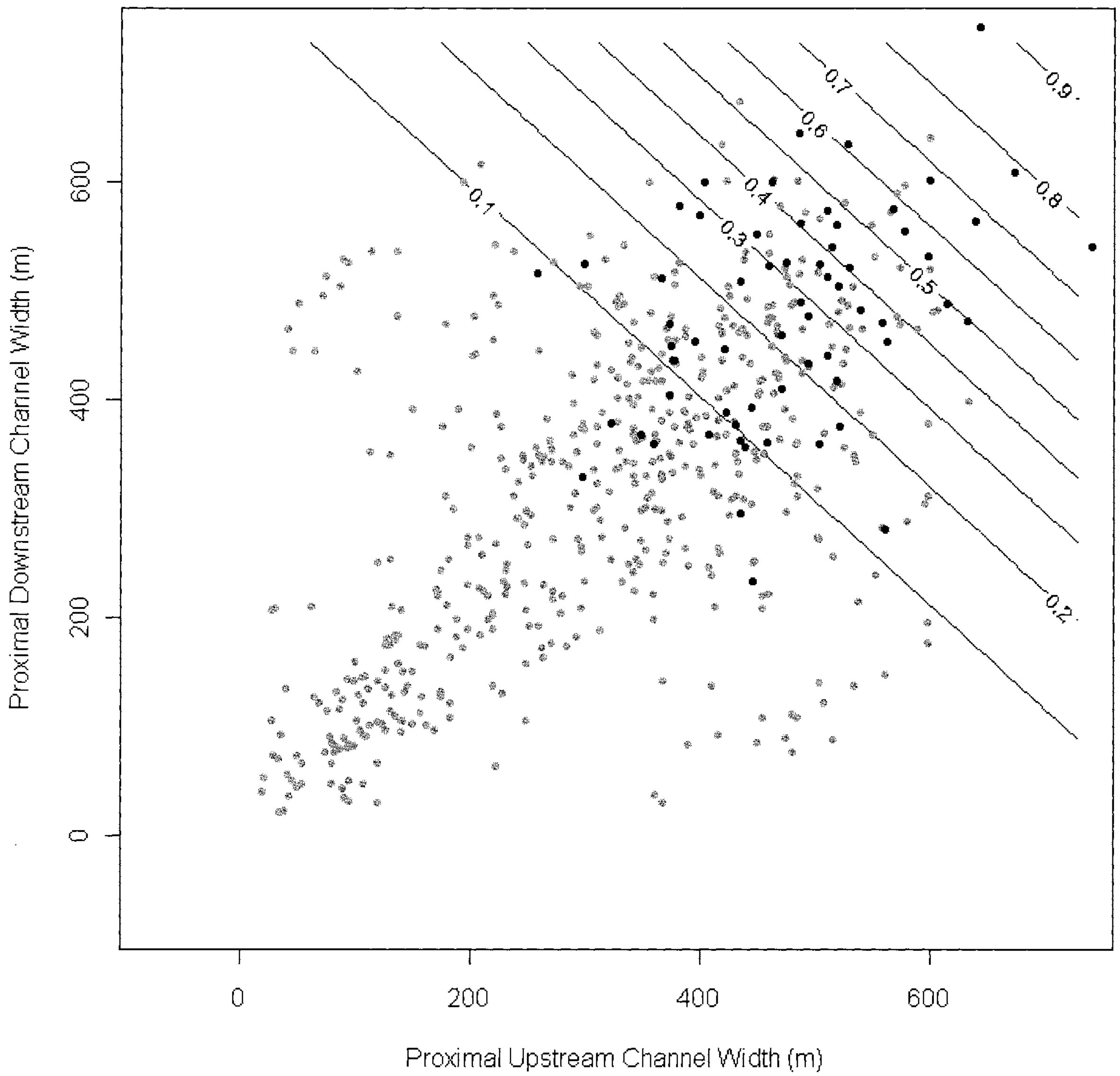

Figure 3. Contour plot from the top model showing a positive relationship between increased proximal upstream (*x*-axis) and proximal downstream (*y*-axis) channel width against increased nesting incidence by interior least terns and piping plovers on the lower Platte River. Diagonal contour lines at 0.1 m intervals in the plot area show increases in the probability of nesting incidence. Dots are unique river segments data points; black dots are nesting (presence) and gray dots are no nesting (absence).

between channel width and nesting terns and plovers, our results will be useful to decision makers assessing project designs and prioritizing project implementation.

A possible explanation for the relationship between wide channels and nesting involves predator avoidance. Interior least tern and northern Great Plains piping plover nests and chicks are frequently attacked by predators. Numerous studies have demonstrated that shorebird site use and behavior is affected by the presence of avian predators (Cresswell 1994; Cresswell and Whitfield 1994) and shorebird site use is known to change in response to the presence of certain raptors (Ydenberg et al. 2004). Sandbars located in wide river channels are less accessible to terrestrial predators such as coyotes (*Canis latrans*) and raccoons (*Procyon lotor*). Avian predators such as American kestrel (*Falco sparverius*; Kruse et al. 2001), great horned owl (*Bubo virginianus*; Kruse et al. 2001), and American crow (*Corvus brachyrhynchos*; Kruse et al. 2001) prey on tern and plover nests and chicks. It seems plausible that terns and plovers select nesting sites further from stabilized banks that have large trees and other structures that avian predators use for perching.

In addition to reduced predation, wider portions of rivers may provide an advantage to nesting interior least terns because of proximity to food resources for these fish-eating birds. Wider portions of braided rivers, such as the lower Platte River, possess an array of shallow-water habitat complexes (Schumm 1985) that are attractive to small fish. Higher fish densities are known to influence the behavior of fish-eating birds and their breeding success (Jodice et al. 2006). Adult interior least terns themselves feed on and feed their chicks the small-bodied fish that occur in high abundance in these shallow-water habitats (Callam 1989; Stucker et al. 2011).

Terns and plovers respond to a suite of variables when selecting nesting sites. However, some of these other variables, such as sandbar size and elevation, are ephemeral and ever-changing due to variable river flows. As a result, they are challenging to measure reliably and effectively. Consequently, channel width may serve as a useful and easy-to-measure indicator of the suitability of the lower Platte River for nesting terns and plovers. We recommend future tern and plover surveys be refined to include channel width measurements along with nest counts and productivity measures. This information would allow a more complex suite of variables to be included in analyses, making results more informative and species–habitat relationships more predictive.

In the future, interior least tern and piping plover recovery and management will increasingly rely on effective human decision making, whether through proactive habitat creation or regulatory action. In either case, there is a need to explicitly quantify the ecological relationships that apply to management decisions. Defining these relationships and understanding their consequences will provide decision makers the opportunity to consider the trade-offs of future development against potential impacts to interior least terns and piping plovers, as well as to evaluate the likelihood of success of habitat projects intended to benefit these two imperiled species.

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