North American Journal of Fisheries Management 25:301–307, 2005

DOI: 10.1577/M03-229.1

[Management Brief]

Characteristics of Spawning Lake Sturgeon in the Upper Black River, Michigan

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Abstract.—The population of lake sturgeon *Acipenser fulvescens* in Black Lake, Michigan, is confined to a smaller spatial habitat than was historically available, which has led to concern over the future viability of the population. Biological data were collected from spawning lake sturgeons in the Upper Black River in 2001 and 2002 to assess the size of the spawning run and the condition of spawning fish relative to other populations. A 1.6-km section of the total 11 km of available habitat in the Upper Black River was an important spawning location for lake sturgeon. Spawning fish were captured and data were collected at the spawning sites from 115 adults in 2001 and 104 adults in 2002. Fish gender was determined by the presence of ripe gametes. The male : female sex ratio was 1.55:1 in 2001 and 2.06:1 in 2002. Weight at length for spawning lake sturgeons was comparable to that of other studied populations, and the average size at age of spawning lake sturgeons was slightly higher than for spawning fish from the Sturgeon River, Michigan, an open tributary to Lake Superior with a self-sustaining population. Consecutive-year spawning was documented for 10 male lake sturgeons, which showed an average increase in total length and weight of 1.6 cm and 1.15 kg, respectively. Age estimates predicted by a von Bertalanffy model for the spawning adults predicted males representing 25 different age-classes ranging from age 12 to age 63 and females representing 29 different age-classes ranging from age 20 to age 70. On the basis of our observations of ripe gametes, growth of the annual spawners, and overall condition of the spawning fish, we conclude that the spatially restricted habitat in Black Lake was sufficient to support adult lake sturgeon growth and gamete production.

Lake sturgeons *Acipenser fulvescens* were once a common and abundant component of the fish assemblage of the Great Lakes region (Harkness and Dymond 1961; Houston 1987). Lake sturgeons were found in all the Great Lakes and in many of the large rivers and inland lakes that were directly connected to the Great Lakes. However, since the late 1800s, the abundance of lake sturgeons has drastically declined throughout the species' range as a result of overharvest, habitat destruction, and construction of dams that impede migrations to spawning habitat (Hay-Chmielewski and Whelan 1997). Black Lake, an inland lake with restricted spatial habitat in Cheboygan and Presque Isle counties, Michigan, is the only inland lake in Michigan known to contain a naturally reproducing population of lake sturgeons. However, the population has been steadily declining since at least 1975 (Baker and Borgeson 1999) and there is concern over its future viability. The causes of the population decline have been attributed to overharvesting and lack of recruitment (Baker and Borgeson 1999) associated with hydropower dam operation (since 1949) on the Upper Black River, the only known spawning stream for lake sturgeons in Black Lake (Smith 2003). Auer (1996b) questioned the long-term viability of lake sturgeon populations in isolated water bodies, citing the importance of long-distance migration in the life history of lake sturgeons. Lake sturgeons in Black Lake once had unrestricted access to lakes Huron and Michigan but the population has been isolated from the Great Lakes since the construction of Alverno Dam on the Lower Black River in 1903. Available habitat for Black Lake lake sturgeons now consists of the 8-km riverine stretch of the Lower Black River, the 4,101 ha within Black Lake, and the 11-km riverine stretch of the Upper Black River. Lake sturgeons can pass over or through Alverno Dam and further downstream to the Cheboygan River and Lake Huron but the dam prevents them from returning to Black Lake.

Previous studies have focused on adult lake sturgeon ecology (Harkness and Dymond 1961; Priegel and Wirth 1971), spearing harvest and exploitation (Priegel and Wirth 1975; Folz and Meyers 1985;

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Received November 25, 2003; accepted April 23, 2004
Published online March 4, 2005

Bruch 1999), age and growth (Probst and Cooper 1955; Wilson 1987), spawning behavior (Bruch and Binkowski 2002), and movements of adults (Lyons and Kempinger 1992; Auer 1999) in the Great Lakes watershed. However, all of these studies were conducted on populations that occupy much larger water bodies than Black Lake; few studies have investigated adult lake sturgeon ecology in inland lakes that have become isolated from the Great Lakes. Thuemler (1985, 1988, 1997), who reported on lake sturgeon status, management, harvest, and movement of stocked fish in the Menominee River, a river system fragmented by hydropower dam development, suggested that conservative management was necessary for perpetuation of the fishery. Studies of isolated lake sturgeon populations will be important to the future management of the species because most populations are currently restricted to habitats that are fragmented and smaller than their historical size. In addition, most lake sturgeon populations in the Great Lakes have declined to such a low abundance that current populations are too small or too dispersed for research to adequately assess population size and reproductive potential. The small, self-sustaining population that remains in the isolated system of Black Lake provides a unique opportunity to study the biological characteristics and abundance of spawning fish in a spatially restricted water body.

Rehabilitation and recovery of lake sturgeons will require understanding current stock size and habitat needs. Black Lake can also be used as a model system to study the life history dynamics of lake sturgeons because the fish are isolated from the Great Lakes, occupying a restricted spatial habitat that is easier to sample and assess. Previous studies on Black Lake have provided limited information on the ecology (Baker 1980), movements (Hay-Chmielewski 1987), and abundance (Baker and Borgeson 1999) of lake sturgeons. This study is the first to describe the biological characteristics of spawning lake sturgeons for the Black Lake population.

Effective strategies for management of lake sturgeons will require adequate biological information on all life stages. The objective of this study was to assess the biological condition of spawning adult lake sturgeons in the Upper Black River to help fisheries managers make informed decisions about managing this fishery into the future. In addition, we compare the characteristics of spawning lake sturgeons from the Upper Black River with those of other populations to gain insight into whether long-term isolation in a restricted habitat may be affecting adult fish negatively.

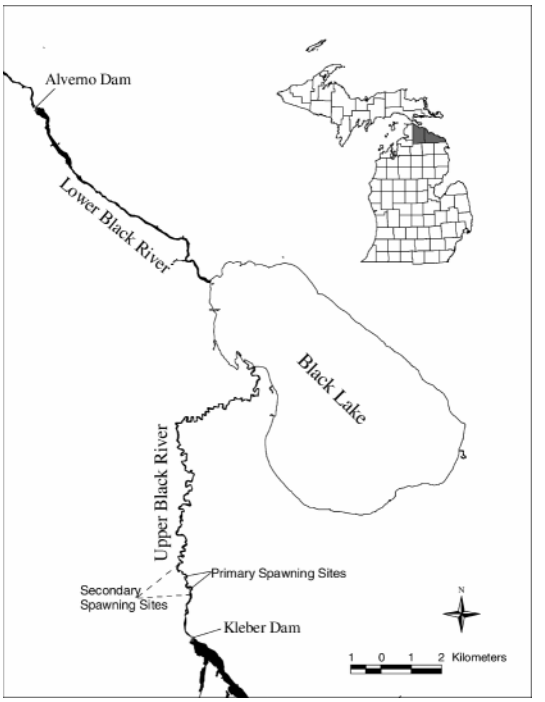

FIGURE 1.—Map of the lake sturgeon study area of Black Lake, Michigan, showing spawning locations and tagging sites in the Upper Black River.

Study Site

Black Lake, in Cheboygan and Presque Isle Counties, Michigan (Figure 1), is the eighth largest inland lake in Michigan, with a surface area of 4,101 ha (Hay-Chmielewski 1987). The average depth of the lake is 7.5 m; the maximum depth is 15.3 m in the southern half of the basin, whereas the maximum depth in the shallower northern end of the basin is less than 10 m. Black Lake has a maximum width of 4.8 km and a maximum length of 9.6 km. Substrate in Black Lake has been characterized as muck in the profundal zone and sand or sandy-muck in the littoral zone (Hay-Chmielewski 1987).

The Upper Black River, a fourth-order stream, is the largest source of inflow into Black Lake, contributing an average discharge of 6.4 m^3/s (TMWC and NMCG 1991). The Upper Black River watershed covers over 92,470 ha and is 65.3% of the Black Lake watershed. The Upper Black River main stem is 91.7 km long but lake sturgeons are restricted to the lower 11 km by Kleber Dam, built in 1949. The Upper Black River, from its confluence with Black Lake to Kleber Dam, is the principal spawning area. In 1972, four artificial

spawning reefs of rip-rap cobble were placed in the river to provide spawning sturgeon more suitable substrate (Baker 1980). Over the period of almost 30 years these four spots have become impacted with sediment, such that the remaining rip-rap is in poor condition and is evident along the stream banks only.

The Lower Black River, the only source of outflow from the lake, was historically a migration corridor for lake sturgeon moving between Black Lake and Lake Huron. The Lower Black River is 16.4 km long from its origin at Black Lake to its confluence with the Cheboygan River. Alverno Dam, located on the Lower Black River 8 km downstream from Black Lake, was constructed in 1903 and isolates the Black Lake lake sturgeon population from Lake Huron. Although fish can pass Alverno Dam going downstream, the dam prevents their return to Black Lake.

Methods

During spring 2001 and 2002, spawning lake sturgeons were observed and sampled in the Upper Black River, Michigan. Adult lake sturgeons were captured with trapezoid-shaped dip nets by personnel wading the river from Kleber Dam downstream to the lower section of the spawning grounds (Figure 1). The frames of the dip nets were 78.7 cm wide at the base, 30.5 cm wide across the top, and 70.5 cm long from base to top. Nets had 1.8-m-long detachable handles, and the nylon mesh net bag was 61 cm deep with 1.9-cm-square mesh. Sampling efforts in both years began before spawning activity was observed and continued until spawning activity ceased and fish had left the spawning habitat. At sites where lake sturgeons were observed, fish were captured, measured, tagged, and released. Each fish was measured to the nearest centimeter for total length (TL), fork length (FL), and girth and was weighed to the nearest kilogram with a 100-kg scale (Detecto). Fish gender was determined by physically forcing eggs or milt from the genital opening. Captured lake sturgeons were tagged internally with a 125-kHz passive integrated transponder (PIT) tag injected under the fourth dorsal scute with a 12-gauge hypodermic PIT tag insertion needle. The PIT tag was an internal glass-encased tag, 14 mm long by 2 mm in diameter (Biomark, Inc.). All lake sturgeons were also tagged externally by inserting a t-bar anchor tag (Floy model) at the base of the dorsal fin with a gun-style grip fish tagger. We used the Floy tag as a visual marker to ensure that the same fish were not continually recaptured on a daily basis, thus minimizing handling stress to the fish during the spawning period. Netting continued at a site until all fish were observed to be tagged.

Following Carlander (1969), condition factors were calculated by the formula $K = (10^6 \times W)/L^b$, where W = fish weight, L = fish total length, and b = the slope of the regression of $\log_{10}W$ on $\log_{10}L$. Because we wanted to minimize stress on the spawning fish, we chose to estimate the age of the spawning lake sturgeons by using a von Bertalanffy growth curve instead of collecting pectoral fin rays from captured fish. The von Bertalanffy curve was generated from age–length data previously collected from Black Lake lake sturgeons (Baker and Borgeson 1999). The equation used was $L_x = L_\infty \times (1 - e^{-k(x-x_0)})$, where L_x is the length at age x, L_∞ is the theoretical maximum length that an individual in the population can attain, K is the rate at which a fish approaches L_∞ (the growth constant for the population), and x_0 is the theoretical time at which the length is zero (Carlander 1969; Baker 1980). Length-frequency histograms were constructed to gain an understanding of the size structure of spawning adults in the Upper Black River.

Results

During the spring spawning period, 115 lake sturgeons were captured and tagged in 2001 and 104 in 2002. In 2001, the fish were captured from April 28 to May 26; in 2002, the dates were from May 7 to May 25. Males were more numerous during each annual spawning period, 70 males being captured in both years whereas 45 and 34 females were captured in 2001 and 2002, respectively. The ratio of males to females was 1.55:1 in 2001 and 2.06:1 in 2002.

Captured lake sturgeons ranged from 112 to 187 cm TL in 2001 and from 109 to 185 cm TL in 2002. Males were generally smaller than females and ranged from 109 to 175 cm (mean = 147 cm) TL (Figure 2); their weight ranged from 7 to 38 kg (mean = 21.5 kg). Females ranged from 140 to 187 cm (mean = 165) TL (Figure 2), and their weight ranged from 22 to 59 kg. The modal length for the pooled data was 153 cm in 2001 and 152 cm in 2002. There were no significant differences in mean fish length between years for pooled data (t-test, $F = 2.67$, $P = 0.10$) or by gender (males: $F = 2.28$, $P = 0.13$; females: $F = 0.407$, $P = 0.53$).

Ten males (14% of the males tagged in 2001) were captured in both 2001 and 2002. The recaptured males were in spawning condition in both

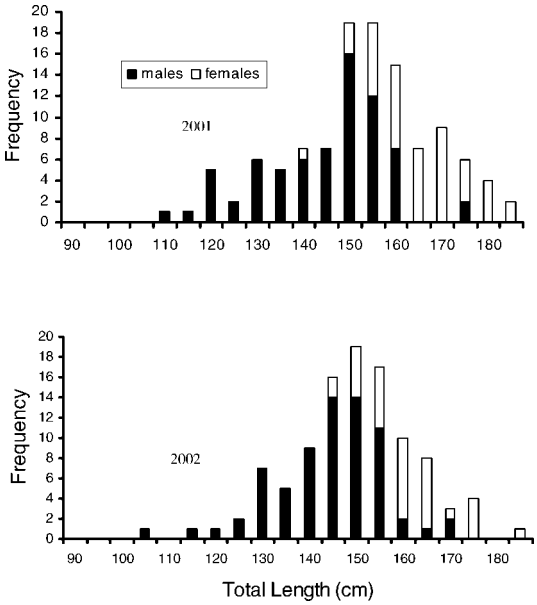

FIGURE 2.—Length-frequency distributions of lake sturgeons captured at the spawning sites in the Upper Black River during 2001 and 2002.

years and were between 120 and 158 cm TL at first capture. Annual gains in length ranged from 0 to 4.5 cm (mean = 1.6 cm) and girth changed from −6.0 to +2.0 cm. (mean = −1.0 cm). Weight change ranged from −3.6 to +5.4 kg (mean = 1.15 kg). There was no clear relationship between fish length at initial capture and subsequent growth in length or weight.

The weight–length relationship for the combined (2001–2002) data was $\log_{10}W = -5.7911 + 3.2983 \log_{10}L$ ($r^2 = 0.8447$, $P < 0.001$), where W is weight (kg), L is TL (cm) and 3.2983 is the slope of the regression (Figure 3). The weight–length relationship for spawning females (2001–2002) was $\log_{10}W = -4.1152 + 2.5592 \log_{10}L$ ($r^2 = 0.6025$; Figure 4). The weight–length relationship for spawning males (2001–02) was $\log_{10}W = -4.6703 + 2.7719 \log_{10}L$ ($r^2 = 0.8187$; Figure 4). Condition factors for females in 2001 and 2002 were 4.03 (SE, 1.36) and 4.17 (SE, 1.17); for males these were 3.5 (SE, 1.18) and 3.78 (SE, 0.61), respectively. There was no statistical difference in condition between years for both males and females (*t*-test, $P = 0.09$). Variation in measured weight for fish 120 to 155 cm long was small; weight at length, however, was more variable for fish larger than 155 cm (Figure 5).

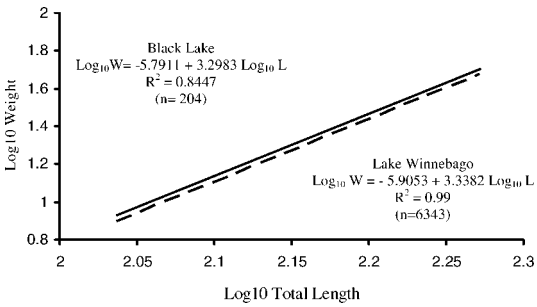

FIGURE 3.—Length−weight regression for spawning lake sturgeons (combined sexes) in the Upper Black River (solid line) compared with the length–weight regression reported for lake sturgeons in Lake Winnebago, Wisconsin (dashed line; Folz and Meyers 1985).

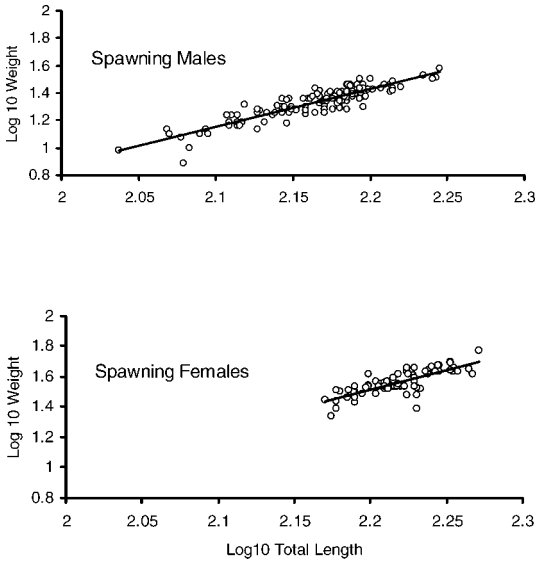

FIGURE 4.—Length–weight regressions for spawning male and female lake sturgeons in the Upper Black River, Michigan, 2001–2002.

The parameters of the von Bertalanffy model

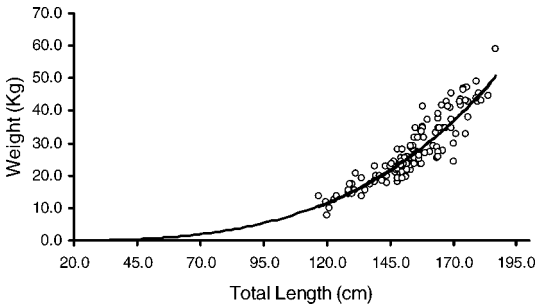

FIGURE 5.—Length–weight relation of lake sturgeons in the Upper Black River during the spring spawning period, 2001–2002. The curved line represents the calculated weights and the dots the data from captured fish.

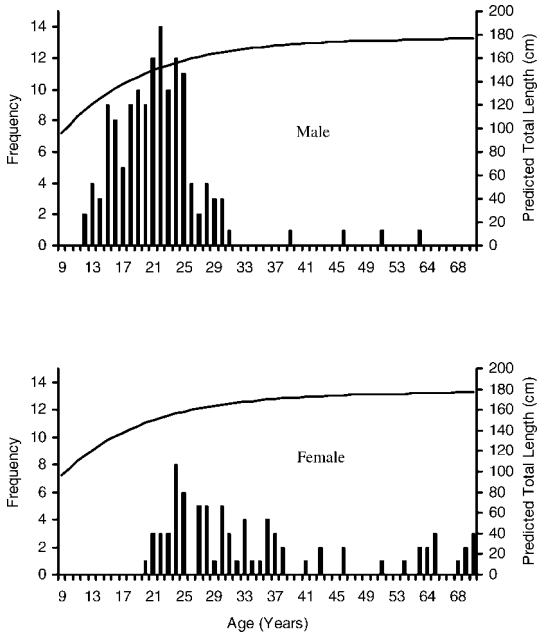

FIGURE 6.—Age-frequency distributions of lake sturgeon spawners from the 2001–2002 spawning stocks (left scale) as predicted by length-at-age relationships from the von Bertalanffy model (regression lines; right scale); length-at-age data were obtained from the Fisheries Division, Michigan Department of Natural Resources,.

for the Black Lake population of lake sturgeons were L_∞ = 176.89 cm, K = 0.091, and t_0 = 0.3546 (Figure 6). The model predicted the presence of males representing 25 different age-classes ranging from age 12 to age 63 and the presence of females representing 29 different age-classes ranging from age 20 to age 70 (Figure 6). Males from ages 15 to 25 represented 78% of the male spawners. Females from ages 20 to 30 represented 54% of the female spawners. The modal age for males was 22 years and for females was 24. Male lake sturgeons older than 33 years were rare in both years.

Discussion

Auer (1996b) noted that sturgeon life histories include long spawning migrations and suggested that ensuring population viability of lake sturgeons might require their unrestricted access to historic habitats. This study indicated that adult lake sturgeons in Black Lake, despite being confined in a restricted habitat, are able to grow, produce gametes, and maintain condition similar to fish from other populations of lake sturgeon studied. Lake sturgeon length-at-age in Black Lake (Baker and Borgeson 1999) was similar to fish from Lake Winnebago, Wisconsin (Bruch 1999). Weight at length for spawning lake sturgeon in the Upper Black River (Figure 3; Table 1) was slightly higher than for fish from most other populations throughout the species' range (Fortin et al. 1996). However, data from other populations were collected during nonspawning periods, when fish are expected to weigh less. The average length at age and weight at age of male and female lake sturgeons spawning in the Upper Black River also exceeded that of lake sturgeons spawning in the Sturgeon River, Michigan, a Lake Superior tributary with a self-sustaining population (N. A. Auer, Michigan Technological University, unpublished data). All of these data suggest that the isolated Black Lake system has sufficient resources to support adult lake sturgeon growth as well as gamete production. The fact that gender was determined for all fish captured indicated that final gamete maturation was able to take place during the relatively short (11 km) migration from Black Lake to the spawning grounds in the Upper Black River.

TABLE 1.—Mean weight of lake sturgeons (≥1,000 mm TL) and mean length of lake sturgeons aged 23 to 27 years from Upper Black River, Michigan, and other selected populations in the species' range (Fortin et al. 1996).

Population	Weight (g)	Total length (mm)
Lake Wisconsin, Wisconsin	5,728	1,491
Upper Black River, Michigan	6,390	1,410
Lake Nipissing, Ontario	5,460	1,383
Lake of the Woods, Minnesota–Ontario	6,119	1,361
Upper Wisconsin Lakes, Wisconsin	5,721	1,351
Menominee River, Wisconsin–Michigan	5,100	1,321
Groundhog and Mattagami rivers, Ontario	6,515	1,213
Nelson River, Ontario	6,302	1,144
Lake Nipigon, Ontario	5,185	1,076
Moose River, Ontario	5,614	1,065
Saskatchewan River, Saskatchewan	5,366	1,015
Kenogami River, Ontario	5,391	848

The tagging data from this study indicated that annual lake sturgeon spawning runs in the Upper Black River were similar in magnitude to spawning runs in the Sturgeon River, Michigan. Auer (1996a) reported catches from 58 to 135 individual lake sturgeons in the years 1987–1992. Both the Sturgeon River and Upper Black River are small, shallow, wadeable rivers, and the number of fish captured and tagged in both rivers represents a large proportion of the spawning run (N. A. Auer, Michigan Technological University, personal communication). The Sturgeon River population is self-sustaining although data on long-term population abundance are lacking.

Previous reports of spawning male to female sex ratios for self-sustaining lake sturgeon populations varied from 1:1.06 (Roussow 1957), 1.25:1, and 2.7:1 (Auer 1999) to greater differences of 5.7:1 (Folz and Meyers 1985; Bruch and Binkowski 2002), 8.5:1, and 9.6:1 (Lyons and Kempinger 1992). Males are expected to outnumber females in lake sturgeon spawning runs given the species' life history (males mature earlier and spawn more frequently). The sex ratios (1.55:1 and 2.06:1) found at the spawning sites on the Upper Black River were within the range reported for other self-sustaining populations in the Sturgeon River, Michigan, and the Ottawa River, Canada, and therefore should be adequate to ensure successful spawning. Higher exploitation of females in Lake Winnebago has been hypothesized as one of the factors leading to the more skewed sex ratios observed in the Wolf River spawning run (Folz and Meyers 1985; Lyons and Kempinger 1992; Bruch 1999). Gender data for lake sturgeons harvested from Black Lake were not collected from 1948 to 1999. However, recent data (2000–2003; Michigan Department of Natural Resources, unpublished data) indicate that harvest of males (12) has exceeded that of females (9).

The population size of lake sturgeons has declined throughout most of the species' native range. Understanding the population-specific spawning periodicity can provide information as to the true population size. Previous research (Harkness and Dymond 1961) suggested that male lake sturgeon spawn every other year and females spawn every 4 to 7 years. Recent work (Lyons and Kempinger 1992; Bruch et al. 2001) indicated that males spawn annually or biannually and females spawn every 3 to 4 years. The intervals between spawning in the Sturgeon River, a Lake Superior tributary, were observed to be 2 to 4 years for males and 3 to 7 years for females (Auer 1999). Tagging data from the 2001 and 2002 spawning periods indicated that some (14%) male lake sturgeon in Black Lake spawn every year, whereas others spawn less frequently or at irregular intervals. Furthermore, males that spawned in 2001 and 2002 not only produced gametes in consecutive years but also grew an average of 1.6 cm TL and gained an average of 1.15 kg between spawning events. Four of the males that spawned in both years weighed less and had smaller girth measurements in 2002 than in 2001. However, this is because the fish captured in 2001 were taken in the early stages of spawning, when they still retained most of their gametes, but those in 2002 were captured after spawning most of their gametes. Consecutive year spawning by these 10 males further supports the conclusion that ample food resources exist in Black Lake and that the restricted spatial habitat is not adversely affecting adult lake sturgeon. Spawning periodicity for females in Black Lake is still undetermined and more years of sampling are necessary to document returning females during the spawning run.

Male lake sturgeons in Black Lake are recruiting to the spawning stock at 110 cm TL and females at approximately 140 cm TL. These data are similar to data for the Sturgeon River, Michigan (Auer 1996a). Kempinger (1988) found that a 25-year-old female in its first year of maturity was 140 cm TL and weighed 22.5 kg. Bruch and Binkowski (2002) also found females recruiting to the spawning stock at 140 cm in Lake Winnebago, Wisconsin.

Successful management of lake sturgeons will require an understanding of the effects that habitat changes (including reductions) are having on the ecology of populations. The results of this study suggest that individual adult lake sturgeons can survive, grow, and produce viable gametes in restricted spatial habitats. Furthermore, lake sturgeon larvae have been captured in the Upper Black River (Smith 2003), a clear indication that spawning is successful. Therefore, if reduced habitat availability is a factor in lake sturgeon population declines, the effect may be greater on the larvae or juveniles, and future research efforts should be directed at understanding the ecology of those life stages. Finally, the baseline data this study provides on characteristics of spawning lake sturgeons will enhance lake sturgeon management efforts in Black Lake.

Acknowledgments

We thank the Michigan Department of Natural Resources and Sturgeon for Tomorrow, Black Lake

Chapter, for funding this study. We also thank the numerous volunteers that contributed to this project, particularly Brenda and Gil Archambo and Doug and Ellie Wilson. We also thank the technicians who worked on this project, Matt Kerr, Melissa Ryneski, and Tom Tryban.

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