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Habitat use and movements of shovelnose sturgeon in Pool 13 of the upper Mississippi River during extreme low flow conditions

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Synopsis

We monitored habitat use and movement of 27 adult shovelnose sturgeon in Pool 13 of the upper Mississippi River, Iowa-Illinois, by radio-telemetry in April through August 1988. Our objective was to determine the response of this species to unusually low water conditions in the upper Mississippi River in 1988. Most (94%) telemetry contacts were made in 3 habitat types: main channel (50%), main channel border where wing dams were present (29%), and tailwaters of Lock and Dam 12 (15%). Habitat use in spring was affected by the extreme low flows. We often found tagged shovelnose sturgeon in the main channel and tailwaters during the spring period (11 March–20 May) where water velocities were highest. This was in contrast to other studies where shovelnose sturgeon did not occupy those areas during years with normal spring flows. Shovelnose sturgeon were typically found in areas with a sand bottom, mean water depth of 5.8 m, and mean bottom current velocity of 0.23 m sec^{-1}. They occupied areas of swifter current but were not always found in the fastest current in their immediate vicinity. Tagged shovelnose sturgeon tended to remain in the upper, more riverine portion of the pool, and we observed no emigration from the study pool. Linear total range of movement from the tagging site ranged from 1.9 to 54.6 km during the study period.

Introduction

A series of locks and dams constructed on the upper Mississippi River by the U.S. Army Corps of Engineers to aid navigation has greatly altered the natural discharge and flow regime of the river. The effect of these modifications on habitat use and migratory behavior of endemic fishes is not well understood. The shovelnose sturgeon, *Scaphirhynchus platorynchus*, has had a long evolutionary association with the river and is widely distributed in the Mississippi River basin (Bailey & Cross 1954). The shovelnose sturgeon is the most abundant sturgeon species in Iowa waters of the Mississippi River (Helms 1974) and is a commercially valuable species.

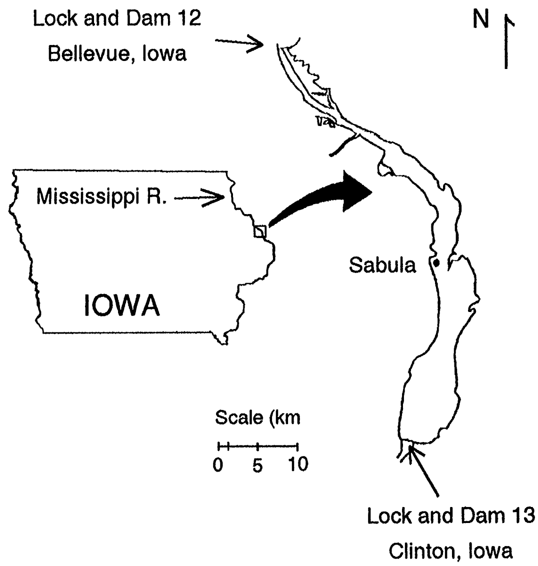

Figure 1. Study area, Pool 13, upper Mississippi River.

Shovelnose sturgeon have declined in abundance in the Mississippi River since the early 1900s (Pflieger 1975). The cause of the decline is unclear but is commonly attributed to a combination of exploitation, habitat alteration, and pollution. Commercial fishing and the impoundment of the upper Mississippi River by construction of the lock and dam system in the early 1940s may have reduced the abundance and distribution of this large-river species. Distribution of the shovelnose sturgeon in the Missouri River system has been restricted by the construction of six mainstem reservoirs (Held 1969). Impoundment and manipulation of water levels in the Volga River has had a similar adverse impact on the abundance and reproduction of several species of Russian sturgeons (Yelizarov 1968, Khoroshko 1972).

Information on shovelnose sturgeon habitat use and movements in a variety of annual flow regimes is needed to understand and predict the response of this species to changes in river conditions. Previous studies indicated that shovelnose sturgeon prefer areas of current (Coker 1930), such as the main channel, main channel border, and near wing dams (Pitlo 1981, Hurley et al. 1987). They also tend to be found in upstream, lotic reaches rather than in lower, lentic reaches of each impounded pool (Helms 1974).

The objectives of our study were to determine habitat use and movement of shovelnose sturgeon during conditions of extremely low discharge. This information will provide a better understanding of the potential effects of increased navigation, future hydropower projects, and variations in river flow regimes on shovelnose sturgeon.

Methods

Study area

Pool 13 is one of 26 pools in the upper Mississippi River, and extends from Lock and Dam 12 at Bellevue, Iowa, to Lock and Dam 13 at Clinton, Iowa. The pool is 55 km long, 0.5 to 6.4 km wide, and covers 11 379 ha at normal pool (Figure 1). Mean annual flow at Lock and Dam 13 is 1342 m^3 sec^{-1}. The portion of the pool upstream from Sabula, Iowa, is essentially riverine, whereas the lower portion is lacustrine (Hurley et al. 1987).

Six extrained river habitats as defined by the Upper Mississippi River Conservation Committee are found in Pool 13: tailwaters (the area within 0.8 km downstream of the dams), main channel, main channel border, side channels, river lakes and ponds (usually directly above navigation dams), and backwater lakes located away from the channel area (Rasmussen 1979, Eckblad 1986). Because there were several habitat types in the 0.8 km reach in Pool 13 typically defined as tailwaters (Rasmussen 1979), we redefined the tailwater zone as the area directly below Lock and Dam 12 downriver to the first wing dam on the Illinois side of the river. We subdivided the main channel border habitat to reflect the presence or absence of wing dams. At normal pool level, available habitat in Pool 13 consists of about 0.3% tailwaters, 10.1% main channel, 4.8% main channel border with wing dams, 5.3% main channel border without wing dams, 4.7% side channel, 9.8% slough, and 64.5% lake and backwater (Hurley 1983).

Drought conditions persisted throughout the Mississippi River watershed during 1987 and 1988. Mean monthly precipitation measured during March-August 1988 at Lock and Dam 11 at Dubuque, Iowa, averaged 42% below the previous 125-year monthly means. Mean monthly flows through Lock and Dam 13 at Clinton during the same period averaged 42% less than the monthly means from the preceding 47 years. There was no spring flood in 1988, and the roller dam gates at Locks and Dams 12 and 13 were never fully opened.

We apportioned data on river conditions into 2 distinct periods, based on daily discharge. In spring (11 March–20 May), average daily discharge was 1 530 $m^3 s^{-1}$, and average tailwater stage was 2.2 m at Lock and Dam 12. In summer (21 May–12 August), discharge and tailwater stage averaged 496 $m^3 s^{-1}$ and 1.1 m. Summer flows were significantly lower and more stable than during spring (Moen et al. 1992). Surface water temperatures in the main channel increased from 13.8 °C in early May to 27.4 °C in mid-August. Water temperatures in the spring and summer periods averaged 17.1 °C and 24.9 °C (Moen et al. 1992).

Data collection

Telemetry equipment used in this study was obtained from Advanced Telemetry Systems, Isanti, Minnesota. Each radio transmitter was equipped with a 25 cm antenna and weighed about 10 g. Signals were broadcast at 1 s intervals on a unique frequency between 48.440 and 49.778 MHZ. Expected transmitter life was 60–90 d. Signals were monitored with a programmable scanning receiver attached to a 4-element directional Yagi antenna, mounted vertically on a collapsible 3 m mast.

Twenty-seven shovelnose sturgeon were fitted with radio transmitters. Fish were captured in stationary-set trammel nets fished overnight by a commercial fisherman in the area just downstream from the tailwaters of Lock and Dam 12. Transmitters were mounted externally by drilling small holes through the base of the carina of the fourth and sixth dorsal scutes and attached with wire drawn through the holes (see Curtis 1990 for details on fish capture and tagging). This method of external attachment has been successfully used on shovelnose sturgeon (Hurley et al. 1987) and shortnose sturgeon (*Acipenser brevirostrum*; Buckley & Kynard 1985). Because of the relatively short life expectancy of the transmitters, we tagged two groups of fish, one month apart, to ensure that some tagged shovelnose sturgeon could be monitored through at least mid-August. Tagging was done on 26 April (14 fish) and 25 May (13 fish). Fork lengths (FL) of tagged fish ranged from 62.2 to 80.4 cm (mean = 71.5 cm) and weights ranged from 0.91 to 2.5 kg (mean = 1.65 kg). Twenty-two females 62.2–80.4 cm (mean = 71.9 cm) and 0.91–2.49 kg (mean = 1.74 kg) and five males 70.1–74.0 cm (mean = 72.2 cm) and 1.18–1.57 kg (mean = 1.41 kg) were tagged. Because our study was part of a larger study to locate shovelnose sturgeon spawning grounds, a larger proportion of mature, gravid females was selected for radio-tagging.

Searches to locate radio-tagged shovelnose sturgeon were conducted daily by boat during daylight hours, and tagged fish were located as often as possible (usually several times per week). We attempted to maneuver the boat close to each fish, and recorded location and habitat type. Although we conducted no specific tests of the detection range of the transmitters used, initial tracking of tagged fish indicated that signal strengths were sufficient to allow us to locate fish under most conditions.

Specific habitat variables were measured at 72 fish locations, 15 in the tailwaters of Lock and Dam 12 and 57 in areas outside the tailwaters. At these locations we measured depth, current velocity (at 30.5 cm below the surface, 0.6 × the depth measured from the surface, and 30.5 cm above the bottom), surface water temperature, and predominant substrate material present in Ponar dredge samples. We calculated mean column velocity (MCV) at each site from the current velocities at the 3 depths. The distance between the farthest upstream and downstream contact locations was used as a measure of the linear range for individual fish.

Conditions in the tailwaters were highly variable and subject to the positioning of the dam's roller gates. To characterize the tailwater habitat when shovelnose sturgeon were found there, current velocities were measured and water temperatures were recorded at three index sites evenly spaced along a shore-to-shore transect that bisected the tailwater area. We used these data collectively to characterize general tailwater conditions.

Results

Movement

A total of 212 telemetry contacts on 27 tagged shovelnose sturgeon was made between 28 April and 3 August 1988. The number of contacts per individual averaged 7.9 (SE = 1.04; range 1 to 20); Mean number of contacts with females was 8.4 (SE = 1.13; n = 22), compared to 5.4 (SE = 2.06; n = 5) for males. Although there was considerable variation in movement patterns among individual fish, the tagged sturgeon tended to remain in the upper, riverine portion of Pool 13 above Sabula, Iowa. Rapid downstream movement of 2 fish was observed, and these individuals may have left the study pool. However, no radio-tagged shovelnose sturgeon were located during intermittent tracking in the pools immediately upstream and downstream of the study pool (i.e., Pools 12 and 14). Several tagged shovelnose sturgeon moved downstream within Pool 13 between 26 May and 18 June, and several more fish moved more than 10 km downriver during the last week in June. These movements occurred during periods of generally declining discharge, but telemetry contacts were not made often enough with radio-tagged fish to detect responses to short-term changes in flows. Detailed analyses of movement patterns in relation to river conditions would not have been meaningful because of the relatively few contacts with individual tagged fish and the often large time gaps between contacts.

Radio-tagged shovelnose sturgeon showed no tendency to congregate in any area except the initial point of capture, and no evidence of spawning activity was observed. No shovelnose sturgeon eggs were collected in a concurrent study to document actual reproduction by this species in Pool 13. Tagged fish were subsequently found in areas in Pool 13 suggested by Hurley & Nickum (1984) as potential spawning areas, but we did not detect movements associated with possible spawning activity there.

Several shovelnose sturgeon were found in narrowly restricted areas for long periods (up to 1 month or longer). Total ranges of movement varied between 1.9 and 54.6 km (mean 18.5 km). There were significant differences between the total movement ranges among fish tagged on different dates: sturgeon tagged on 26 April moved 1.9 to 23.6 km (mean 13.3 km), whereas distances moved by those tagged on 25 May ranged from 2.5 to 54.6 km (mean 24.1 km; $t = 2.83$, $p = 0.009$). Fish tagged on 26 April tended to remain in areas well upstream from those tagged in late May, although some overlap was noted. There was no relation between linear range of movement and fish length ($r^2 = 0.008$, $p = 0.65$). Males and females did not differ significantly in range of movement ($t = 0.83$, $p = 0.41$), although the number of males tagged was small.

Table 1. Numbers of contacts with tagged shovelnose sturgeon in Pool 13 of the upper Mississippi River in spring and summer 1988. Numbers of parentheses are column percentages, N is the number of tagged fish monitored during each season.

Habitat type	Spring (N = 13)	Summer (N = 24)	Combined
Tailwaters	17 (17.9)	14 (12.0)	31 (14.6)
Main-channel	34 (35.8)	73 (62.4)	107 (50.5)
Main-channel border with wing dams	41 (43.6)	20 (17.1)	61 (28.8)
Main-channel border without wing dams	2 (2.1)	8 (6.8)	10 (4.7)
Side channel	1 (1.0)	1 (0.9)	2 (0.9)
Slough	0	0	0
Lake and backwater	0	1 (0.9)	1 (0.5)
All	95 (100)	117 (100)	212 (100)

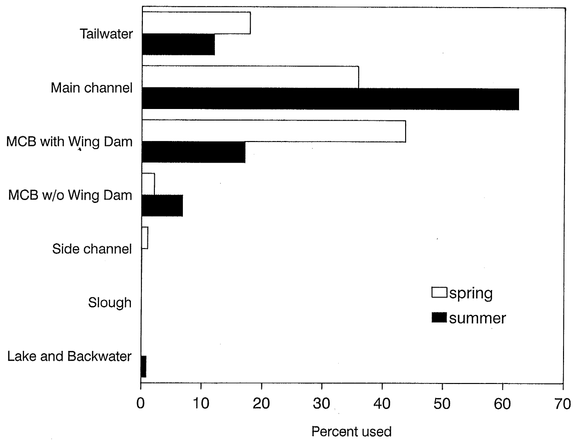

Figure 2. Habitat use by radio-tagged shovelnose sturgeon during spring and summer in Pool 13 of the upper Mississippi River 1988. MCB = main channel border, w/o = without.

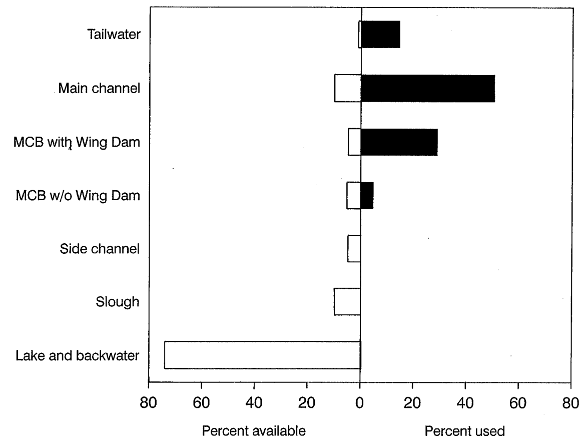

Figure 3. Habitat availability and use by radio-tagged shovelnose sturgeon in Pool 13 of the upper Mississippi River, April-August 1988. MCB = main channel border, w/o = without.

Habitat use

Radio-tagged shovelnose sturgeon were most often found in the main channel (50%), but they were also found in main channel border areas with wing dams (29%) and the tailwaters of Lock and Dam 12 (15%; Table 1). There were significant differences in habitats used during the spring and summer periods χ^2 = 24.3; p = 0.000; df = 5). Main channel border areas with wing dams and the main channel areas were most often during spring, whereas the main channel was used most in summer (Figure 2). Use of main channel border areas without wing dams was limited, but these areas were used more often in summer than in spring. Side channels and closing dam areas were rarely used. We located only one fish in the lower, lacustrine area of the pool; its last known location was on the upriver side of Lock and Dam 13. Shovelnose sturgeon found near wing dams were typically located between the outer end of the wing dam and the edge of the main channel, usually just downstream from the wing dam. These sites were typically more turbulent than the surrounding areas and contained deep scour holes. We rarely found radio-tagged fish in areas directly behind a wing dam, and slough areas were never used. We observed no reaction to the tracking boat, regardless of habitat type.

Habitats were not used in proportion to their availability. Main channel, main channel border areas with wing dams, and tailwater areas were used in much larger proportions than they were available (Figure 3), whereas lake and backwater, the most abundant habitat types, were almost never used. Habitat types used by shovelnose sturgeon in spring and summer of 1988 made up only 25% of all available habitat in Pool 13.

Habitat conditions

Radio-tagged shovelnose sturgeon were found in water depths that ranged from 2.7 to 8.2 m (mean = 5.3 m SE = 0.2 m) and were found in depths ranging from 4.6 to 6.1 m more than 60% of the time. Clean sand was the predominant substrate type in areas where tagged fish were found; 92% of all observations were made over sand bottom. We occasionally found shovelnose sturgeon in areas with a mixed sand and silt substrate (3.4%), and one fish was sampled twice over rock and gravel substrates.

Surface current velocities at shovelnose sturgeon locations ranged from 0.13 to 0.64 m s^{-1} (mean = 0.36 m SE = 0.17 m). Shovelnose sturgeon were most commonly found in areas with surface current velocities of 0.20–0.64 m s^{-1} (bottom velocities were not measured). Current velocities at 0.6 × depth were slightly less than at the surface, ranging from 0.12 to 0.60 m s^{-1} (mean = 0.32 m SE = 0.016 m). Bottom current velocities ranged from 0.0 to 0.52 m s^{-1}

(mean = 0.23 SE = 0.016 m). Shovelnose sturgeon were most commonly located in bottom current velocities of 0.20–0.45 m s^{-1}. Bottom current velocities of zero or near-zero were measured at several fish locations. These measurements were likely taken behind a sand ridge (common in the main channel) or some other physical obstruction. We were unable to determine if an individual sturgeon was located behind an obstruction or merely adjacent to it.

Mean column velocities (MCV) ranged from 0.10 to 0.57 m s^{-1} (mean = 0.31 SE = 0.015 m) and represent a characterization of the general conditions that would be encountered by a shovelnose sturgeon if it were to make use of the entire water column. Shovelnose sturgeon probably remain on or near the bottom, but some use of the upper water column does occur. Shovelnose sturgeon were occasionally observed at the surface during tracking, but no radio-tagged fish were observed on the surface. Use of the upper water column could not have been detected with the telemetry equipment used in this study.

Surface water temperatures at shovelnose sturgeon locations ranged from 17.0 to 28.5 °C. However, water temperatures increased during the study period; the range of observed temperatures reflected this trend rather than temperature selection by shovelnose sturgeon. We found no relation between surface water temperatures and depths used by fish ($r^2 = 0.026$; $p = 0.24$), and there was no indication that sturgeon were moving into deeper (and possibly cooler) water as surface water temperatures increased.

Tagged shovelnose sturgeon were found in a variety of locations throughout the tailwaters of Lock and Dam 12, but we were unable to determine if tagged shovelnose sturgeon were on the bottom or pelagic. Because current velocities at the 3 depths sampled at each index site were highly variable among index locations and depths, they were recorded as ranges. Surface current velocities ranged from 0.0 to 0.74 m s^{-1} and velocities at 0.6 × depth ranged from 0.04 to 0.59 m s^{-1} (bottom velocities were not measured). Current velocities and patterns would often change substantially while measurements were being made, but velocities measured in the tailwaters were consistently higher than at downriver sites.

Substrate in the tailwaters consisted of patches of bedrock and clean sand. Water depths at the sampling locations ranged from 13 to 23 m. Surface water temperatures in the tailwaters ranged from 24.5 to 28.0 °C during June and July.

Discussion

Shovelnose sturgeon radio-tagged in our study generally remained in the upper, riverine portion of Pool 13. The tendency to occupy only the upper part of the pool is likely related to the impoundment of the river. Held (1969) reported that the capture of sturgeon in Lewis and Clark Lake on the Missouri River is uncommon except in the upstream portion of the lake and is restricted to lotic areas of the old river channel. It is not known how much suitable habitat may have existed in the study area before impoundment by the lock and dam system, but it is likely that shovelnose sturgeon were more widely distributed along the river. The abnormally low flows in 1988 further reduced the amount of suitable habitat in the pool, particularly side channels.

We observed radio-tagged shovelnose sturgeon to exhibit sedentary behavior consistent with that observed in other studies where tracking was conducted during daylight hours. Hurley et al. (1987) reported use of 2 distinct types of home areas by shovelnose sturgeon: (1) restricted home areas less than 50 m in diameter, usually associated with wing and closing dams and (2) extended home areas associated with channel habitats < 1 km long. Shovelnose sturgeon exhibiting limited movement in the present study usually were found in the main channel border associated with wing dams. They were often found in or near the scour hole just outside and slightly downstream from the wing dam. These sturgeon may have been exhibiting behavior similar to the use of restricted home areas described by Hurley et al. (1987). Helms (1974) also found that tagged shovelnose sturgeon did not move great distances in Pool 13 of the upper Mississippi River. Moos (1978) and Christenson (1975) reported only limited movement by shovelnose sturgeon in the Missouri River and Red Cedar-Chippewa River system. It is not known if shovelnose sturgeon exhibit diel activity patterns, and gaps between telemetry contacts in our study would have prevented detection of movements away from locations where tagged fish were found during the day.

The small number of contacts with some radio-tagged fish in our study may have occurred for several reasons. Several of our radio-tagged sturgeon were caught by commercial fishermen in Pool 13, and their transmitters returned. Other fish may have been caught and not reported. Shovelnose sturgeon were sometimes difficult to locate due to relatively low signal strengths, particularly in the deep pool below Lock and Dam 12. Transmitter failure was also possible, but no evidence of failure was noted.

Shovelnose sturgeon are not normally abundant in the areas near the tailwaters of Lock and Dam 12 until late April, when commercial fishermen begin to capture large numbers of fish moving upriver (Wayne Kress personal communication). This upriver movement is likely related to spawning. Timing of the downriver movement was similar among fish tagged on the different dates, but our data were insufficient to determine if it was directly related to flow patterns. Movement of tagged sturgeon downriver occurred between 26 May and 18 June, and several fish moved more than 10 km downriver during the last week in June. The reason for this movement is unknown, although it occurred during a period of generally declining flows. The fish may have been homing to downstream areas, or the movement may have been a spawning or post-spawning migration.

Shovelnose sturgeon captured and tagged on 25 May generally dispersed much farther downstream than those tagged on 26 April, which suggests localized stocks that migrated upriver at different times during spring, although it is not known if different stocks exist. Hurley (1983) reported no movement between pools by radio-tagged shovelnose sturgeon in the same pool in 1982, suggesting that fish living in Pool 13 may spawn within the pool (although they did observe some movement between pools over a period of several years). Temporal segregation of spawning in the vicinity of the tailwaters was possible, but no fish with extrudable sex products were observed on either tagging date.

Our results indicate that shovelnose sturgeon used the tailwater, main channel, and main-channel border habitats in spring 1988 because of the low spring flows. Shovelnose sturgeon are not typically found in the main channel or tailwaters in the spring when the upper Mississippi River normally reaches peak flow levels and the gates of the dam are opened to allow a free-flowing river. Hurley et al. (1987) found shovelnose sturgeon to be most abundant in areas outside the main channel, often behind wing and closing dams, in side channels, and in the main channel border during high spring flows in 1982. Shovelnose sturgeon in our study were rarely found in side channels or near closing dams during the low spring flows in 1988. This suggests that these areas may serve as refuges during periods of high spring flows. Additional sampling should be conducted in downriver, lacustrine areas of the pool to confirm the use, if any, of that area by shovelnose sturgeon. The contact with one fish near Lock and Dam 13 suggests that this area contains at least some suitable habitat for shovelnose sturgeon.

Despite the low flow rates in 1988, shovelnose sturgeon were consistently found in areas of relatively swift current, in several habitat types. This species is known to inhabit areas with a swift current (Pflieger 1975), often in main channel (Hubert & Schmitt 1982) or main channel border areas, often associated with wing dams (Pitlo 1981). Hurley et al. (1987) found that shovelnose sturgeon in Pool 13 utilized current velocities of 0.40–0.70 m s^{-1} at the surface and 0.20–0.40 m s^{-1} on the bottom. The mean bottom velocity used by shovelnose sturgeon in our study was 0.23 m s^{-1}, at the lower end of this range. The generally lower velocities used by shovelnose sturgeon in 1988 may be more a function of availability than preference because river conditions in 1982 were characterized by high spring flows and near-normal summer flows. Water depths at locations used by shovelnose sturgeon in our study averaged 1 m deeper than those reported by Hurley et al. (1987) in 1982. Water depth and substrate type may be only secondary factors affecting shovelnose sturgeon distribution. Also, the lack of a significant relation between depth and water temperature suggests that shovelnose sturgeon were not changing depths to find or avoid any specific temperatures.

Shovelnose sturgeon made considerable use of the tailwaters of Lock and Dam 12 in 1988. This is the first documentation of tailwater use over an extended period in the upper Mississippi River. Hurley et al. (1987) reported only limited use of the tailwaters of Lock and Dam 12 by shovelnose sturgeon in 1982. Sturgeon using the tailwaters in 1988 may have been attempting to move upstream into Pool 12 and were blocked by the dam, or they may use this type of habitat more than previously thought. The highest flows are normally found in the tailwaters, and in 1988 current velocities greater than 0.50 m s^{-1} were usually found only in or just downstream from the tailwaters, suggesting that shovelnose sturgeon might have been seeking higher current velocities than were available downriver.

Tagged shovelnose sturgeon were not always found in the fastest current velocities available near sites where they were located, which indicates that current velocities in 1988 were above the minimum required for survival despite the record low flows. Our tagged sturgeon exhibited behavior in spring nearly identical to that described by Hurley et al. (1987) as normal for mid- to late summer, indicating that movement and habitat use is strongly influenced by flow levels. It is not known if low flow levels affected spawning or reproductive success in 1988, and further research is needed on spawning and early life history of this species and the effects of various flow regimes on reproduction.

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