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Blue Sucker Summer Utilization Distributions and Inter-annual Fidelity to Summering Habitats

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Abstract: Blue Sucker *Cycleptus elongatus* populations in the Missouri River are believed to be declining. The decline is most likely attributable to anthropogenic modifications including channelization and dam construction. We compared 2008 and 2009 summer use distribution (UD) for 21 blue suckers implanted with acoustic tags to better understand how blue suckers use the Missouri River. UD are used to analyze space-use requirements based on the home range concept. The geometric mean 95% UD range was 1.9 river kilometers (RKM) in 2008 and 0.3 RKM in 2009, and differed statistically by year. The upper bound of the 2008 95% UD accounted for 96% of the variation in the upper bound of the 2009 95% UD when regressed against each other, and the slope did not differ from one, which indicates that UD boundary locations were similar between years. Results were similar for the lower bound. Blue suckers appear to have a high degree of fidelity to sites occupied during the summer even though they undertake substantial (>20 RKM) seasonal migrations. This fidelity could increase the species' vulnerability to natural and anthropogenic disturbances, however, knowledge of this behavior should also serve as a guide for conservation efforts.

Keywords: blue sucker, fidelity, use distribution, telemetry

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Introduction

The blue sucker *Cycleptus elongatus* is a species of concern in the 23 states that compose its current range (Elstad and Werdon 1993, Hand and Jackson 2003, Jelks et al. 2008). However, there is currently insufficient evidence to formally support a threatened or endangered listing under the Endangered Species Act of 1973. Blue sucker populations are believed to be declining in the Missouri River (Coker 1930, Pflieger 1997). The decline is most likely attributable to anthropogenic modifications (e.g., dams, channelization, and stream degradation) that have occurred on most of the rivers in the Missouri River basin (Etnier and Starnes 1993). These modifications can reduce habitat quality and quantity and negatively affect key life history components of the blue sucker.

Adult blue suckers in the Missouri River likely spend the summer feeding to build up energy reserves for spawning migration and spawning. Neely, Pegg, and Mestl (2009) documented a bisected migration where adult blue suckers moved upstream to overwintering areas in the fall, remained relatively sedentary through the winter, and continued to upstream spawning sites in the spring. Neely, Pegg, and Mestl (2009) also noted that many of the blue suckers displayed some intra-annual site fidelity, returning to the sites where they were initially tagged in October of the previous year.

Switzer (1993) defined site fidelity as the return to, and reuse of, a previously occupied location. Site fidelity has been documented in many migratory riverine fishes and describes behaviors that are enacted for a variety of reasons. Some catostomid species are known to exhibit spawning site fidelity that presumably conveys a survival advantage to their progeny. Tyus and Karp (1990) recaptured 27 tagged razorback suckers *Xyrauchen texanus* in the same spawning reach in different years. Some of these fish even demonstrated fidelity to specific spawning riffles. Robust redhorse *Moxostoma robustum* have been observed making migrations in excess of 100 km to reach particular gravel bars in the Savannah River in Georgia and South Carolina (Grabowski and Isely 2007). The white sucker *Catostomus commersonii* has been shown to home to spawning streams as well (Werner 1979).

While much attention has been focused on spawning site fidelity for its implications to population structure and dynamics, relatively little attention has been focused on site fidelity during other parts of the life cycle. Some riverine migrants have been observed exhibiting inter-annual fidelity to habitats utilized during the summer (Buckley and Kynard 1985, Pellett, Van Dyck, and Adams 1998, Knights et al. 2002, Parsley, Popoff, and Wright 2008). Additionally, catostomids have also documented fish captured prior to spawning migrations returning to

the original capture site after spawning (Mueller et al. 2000, Neely, Pegg, and Mestl 2009). Understanding fidelity to summer habitats may be important for understanding species distribution, habitat use, and biological requirements. These issues are likely important in the Missouri River where extensive modifications to riverine habitats have been and are currently being conducted (U.S. Army Corps of Engineers 2016). Therefore, it is essential that these modifications do not negatively affect areas important for blue suckers and other native riverine fishes like summer feeding areas that ultimately may be important to spawning success. We quantified 95% summer UD to determine the degree of site fidelity that blue suckers exhibit by comparing UD calculated from detections in 2008 and 2009. As applied in Neely et al. (2009), UD are used to analyze space-use requirements based on the home range concept defined by Kernohan et al. (2001:126) as “the extent of area with a defined probability of occurrence of an animal during a specific time period.” We also considered respective mean temperature and daily flow values for 2008 and 2009 to determine whether those factors influenced UD significantly. Use distributions are an extension of the home-range concept, and factors that influence home range size have been extensively studied in terrestrial animals. Variation in home range size has been shown to be influenced by resource availability, population density, social factors, and anthropogenic influences (Young and Ruff 1982, Van Orsdel, Hanby, and Bygott 1985, South 1999, Lariviere and Messier 2001, Crooks 2002, Beckmann and Berger 2003, Boydston et al. 2003, Oehler et al. 2003, Gehring and Swihart 2004, Kjellander et al. 2004).

Material and Methods

Study area

The study reach encompassed the Missouri River below Gavins Point Dam at river kilometer (RKM) 1305 downstream to RKM 591 (Figure 1), and is composed of three distinct segments. The unchannelized segment extends from Gavins Point Dam (RKM 1305) to RKM 1212 near Ponca, Nebraska. Morphology of the unchannelized reach remains largely unaltered with predominately sand substrates and a system of braided channels with numerous sand bars and islands through-out the reach. A wide range of depth and water velocities characterizes this section; however, water released from the dam through hypolimnetic releases significantly alters the natural flow (Hesse and Mestl 1993). The river enters a series of training structures at RKM 1212 that channelize the river by the time it reaches Sioux City, Iowa (RKM 1183). The Missouri River is channelized from Sioux City, Iowa to its

mouth at St. Louis, Missouri (RKM 0). Channelized sections of the Missouri River have been restricted by revetted outside bends and dike structures on inside bends to manipulate the river for navigation and flood control. Habitat is very homogenous and is characterized predominantly by sand and silt substrate (Hesse et al. 1989).

Fish capture and transmitter implantation

Blue suckers were captured using a boat-mounted, DC electrofisher unit in March 2007 ($N = 10$) and October 2007 ($N = 40$). All fish were measured for total length (TL) to the nearest millimeter and selected for transmitter implantation based on TL. Minimum TL for implantation was 620 mm, to ensure sexual maturity (Moss, Scanlan, and Anderson 1983, Daugherty, Bacula, and Sutton 2008). A combined acoustic and radio transmitter (CART) measuring 16 mm in diameter, 79 mm in length, and with a mass of 36 g in air (Lotek, Newmarket, ON, Canada) was implanted into the peritoneal cavity of each fish. We used a modified shielded needle technique to pass the antenna through the body wall (Ross and Kleiner 1982). Further descriptions of the tag implantation procedure can be found in Neely, Pegg, and Mestl (2009). Gender identification was done through visual gonad assessment during implantation surgery (Neely, Pegg, and Mestl 2010). All individuals were released immediately following CART implantation.

Data collection and analyses

Telemetered blue suckers were relocated weekly from March through November 2007, March through November 2008, and February through November 2009. Tracking efforts through July 2008 are described in Neely, Pegg, and Mestl (2009). Detections of blue suckers after July 2008 were made during telemetry surveys conducted as part of a collaborative effort between Nebraska Game and Parks Commission and the US Geological Survey's Columbia Environmental Research Center to study reproductively active pallid sturgeon *Scaphirhynchus albus*. A core stretch of the channelized Missouri River was tracked 1-2 times per week from February through November. The core stretch was 251 kilometers long and began at RKM 1112, near Decatur, Nebraska and continued downstream to Brownville, Nebraska at RKM 861. River sweeps were conducted no less than 5 times per year in an attempt to ensure that all telemetered fish were relocated regularly. These sweeps encompassed the entire lower Missouri River from Gavins Point Dam to the mouth. Tracking boats were equipped with global positioning systems (GPS) with 1.0 m accuracy (Trimble, Sunnyvale, CA, USA) and two receivers each coupled with a submersible hydrophone (Lotek, Newmarket, ON, Canada)

Figure 1. Study Area

to locate acoustic transmitters. Telemetered fish were relocated by boat while tracking downstream at a speed just faster than the surface velocity of the river ($<10 \text{ k h}^{-1}$). Individual acoustic code, water depth, surface water temperature, presence of large woody debris and geographical coordinates were recorded once a fish was relocated and entered into a custom ArcPad application (ESRI, Redlands, CA, USA).

We calculated UD's following methods described by Aebischer, Robertson, and Kenward (1993). Ninety-five percent UD's were determined by subtracting the 2.5th percentile from the 97.5th percentile of detection river kilometers for each individual with greater than three detections for both the summer of 2008 and the summer of 2009. The summer season included fish locations from June through September and corresponds, approximately,

Figure 2. Ninety-five percent use distribution for twenty-one blue suckers from the Missouri River during the summers of 2008 and 2009. The x-axis is ordered by Fish ID

to the annual period of post-spawning behavior exhibited by blue suckers (Neely, Pegg, and Mestl 2010). Describing univariate UD across years requires comparing changes in both the size of the UD (i.e., the range in kilometers) and the location (i.e., upper and lower RKM) of the UD. Paired *t*-tests were conducted using $\log_{10}$ -transformed data to determine if mean UD range in kilometers differed across the two years of the study. When regressing the 2009 summer UD bounds against 2008 summer UD bounds, a slope (b) = 1 would indicate that the locations of UD bounds were similar between the two years. How upper and lower bounds (i.e., 97.5th and 2.5th percentiles of detection RKM within fish and year) vary between years provides a measure of fidelity to a location. Flow and temperature data from the USGS gauging station at Sioux City, Iowa were used to characterize flow and temperature during the summers of 2008 and 2009. All data analyses were conducted using SAS statistical software (SAS Institute 2004), and significance was declared at $\alpha = 0.05$.

Results

Twenty-one of the 50 blue suckers were detected more than 3 times in the summers of 2008 and 2009 (Table 1). Over

two thirds (15) of the individuals in the summer detection data set made migrations of over 20 kilometers between the summers of 2008 and 2009. The ratio of females to males in the summer detection data set (female:male = 7:14) did not differ significantly from what was expected based upon the original sample (female:male = 19:31, $\chi^2 = 0.13$, $df = 1$, $P = 0.71$), and no difference could be detected in the mean UD range by sex for 2008 or 2009 (2008: $t = 1.04$, $df = 19$, $P = 0.31$; 2009: $t = 0.99$, $df = 19$, $P = 0.33$). The average number of detections per fish was higher in 2008 ($x = 18.1$, $SE = 0.68$, $n = 21$) than in 2009 ($x = 8.1$, $SE = 0.65$, $n = 21$; $t = 10.74$, $df = 40$, $P < 0.0001$). Fewer detections per individual could bias UD; however, we found no correlation between the number of detections and UD range ($r = 0.01$, $P = 0.95$, $n = 42$). Use distributions were concentrated around RKM 970, the approximate location of release following implantation (Figure 2). The geometric mean 95% UD range was 1.9 RKM ($SE = 1.4$, $n = 21$) in 2008 and 0.3 RKM ($SE = 1.8$, $n = 21$) in 2009, and differed by year ($t = 2.68$, $df = 40$, $P = 0.01$). Mean daily water temperature was, on average, 1°C warmer in 2008 than in 2009 ($t = 3.12$, $df = 240$, $P = 0.002$, Figure 3), and mean daily flows were significantly lower in 2008 than 2009 ($t = 19.75$, $df = 197$, $P < 0.0001$, Figure 4).

Table 1. Range, upper bound and lower bound (kilometers) of 95% summer use distribution (UD) of telemetered blue suckers in the Missouri River for 2008 and 2009.

Unique ID	Sex	Year	Summer Detections	95% UD Summer Lower Bound	95% UD Summer Upper Bound	95% Summer UD Range
611	M	2008	20	970.9	973.2	2.3
		2009	6	971.1	973.0	1.9
613	M	2008	19	966.1	971.9	5.8
		2009	6	970.9	970.9	0.0
615	F	2008	22	970.0	971.1	1.1
		2009	4	970.0	970.3	0.3
616	F	2008	18	968.5	970.9	2.4
		2009	5	969.1	969.6	0.5
617	F	2008	21	964.5	971.1	6.6
		2009	8	927.1	969.5	42.3
618	M	2008	19	963.2	968.0	4.8
		2009	7	967.7	967.7	0.0
620	M	2008	19	964.2	970.0	5.8
		2009	12	968.5	968.8	0.3
621	M	2008	20	965.1	968.8	3.7
		2009	11	967.1	968.3	1.3
623	M	2008	19	969.1	970.0	0.8
		2009	7	969.1	969.6	0.5
624	M	2008	21	958.4	960.0	1.6
		2009	12	958.8	959.3	0.5
628	M	2008	11	929.7	932.0	2.3
		2009	6	930.8	931.5	0.6
629	M	2008	10	946.1	956.3	10.1
		2009	6	954.0	961.9	7.9
631	M	2008	19	968.5	969.0	0.5
		2009	12	968.3	969.0	0.6
635	F	2008	18	967.9	969.5	1.6
		2009	9	967.7	969.0	1.3
638	M	2008	19	971.1	971.6	0.5
		2009	8	971.1	971.6	0.5
640	F	2008	18	966.3	974.9	8.7
		2009	11	969.6	975.7	6.1
641	F	2008	20	971.2	973.2	1.9
		2009	11	971.1	972.0	1.0
643	M	2008	17	954.7	971.6	16.9
		2009	4	970.9	976.4	5.5
647	M	2008	13	877.7	1147.1	269.4
		2009	4	877.7	877.7	0.0
649	M	2008	19	972.2	972.8	0.6
		2009	8	971.7	974.8	3.1
650	F	2008	20	970.6	971.7	1.1
		2009	13	970.6	971.2	0.6

Figure 3. Thermograph of the Missouri River at the U.S. Geological Survey gauging station at Sioux City, Iowa for June through September of 2008 and 2009. The x-axis is reported in “day of year” instead of day/month because 2008 was a leap year, therefore the day/month dates do not match between years. Day 160 is 8 June and 9 June in 2008 and 2009 respectively.

Figure 4. Hydrograph of the Missouri River at the U.S. Geological Survey gauging station at Sioux City, Iowa for June through September of 2008 and 2009. The x-axis is reported in “day of year” instead of day/month because 2008 was a leap year, therefore the day/month dates do not match between years. Day 160 is 8 June and 9 June in 2008 and 2009 respectively.

The upper bound of the 2008 95% UD (UD_{UB}) accounted for 96% of the variation in the upper bound of the 2009 95% UD ($2009_UD_{UB} = 21.7235 + 0.9777 * 2008_UD_{UB}$, $r^2 = 0.96$, $P > 0.0001$, $n = 20$; (Figure 5)) and the slope did not differ from 1 ($t = 0.48$, $df = 18$, $P = 0.64$) indicating that blue suckers were using similar upper bounds in 2008 and 2009. The lower bound of the 2008 95% UD (UD_{LB}) accounted for 97% of the variation in the lower bound of the 2009 95% UD ($2009_UD_{LB} = 15.1749 + 0.9865 * 2008_UD_{LB}$, $r^2 = 0.97$, $P > 0.0001$, $n = 20$; (Figure 6)) and the slope did not differ from 1 ($t = 0.311$, $df = 18$, $P = 0.76$).

Forty-seven of these 50 blue suckers were relocated at least once throughout the study. Undetected fish probably moved into tributaries. Blue suckers in this study were located by Neely et al. (2009) using the Big Sioux River (RKM 1,181). Additionally, the Platte River (RKM 957) is a major tributary within 15 km of the area where site fidelity was concentrated and could be another area to where fish were lost. It is also possible that transmitter malfunction or battery expiration lead to researchers' inability to detect certain individuals.

Figure 5. Relation of 2008 95% summer UD upper bound (RKM) to 2009 summer UD upper bound for 20 of the 21 telemetered blue suckers. One blue sucker (Unique ID 647) was an outlier with studentized residuals greater than 2 and excluded from the analysis.

Figure 6. Relation of 2008 95% summer UD lower bound (RKM) to 2009 summer UD lower bound for 20 of the 21 telemetered blue suckers. One blue sucker (Unique ID 647) was an outlier with studentized residuals greater than 2 and excluded from the analysis.

Discussion

We observed that the range of river kilometers used by blue suckers differed between years. However, the approximate location of those ranges within the Missouri River did not often differ (Figure 2). Similarity in use distribution location from 2008 to 2009 indicates high site fidelity for blue suckers across years. Two thirds of

the individuals undertook migrations of greater than 20 RKMs and were able to home to the same areas from which they left over seven months prior. Neely, Pegg, and Mestl (2009) suggested that blue suckers were displaying fidelity to summer feeding areas across years when they noted that blue suckers returned to the area that they were implanted the year prior.

How animals use space to fulfill their biological requirements is complex and likely includes characteristics of the environment (e.g., habitat stability, predictability of reproductive failure, variability of habitat quality, and population pressure) and characteristics of the individual like previous reproductive success, age, and knowledge of other sites (Switzer 1993, Moyer, McCown, and Madan 2007). Switzer (1993) also suggests that, among other things, site fidelity is related to the cost of changing habitats, age, adult mortality, and habitat quality heterogeneity. Habitats used by migratory species during the summer can be critical feeding areas that enable fish to build energy reserves necessary for spawning and migration. Blue suckers are likely feeding heavily during the summer to build energy reserves for the fall migration (Moss, Scanlan, and Anderson 1983, Neely, Pegg, and Mestl 2009). Blue suckers feed mostly on aquatic larvae and Neely, Pegg, and Mestl (2009) reported that telemetered blue suckers were detected within 10 meters of visible woody debris, to which aquatic larvae commonly attach, in 27% of early summer detections. Blue suckers may have selected and returned to the same habitats because they offer adequate food resources. Switzer (1993) also suggests that site fidelity should increase as habitat heterogeneity decreases. This is an interesting hypothesis to consider when studying a fish in a system that was once very heterogeneous, but now, through anthropogenic modification, is relatively homogeneous. Any results that we present must be interpreted with the caveat that blue suckers used for this study were living in a highly altered system. Without a comparable study conducted under reference conditions it is impossible to know the degree to which behaviors have been altered.

Site fidelity has been documented for many riverine species including golden perch *Macquaria ambigua* (Crook 2004), common carp *Cyprinus carpio* (Crook 2004), flathead catfish *Pylodictis olivaris* (Vokoun and Rabeni 2005), and razorback suckers (Tyus and Karp 1990). Many authors have focused on spawning site fidelity because of the obvious implications for population structure and management. Some of these authors have noted apparent fidelity to habitats used during the summer (Parsley, Popoff, and Wright 2008, Neely, Pegg, and Mestl 2009). Advances in tag life are now allowing researchers to conduct long term telemetry studies. These studies are finding intra-annual site fidelity to summer habitats are more common than originally thought. For example, Hurley, Hubert, and Nickum (1987) reported homing behavior in 8 of 22 shovelnose sturgeon *Scaphirhynchus platyrhynchus* tracked in Pool 13 of the Upper Mississippi River. Knights et al. (2002) documented lake sturgeon *Acipenser fulvescens* using core areas in the Mississippi River. Kieffer and Kynard (1993)

found that shortnose sturgeon *Acipenser brevirostrum* use discrete river reaches for spawning, summering, and wintering and hypothesized that habitat selection was related to food abundance. Shortnose sturgeon exhibited movements that Buckley and Kynard (1985) described as exact and directed between discrete areas. Pellett, Van Dyck, and Adams (1998) reported channel catfish *Ictalurus punctatus* homing to summer habitats in the lower Wisconsin and upper Mississippi rivers. Flathead catfish were also documented to return to summering habitats in consecutive years (Daugherty, Bacula, and Sutton 2008). Buzby and Deegan (2000) documented similar inter-annual fidelity to summer feeding sites in arctic grayling *Thymallus arcticus*. Each of the above species is similar to blue suckers in the Missouri River in that they undertake spawning migrations and appear to have high fidelity to summer feeding sites. Our results also further confirm that migratory species' movement patterns are complex and include movement patterns beyond a single, annual event. Implications for not understanding these complex movements could range from a localized-individual to a population-level response that would include decreased fitness or even extirpation as human actions continue to influence these altered systems.

Many of our observations parallel observations made by Buzby and Deegan (2000). We saw no upstream or downstream trends across years, and site fidelity did not appear to be related to gender. Buzby and Deegan (2000) also noted that a high degree of fidelity to summer feeding sites increases a fish's vulnerability to natural and anthropogenic disturbances. Future studies should focus on how modifications to the Missouri River habitat affect food availability and blue sucker distribution and movements. This study highlights the important contributions that long-term telemetry studies can have when dealing with species of conservation concern. Although sample sizes are typically small, long-term telemetry studies can contribute information that is otherwise unobtainable through other sampling methodologies.

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