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Habitat associations of shovelnose sturgeon *Scaphirhynchus platorynchus* (Rafinesque, 1820) in the lower Platte River, Nebraska

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Summary
Human induced alterations of river systems are ubiquitous throughout the world. Alterations have reduced riverine habitat and negatively affected riverine species; therefore, it is crucial to understand what habitats are important to riverine fish at multiple scales. Most research has focused around microhabitats (i.e., depth) with little effort on how the reach scale habitat (i.e., geomorphic landscape) influences riverine fish abundance. We examined habitat associations of shovelnose sturgeon sampled with two gears (trotlines and trammel nets) at multiple spatial scales in the lower Platte River, NE, a system that has not been overtly altered in physical description. At a microhabitat scale, shovelnose sturgeon abundance was influenced by velocities and temperatures within the lower Platte River. The influence of velocity was contradictory between gears suggesting that gear limitations may have been present. Shovelnose sturgeon abundance increased in close proximity to a tributary interaction with the lower Platte River in both gears. Portions of the river with a relatively medium valley width, low-medium sinuosity, and wide channel had the lowest shovelnose sturgeon abundance for both gears. Our results provide insight at multiple habitat scales on the landscape that may help managers and policy makers develop sound approaches to protecting and mitigating habitat for shovelnose sturgeon and other riverine species.

1 | INTRODUCTION

Rivers are dynamic systems that contain a complex array of physical features at a variety of spatial and temporal scales (Dettmers et al., 2001). The complexity of river system determines the orientation and persistence of riverine species found within that river (Riverine Ecosystem Synthesis; Thorpe, Thoms, & Delong, 2006). The diversity of habitats found along the spatial orientation of a river will dictate the ecological function and biological community found within that river. Determining what habitats are associated along the spatial orientation of a river at multiple scales will help to determine what habitats may be important for riverine species. For instance, Hintz et al. (2015) has found that small-scale, macrohabitats (i.e., sand dunes) generated from large-scale alluvial islands will benefit shovelnose sturgeon (*Scaphirhynchus platorynchus*) within the middle Mississippi River. The successful conservation and management of riverine species requires an understanding of what habitats at multiple scales are important to these species.

Research on habitat preferences among fish populations largely focus on microhabitats, with little consideration for the reach scale habitats (i.e., geomorphic landscapes; Frissell, Liss, Warren, & Hurley, 1986). Geomorphic landscapes surrounding rivers dictate habitat availability and help form microhabitats that fish will occupy (Frissell et al., 1986; Gorman & Karr, 1978; Hawkins et al., 1993; Herrala, Kroboth, Kuntz, & Schramm, 2014; Hintz et al., 2015; Lammert & Allan, 1999; Phelps et al., 2010; Poff & Allan, 1995; Rosgen, 1994; Schlosser, 1982). Herrala et al. (2014) found that island tips and natural bank habitat were frequented by pallid sturgeon (*Scaphirhynchus albus*) in the lower Mississippi River. Linking associations between geomorphic features and other riverine species, like shovelnose sturgeon, could provide a broader understanding of habitat associations that cannot be achieved at the microhabitat level.

Shovelnose sturgeon are a large-river, long-lived fish species found throughout the Missouri and Mississippi River basins. The river landscape found within the shovelnose sturgeon natural range has been significantly altered over time, contributing to the shovelnose sturgeon decline. Key information on the habitats associated with shovelnose sturgeon, or any riverine species, is needed to develop conservation and restoration strategies. This information can be difficult to obtain in the field due to declining abundances of shovelnose sturgeon. Therefore, it makes it important to understand how a stable shovelnose sturgeon population is using riverine habitats to gain information on what habitat preferences are preferred by the species.

Current evidence has suggested that the shovelnose sturgeon population found in the lower Platte River, a tributary to the Missouri River, has remained stable through time despite anthropogenic changes that have occurred here (Hammen, 2016; Peters and Parham 2008). The hydrology of the lower Platte River is influenced by the Loup and Elkhorn River tributaries and the regional anthropogenic changes in the form of irrigation and hydroelectricity production from the Loup Power Canal (Hadley, Karlinger, Burns, & Eschner, 1987; Spurgeon, Hamel, & Pegg, 2016). Even with landscape changes throughout the lower Platte River, this system has retained much of its connectivity and original physical characteristics (Eschner, Hadley, & Crowley, 1983; Randle & Samad, 2003) by allowing the Loup and Elkhorn River tributaries of the lower Platte River to retain seasonal flow patterns with flood peaks in spring followed by low flows in the summer (Elliot, Huhmann, & Jacobson, 2009). Understanding how microhabitats and geomorphic landscapes within the lower Platte River influence shovelnose sturgeon abundance will help better understand how physical components of a river help shape shovelnose sturgeon distribution. This knowledge will provide crucial information on how to enhance riverine restoration to protect shovelnose sturgeon and riverine fish communities. Therefore, habitat associations were used with shovelnose sturgeon abundance to identify crucial habitats in the lower Platte River at two different scales (microhabitat and geomorphic).

2 | MATERIALS AND METHODS

2.1 | Fish collection

Shovelnose sturgeon were collected from the lower Platte River, Nebraska (Figure 1) in 2009–2012 during three seasons (spring [March–May], summer [June–August], fall [September–November]) using two different gears—drifting trammel nets and trotlines. A stratified random sampling design was used to sample shovelnose sturgeon in the lower Platte River. A total of 20 sample sites were randomly selected both above and below the Elkhorn River confluence each season. Seven runs for each gear were taken at each sample site location. Each site was sampled by both gears within a season. These nets are made of three panels of netting and suspended from a float line and a single lead line. Nets were made of multifilament nylon netting with an inner wall 2.4 m deep and the outer wall 1.8 m deep. The net stretch was 38.1 m long with 2.5 cm bar mesh for the inner panel and 20.3 cm bar mesh for the outer panels. The float line was 1–1.3 cm foam line and the lead line will be 22.7 kg. Inflatable buoys (22.9–33.0 cm diameter) were attached to each end of the float line. Deployment of trammel nets were done from the boat by tossing one attached buoy out and deploying the net perpendicular to the channel. Each net was floated for approximately 100 m (min = 75 m, max = 300 m) before being retrieved. Trotlines were 32.0 m long and made of 0.6 cm diameter nylon line. Hooks were placed at 1.5 m intervals along the line with a 30.0 cm hook line. O'Shaughnessy (size = 3/0) hooks were used and baited with nightcrawlers *Lumbricus terrestris*. All sets were overnight with a maximum set time of 24 hr. Start and stop times were recorded for each sample run and Global Position System coordinates were recorded for the starting location of each sample run.

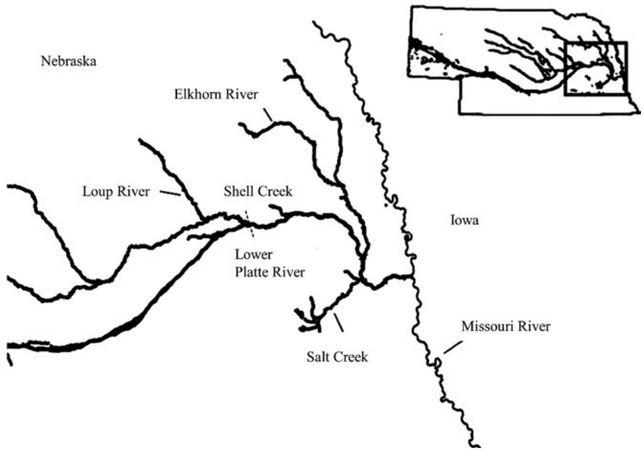

FIGURE 1 Map of lower Platte River, Nebraska, and surrounding confluences. Dashed line represents the furthest upstream site sampled

2.2 | Habitat variables

Water temperature (°C), bottom velocity (m/s) and depth (m), were measured at each site as microhabitat variables. Water temperature was taken at the surface using an YSI® Professional Plus series multiprobe water quality meter. Velocity was taken using a Marsh-McBirney Model 2000 Flo-Mate (Marsh-McBirney, Inc.) and wading rod at 0.20 m of the total depth. Depth was collected using a standard wading rod at the beginning, middle, and end of each run and averaged for that run. Water temperature and bottom velocity were collected during two random runs within a sampling site, while, depth was taken during every run. Geomorphic classifications described by Elliot et al. (2009) were used to test whether large-scale geomorphic landscapes influence shovelnose sturgeon abundance. Elliot et al. (2009) used 2-m resolution digital natural-color orthophotographic quarter-quadrangles complimented by topographic and geologic maps to identify four classifications determined by channel width, valley width, island and sandbar stability, and sinuosity (Table 1; Figure 2). Distance to a tributary interaction was measured as a proxy to evaluate the influence of two lotic systems joining. Distance from

TABLE 1 Descriptions of geomorphic clusters in the lower Platte River, Nebraska, established by Elliot et al. (2009)

Cluster	Description name	Physical process interpretation
1	Wide valley, low sinuosity	This unit characterizes the Lower Platte River upstream from the Loup River confluence. Channel width is variable and the 8,000-m length sinuosity is low. The 2,000-m length sinuosity is somewhat higher indicating greater flow complexity at shorter scales
2	Narrow valley, low sinuosity	This unit occurs in the narrow valley of the Eastern Platte River Gorge (Joeckel and Henebry 2008)
3	Narrow valley, high sinuosity	This unit occurs in the narrow valley of the Eastern Platte River Gorge (Joeckel and Henebry 2008). High sinuosity at 8,000-m scale captures the valley-scale bends. A few bends within the Elkhorn-Loup segment also are included
4	Medium valley, high channel width	This unit includes most of the remainder of the Elkhorn-Loup segment, characterized by medium valley width and low-medium sinuosities. Some relatively wide channel reaches are included in this cluster

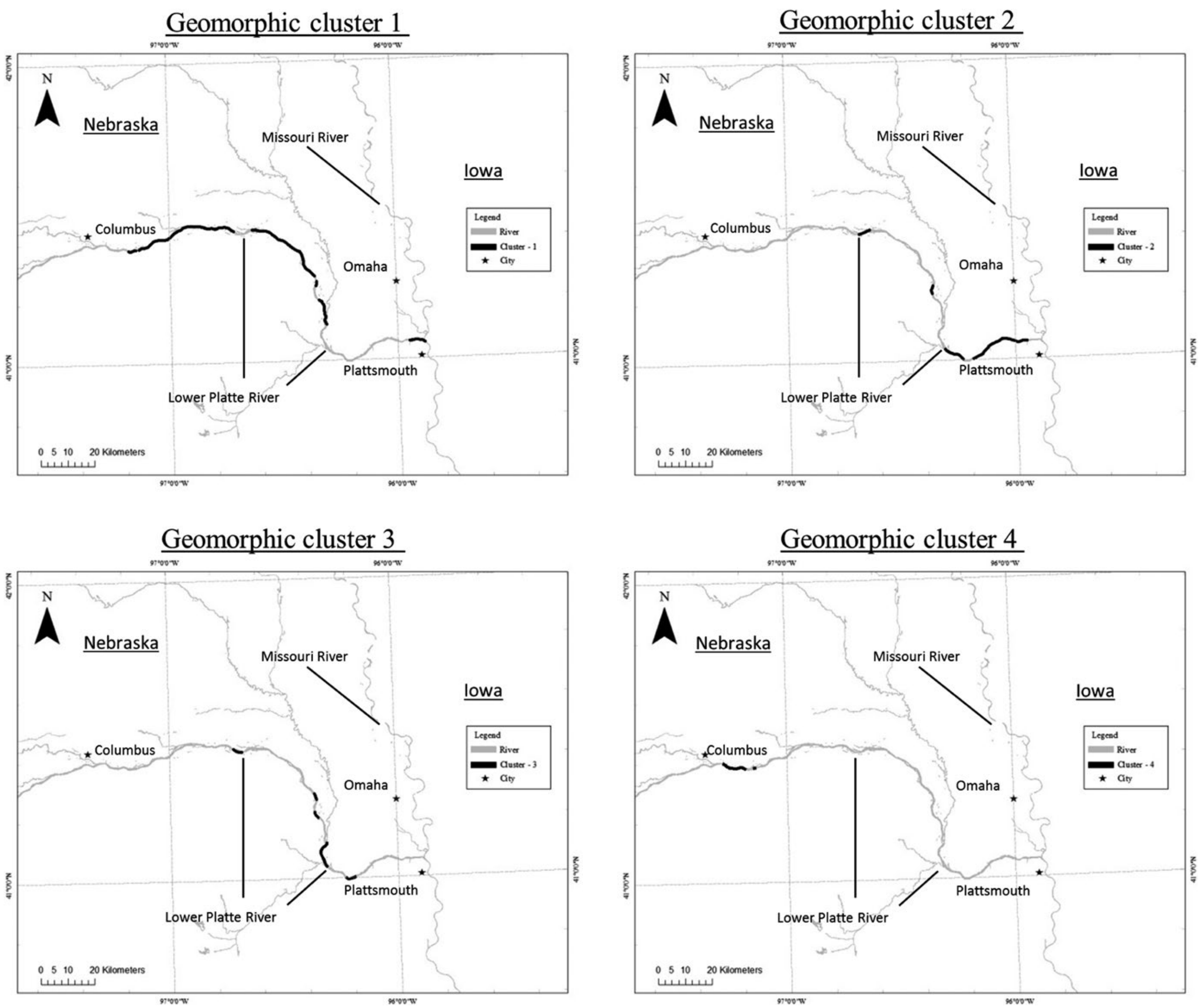

FIGURE 2 Map of the lower Platte River, Nebraska, and location of Elliot et al. (2009) geomorphic classification segments within the lower Platte River. Stars indicate city, gray lines indicate a river, and black lines indicate specific cluster segments

a tributary interaction was measured as the centerline measurement along the lotic system.

2.3 | Statistical analysis

All continuous variables were tested for correlations using a Spearman Rank correlation. Categorical variables were tested for correlation using an intraclass correlation (ICC) in the package ICC (Wolak, Fairbairn, & Paulsen, 2012). If two variables were determined to be correlated then one variable would be dropped from the analysis. A generalized linear mixed model with a Poisson distribution was used to determine the nature and strength of the relation between habitat variables and shovelnose sturgeon abundance. Year and season were considered the random effects parameters.

An Akaike's information criterion (AIC) to select the most parsimonious model out of a set of *a priori* ($N = 8$) candidate models (Table 2) was used to determine the top model. The model with the lowest AIC value was considered the top model, and the ranking of the remaining models was determined by calculating the delta AIC: $\Delta AIC = (AIC_i - AIC_{min})$. Akaike weights (*wi*) were calculated to determine the scale of relative support for each model (Burnham & Anderson, 2002). All statistical analysis was performed in R (version 3.4.0; R Development Core Team, 2017) using the package lme4 (Bates, Maechler, Bolker, & Walker, 2015) and all plots were generated using visreg (Breheny & Burchett, 2013). Abundance (CPUE) was transformed to $\log_{10}(CPUE + 1)$ to counter any overdispersion. The overdispersion test was conducted by the package blmeco (Korner-Nievergelt et al., 2015).

3 | RESULTS

A total of 4,996 gear deployments (trammel nets = 2,385, trotlines = 2,611) captured 2,961 shovelnose sturgeon during 2009–2012 in the lower Platte River. A total of 1,841 shovelnose sturgeon were captured in trammel nets and 1,120 were captured in trotlines. Shovelnose sturgeon median fork length was 567 mm (range = 196–775 mm). River kilometer was left out of the analysis due to the high correlations with geomorphic cluster and temperature (Coefficients >0.60; Table 2). Analysis was done separately for each gear due to concerns that the gears may be fishing habitats at different times during a 24 hr setting. The best candidate model for trammel nets (*wi* = 0.99) contained the effects of bottom velocity, geomorphic cluster, depth, distance to a tributary, and temperature (Table 3). Distance to a tributary, geomorphic cluster and bottom velocity was found to have a significant (ANOVA; $p < .05$) influence on shovelnose sturgeon abundance (Table 4). In trotlines, two models carried the majority of the weight for trotlines and had a minimal ΔAIC (<2.0) between the two models. The top model (*wi* = 0.66) contained the effects of distance to a tributary, geomorphic cluster, temperature, bottom velocity, and depth. The second model (*wi* = 0.33) had the same effects with the absence of depth (Table 3). It was determined that depth was not a significant parameter (ANOVA; z-value = 1.87; $p = .06$; Table 3) and the simpler of the two models was considered the most informative (Arnold, 2010; Burnham & Anderson, 2002).

In both gears, shovelnose sturgeon abundance distance to a tributary had a positive influence on shovelnose sturgeon abundance as you moved in close proximity to a tributary within the lower Platte River (Figure 3). Additionally, shovelnose sturgeon abundances were lowest in a medium valley width, low-medium sinuosity, and wide channel width (cluster 4; Figure 4). In trotlines, when temperatures increased shovelnose sturgeon abundance decreased. However, temperature did not influence shovelnose sturgeon abundance in trammel nets. Bottom velocity had opposite influences on shovelnose sturgeon abundance between the two gears. When bottom velocity increased while using trammel nets shovelnose sturgeon abundance appeared to decrease (Figure 3). In trotlines, when the

TABLE 2 Spearman rank coefficient for each continuous variable in both gears. Intraclass correlation was used for categorical variables. Bold values indicate a correlation exists (Coefficients >0.60)

	Temperature	Tributary	RKM	Velocity	Depth	Cluster
Trammel nets						
Temperature	.	.	.	.	.	.
Tributary	0.32	.	.	.	.	.
RKM	0.43	0.30	.	.	.	.
Velocity	−0.01	−0.04	0.02	.	.	.
Depth	0.06	0.01	0.05	0.06	.	.
Cluster	0.03	0.39	**0.72**	0.02	0.02	.
Trotlines						
Temperature	.	.	.	.	.	.
Tributary	0.47	.	.	.	.	.
RKM	0.53	0.30	.	.	.	.
Velocity	0.01	0.01	0.00	.	.	.
Depth	0.08	0.03	0.00	0.10	.	.
Cluster	0.01	0.38	**0.70**	−0.01	0.01	.

Velocity, bottom velocity (m/s); Temperature, temperature (°C); Depth, depth (m); Tributary, distance from tributary intersection (m); RKM, river kilometer; Cluster, geomorphic cluster.

TABLE 3 The top models for both gears, Akaike's information criterion (AIC), number of parameters (*k*), increase over the lowest AIC (Δ AIC), and Akaike model weight (*wi*), for models used to predict the abundance of shovelnose sturgeon using catch per unit effort (CPUE) throughout the lower Platte River, Nebraska, during 2009–2012. Continuous variables were depth, temperature, bottom velocity, and distance from tributary intersection. Categorical variables were geomorphic cluster. Year and Season were random variables

	AIC	k	Deltas	Weights
Trammel nets				
CPUE ~ velocity + temperature + cluster + depth + tributary	1,689.31	10	0.00	1.00
Trotlines				
CPUE ~ velocity + temperature + cluster + depth + tributary	1,163.81	10	0.00	0.66
CPUE ~ velocity + temperature + cluster + tributary	1,165.17	9	1.36	0.33

Velocity, bottom velocity (m/s); Cluster, geomorphic cluster; Temp, temperature (°C); Depth, depth (m); Tributary, distance from tributary intersection (m).

TABLE 4 Summary of the top zero-inflated model. Both the count model and zero-inflation model coefficients are given. The results shown are the parameter coefficient estimate (estimate), standard error (*SE*), *Z*-value, and *p*-value. Significant parameters are in bold ($p < .05$)

	Estimate	*SE*	*Z*-value	*p*-value
Trammel nets				
Intercept	0.54	0.38	1.42	.16
Velocity	−0.91	0.20	−4.61	**<.01**
Temperature	0.02	0.02	1.46	.14
Cluster 2	−0.82	0.17	−4.72	**<.01**
Cluster 3	0.01	0.14	0.11	.91
Cluster 4	−2.18	0.43	−5.08	**<.01**
Depth	0.07	0.14	0.51	.61
Tributary	−0.03	0.01	−5.61	**<.01**
Trotlines				
Intercept	0.75	0.56	1.32	.19
Velocity	0.6	0.28	2.12	**.03**
Temperature	−0.1	0.02	−6.02	**<.01**
Cluster 2	−0.74	0.22	−3.45	**<.01**
Cluster 3	−0.14	0.19	−0.74	.46
Cluster 4	−2.32	0.53	−4.41	**<.01**
Depth	0.31	0.17	1.87	.06
Tributary	−0.02	0.01	−3.44	**<.01**

bottom velocity increased shovelnose sturgeon abundance also increased (Figure 4).

4 | DISCUSSION

Shovelnose sturgeon were caught at nearly all temperatures, depths, velocities, and geomorphic features found within the lower Platte River. However, when using multiple gears to assess habitat is important to remember that all sampling gear has limitations and how these limitations can influence habitat associations. Within our study velocity influenced shovelnose sturgeon differently dependent on gear. Trammel nets are an active gear that uses the velocity of the river to appropriately deploy and float downstream. When velocity becomes strong (>1.0 m^3/s) trammel nets will drift in the upper water column not allowing the net to properly deploy near the bottom. Shovelnose sturgeon are typically located near the river bottom (Hintz, Grimes, & Garvey, 2016; Keenlyne, 1997; Phelps et al., 2016), therefore, during high water velocity it may limit that ability of trammel nets to capture shovelnose sturgeon. Trotlines are considered a passive gear and deployed to fish along the bottom of the river. Velocity will likely have less influence on trotlines due mostly to the overnight deployment of the gear which allows shovelnose sturgeon a longer time to become captured compared to trammel nets. Therefore, trotlines likely represents the type of velocities influences shovelnose sturgeon abundance, while, trammel nets represents a gear limitation.

Results from this study were similar to other studies where shovelnose sturgeon abundance increased during lower temperatures (Kappenman, Fraser, Toner, Dean, & Webb, 2009) and slower bottom velocities (Bramblett, 1996; Curtis, Ramsey, & Scarnecchia, 1997; Hofpar, 1997; Hurley, Hubert, & Nickum, 1987; Latka, 1994; Lyons, Walchak, Haglund, Kanehl, & Pracheil, 2016; Peters & Parham, 2008; Quist, Tillma, Burlingame, & Guy, 1999). Kappenman et al. (2009) found that growth rates decreased above 24°C and mortality increased when temperatures reached 28°C. Slower velocities may provide refuge for conserving energy as well as forage opportunities. Slower velocities likely provide a congregation of macroinvertebrates and the best opportunities for shovelnose sturgeon to feed. Greater velocities will displace macroinvertebrates into the drift downstream; whereas, slower velocities will reduce downstream displacement of macroinvertebrates and allow macroinvertebrate abundances to increase (Bunn & Arthington, 2002; Dewson, James, & Death, 2007).

Shovelnose sturgeon abundance was greatest around tributary interactions connected to the lower Platte River. Tributary interactions are considered an important component to riverine ecosystems (Benda et al., 2004; Hamel, Rugg, Pegg, Patiño, & Hammen, 2014; Junk, Bayley, & Sparks, 1989; Neely, Pegg, & Mestl, 2010; Pracheil, Pegg, & Mestl, 2009; Rice, Greenwood, & Jones, 2001; Thorpe & Delong, 1994; Vannote, Minshall, Cummins, Sedell, & Cushing, 1980). Specifically, tributary interactions provide nutrient inputs that can change water chemistry, thus increasing primary productivity and invertebrate colonization that benefit fish

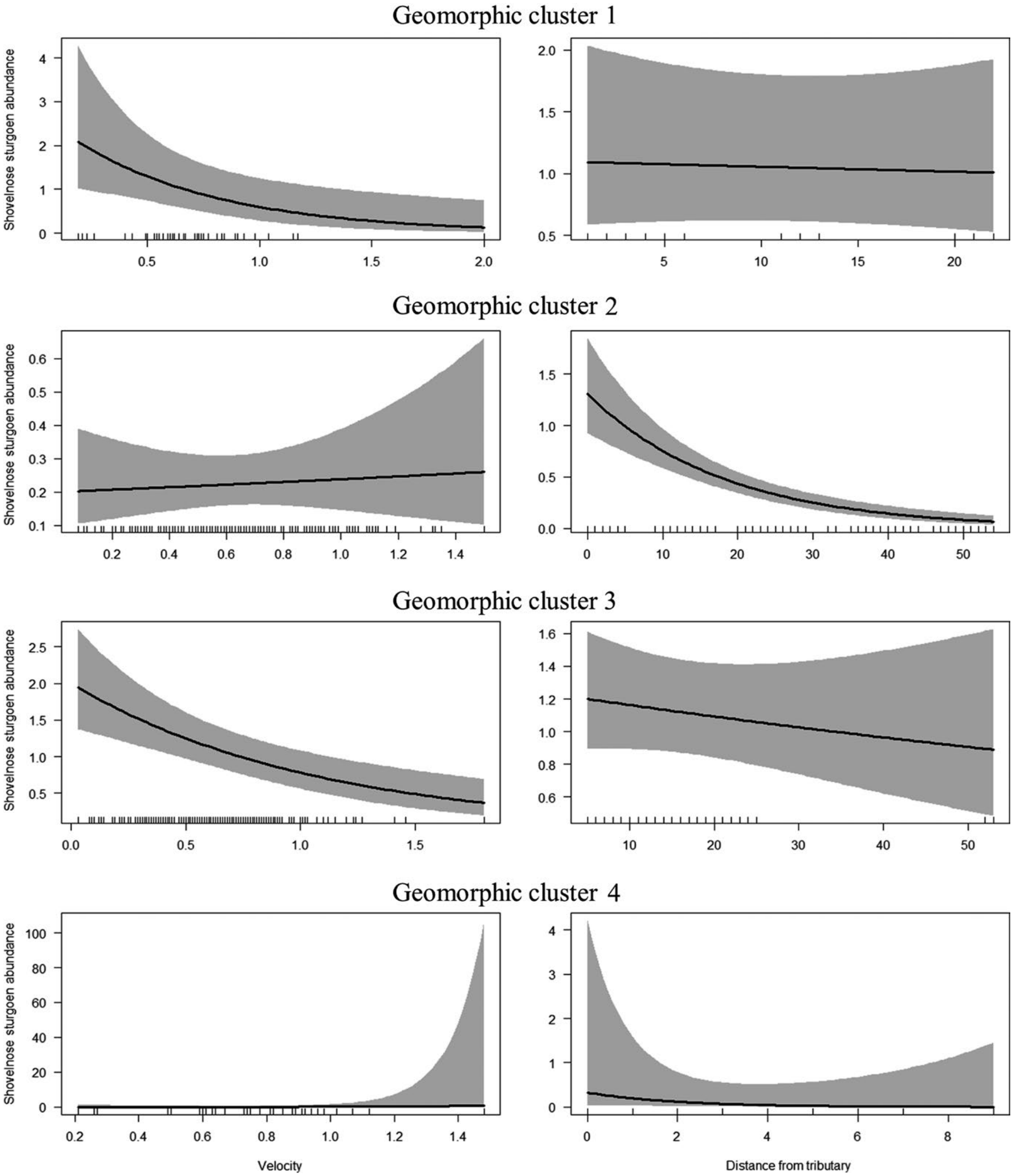

FIGURE 3 Trammel net predictive curves (black line) and 95% confidence intervals (grey shaded area) for shovelnose sturgeon abundance (fish/drift-net) throughout the lower Platte River, Nebraska across all temperatures (°C) and distance from tributary (river kilometer) for all geomorphic clusters from 2009 to 2012. Ticks represent the raw data collected

(Benda et al., 2004; Kiffney, Greene, Hall, & Davies, 2006; Rice et al., 2001). Our results corroborate the importance of tributary interactions to shovelnose sturgeon (Benda et al., 2004; Kiffney et al., 2006; Osborne & Wiley, 1992; Rice et al., 2001) and need to be considered in future management for shovelnose sturgeon and other riverine species.

The flow regime and geomorphic features of the lower Platte River change throughout the river system (Figure 2). Geomorphic features

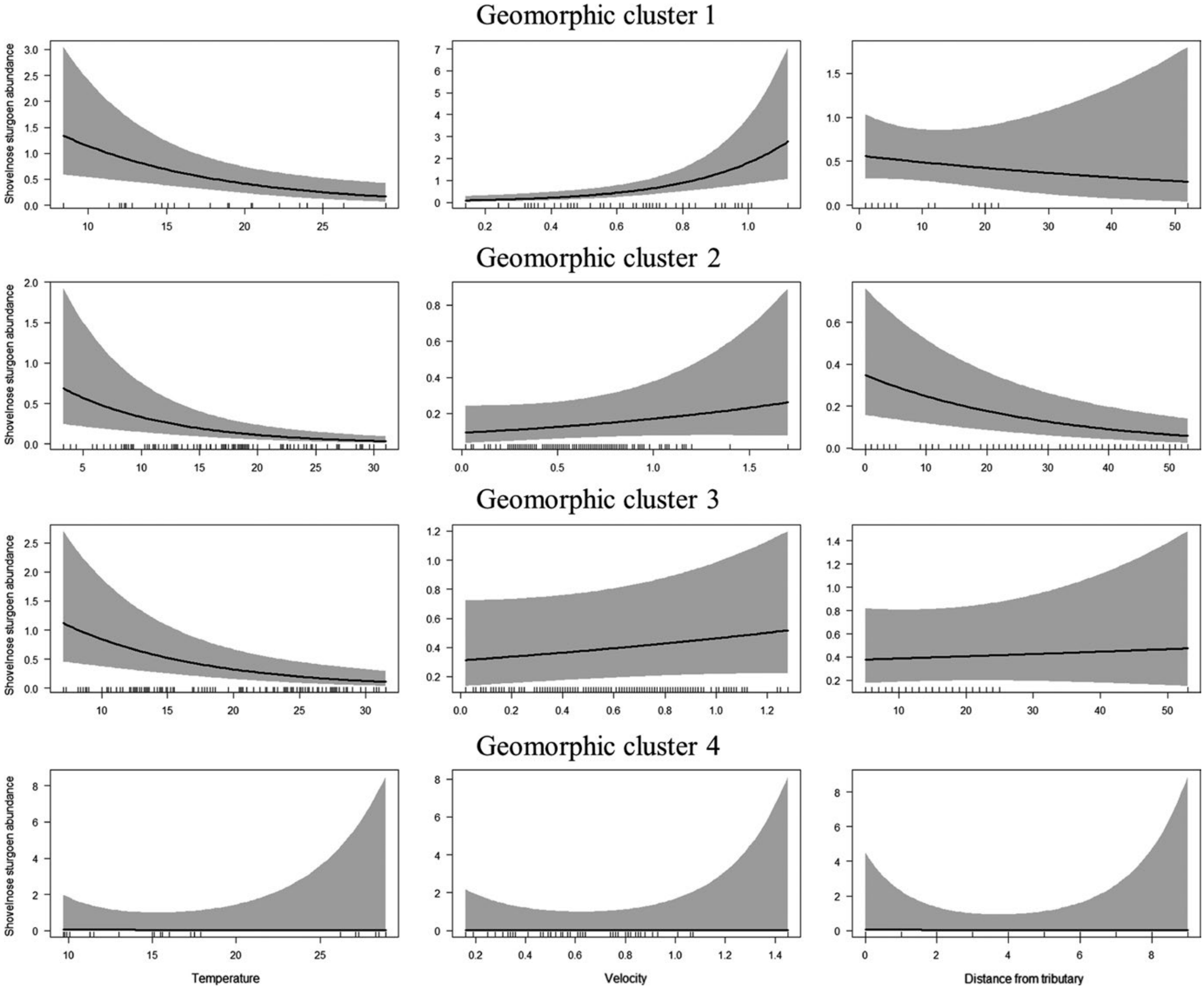

FIGURE 4 Trotline predictive curves (black line) and 95% confidence intervals (grey shaded area) for shovelnose sturgeon abundance (fish/drift-net) throughout the lower Platte River, Nebraska across all temperatures (°C) and distance from tributary (river kilometer) for all geomorphic clusters from 2009 to 2012. Ticks represent the raw data collected

described as a medium valley width, low-medium sinuosity, and wide channel width (cluster 4) generally occurs in the upper portion of the lower Platte River. Low discharge and variable daily and subdaily diel flow patterns (Spurgeon et al., 2016) are more common features in this region compared to the downstream portions of the lower Platte River. The combination of a medium valley width, a low-medium sinuosity, and a wide channel and a variable flow regime of the river could create less favorable conditions for shovelnose sturgeon and many riverine species (Bramblett, 1996; Bramblett & White, 2001; Curtis et al., 1997; Hurley et al., 1987; Quist et al., 1999; this study). Slower currents associated with sinuosity and available sandbar and island complexes have been positively associated shovelnose sturgeon in other river systems (Bramblett, 1996; Gosch, Miller, Gemeinhardt, Sampson, & Bonneau, 2015; Hintz et al., 2015; Phelps et al., 2010, 2016). Hintz et al. (2015) and Phelps et al. (2010) have found that vegetated islands and submerged sand bars are occupied by all ages of shovelnose sturgeon in the Mississippi River. Identifying these large-scale habitats within the lower Platte River have a positive and negative association with shovelnose sturgeon will help focus managers and stake-holders on where restoration and conservation needs should be focused.

We were able to identify key components of a river system at multiple habitat scales that influence shovelnose sturgeon abundance, yet much is still unknown in fully understanding riverine species and what habitats influence their behaviors. Many studies have found other features to be influential to shovelnose sturgeon not identified in this study. Many times these habitats vary greatly at multiple scales depending on aquatic systems, life stage, and diet (Phelps et al., 2016). For instance, island complexes (Hintz et al., 2015; Phelps et al., 2010) sand dunes (Hintz et al., 2016), gravel and rock (Bramblett & White, 2001; Hurley et al., 1987) have all been identified as influential characteristics to shovelnose sturgeon within a river. Shovelnose sturgeon and many riverine species likely have evolved to survive in a diverse array of environments. It becomes important to understand how all these environments function to fully understand how these riverine species interact with the environment to reach the conservation needs of all these species.

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