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ARTICLE

Comparing Size, Movement, and Habitat Selection of Wild and Streamside-Reared Lake Sturgeon

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Abstract
A streamside rearing facility (SRF) on the Big Manistee River, Michigan, was constructed for the purpose of rearing larval and age-0 lake sturgeon *Acipenser fulvescens*. Size, movement, and habitat selection were studied from 2007 to 2008 to determine whether there were differences between age-0 lake sturgeon reared in the streamside facility and natural cohorts. Lake sturgeon reared streamside showed no significant difference in length from their wild counterparts. Movement patterns were studied by attaching external radio transmitters to 17 age-0 streamside (198–250 mm total length) and 17 age-0 wild lake sturgeon (206–262 mm). The average weekly distances traveled by SRF fish ranged from 0.05–2.28 km (of 46 km surveyed) while wild fish traveled 0.04–2.81 km. In the river sections sampled, sand, pebble, and gravel comprised over 92.5% of the encountered substrates and Strauss index values indicated no differences in the presence of wild and SRF sturgeon over these substrates. Age-0 lake sturgeon were most often found in water 1.7 m deep with a velocity of 0.5 m/s, and no statistically significant differences were observed between wild and SRF sturgeon for either depth or velocity during the study years. By September, streamside-reared age-0 lake sturgeon attained a size similar to that of their wild cohorts and exhibited similar movement patterns and substrate association.

Strategies for rehabilitating remnant populations of fishes, including lake sturgeon *Acipenser fulvescens* in the Great Lakes, are continuously adapting in response to scientific data and cultural and social perspectives (CRITFC 1995; Kearney and Fetterolf 2006; LRBOI 2008). Traditionally, the collection of gametes for hatchery use has involved the forceful removal of eggs (Aloisi et al. 2006) or chemically inducing spawning to retrieve eggs quickly (Van Eenennaam et al. 2008). While traditional hatchery stocking has been used widely for most species, these gamete collection methods may be invasive to fish or unfeasible when collection of adult fish is difficult. A current research and management focus in the Great Lakes basin for lake sturgeon is rearing larvae streamside in natal river water (Holtgren et al. 2007; Crossman 2008; LRBOI 2008; Welsh et al. 2010). In 2004, the Little River Band of Ottawa Indians (LRBOI) designed and operated a streamside rearing facility (SRF) on the Big Manistee River, Michigan, capable of rearing approximately 1,000 age-0 lake sturgeon from eggs or larvae collected from their river of

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origin (Holtgren et al. 2007). The SRF was designed to rear only a maximum of 1,000 fish owing to the small population size of Big Manistee River sturgeon, low annual production of eggs and larvae, and management recommendations that less than 10% of wild-produced eggs and larvae to be collected. The annual estimate of spawning lake sturgeon within the Big Manistee River is 21–66 fish, which includes 1–12 females (Peterson et al. 2002; Lallaman 2003; Damstra 2007; Lallaman et al. 2007; Chiotti et al. 2008). Additionally, natural reproduction is believed to be low as observed by the capture of few age-0 and larval sturgeon between 2002 and 2008.

The SRF addressed management concerns of the LRBOI that encompassed cultural and biological criteria. Cultural knowledge maintained that removal of lake sturgeon from their river of origin to an off-site, remote hatchery was unacceptable (LRBOI 2008). The preservation of native species has been important to many tribes and First Nations in North America (CRITFC 1995; LRBOI 2008). For Anishinabek tribes such as the LRBOI, the lake sturgeon, also known as nmé, is a clan animal and maintains an important role in their cultural and spiritual identity. It is known that sturgeon return to their natal waters when they are sexually mature and ready to spawn (Lyons and Kempinger 1992) and site fidelity is high (Homola et al. 2010; N. A. Auer and E. A. Baker, unpublished). Furthermore, strategies promoting the return of fish to their natal waters to spawn adhere to tribal traditional values (LRBOI 2008). The primary biological concerns included genetic conservation and imprinting (Holtgren et al. 2007). Streamside rearing of naturally produced eggs and larvae can maintain annual wild age-0 genotypes (LRBOI, unpublished data) and contribute higher levels of genetic diversity when compared with traditional hatchery practices (Crossman et al. 2010). Streamside rearing may increase age-0 survival, growth, and imprinting to natal waters by providing water chemistry and temperature conditions similar to those in the river, which may potentially affect wild sturgeon life stages (Boiko and Grigor'yan 2002; Holtgren et al. 2007; Crossman 2008; Welsh et al. 2010). Recovery programs aimed at increasing survival of age-0 sturgeon might have a greater effect on population growth than those aimed at juveniles and adults (Gross et al. 2002). Further, Justice et al. (2009) suggested that in some situations releasing fewer fish of a larger size may increase survival rates and, thus, recruitment.

A gap remains in the knowledge of postdrift and early life stages of lake sturgeon with regard to size, movement, and habitat use. Increased recruitment into the adult lake sturgeon population can be improved by protecting and better understanding the early life stages (Gross et al. 2002). Comparisons between hatchery-reared and wild fish have been studied in other species and have indicated disparity between groups regarding survival, site fidelity, and genetic contributions (Smith et al. 2002; Beamish et al. 2008; Pearsons et al. 2009; Tatara et al. 2009). A lack of data exists when comparing hatchery-reared lake sturgeon to wild sturgeon with regard to size, movement, and habitat selection.

Lake sturgeon growth within hatcheries has been recorded previously (Anderson 1984; Fajfer et al. 1999; Volkman et al. 2004; Aloisi et al. 2006) but rarely compared with growth in wild populations (Holtgren et al. 2007). One concern with streamside rearing was that fish released from the facility would show differences in size compared with those in the wild. Kempinger (1996) found that wild age-0 lake sturgeon captured in the Wolf River, Wisconsin, (212 mm mean length at 125 d old) were dramatically larger in length than those raised at the conventional Wild Rose Fish Hatchery (123 mm mean length at 123 d old). Water temperatures between the Wolf River and Wild Rose Hatchery can differ by between 5°C and 10°C (S. Fajfer, Wisconsin Department of Natural Resources, personal communication). The use of streamside rearing, compared with a traditional hatchery setting, allows fish to be reared in conditions more similar to what they would experience in the wild.

There has also been concern that lake sturgeon from hatcheries may not exhibit the same movement patterns as their wild counterparts (Zollweg et al. 2003). Jordan et al. (2006) studied poststocking movement of juvenile (520–613 mm) pallid sturgeon *Scaphirhynchus albus* hatchery-reared for 3 years and noted that in short-term tracking studies (90–400 d), hatchery-reared fish may not have had time to acclimate to a natural environment. Only after 2–3 years did the distribution of hatchery-reared juvenile pallid sturgeon throughout the Missouri River become similar to that of both hatchery-reared and wild pallid sturgeon from other studies (Jordan et al. 2006).

Habitat preference of wild juvenile lake sturgeon has been described by Auer (1996) as possibly the largest gap in life history knowledge. Habitat for juveniles (>29 mm TL) has been identified as areas of pea-sized gravel, coarse sand, and clay (Kempinger 1996; Chiasson et al. 1997; Holtgren and Auer 2004; Benson et al. 2005). Availability of appropriate habitat once sturgeon are released from the streamside facility is a major concern for restoration.

The goal of the LRBOI streamside rearing program is to protect age-0 lake sturgeon long enough so they may reach a size where survival in the wild is increased before returning to their natal system. Also the rearing environment will mimic river conditions for water chemistry to ensure the fish will imprint to their natal waters and return as adults (Boiko and Grigor'yan 2002). The objectives of this study were to make comparisons between streamside-reared and wild lake sturgeon regarding (1) size attained by age-0 fish and (2) movement and habitat selection in natal rivers.

METHODS

Study site.—The main stem of the Big Manistee River (373 km), located in the northwestern lower peninsula of Michigan, flows through parts of 11 Michigan counties and the Little River Band of Ottawa Indians Reservation before emptying into Lake Michigan. This study encompassed the 46-river-kilometer (rkm) section between Tippy Dam and the river mouth, which drains into Manistee Lake (Figure 1).

Sturgeon collection.—Lake sturgeon reared in the SRF were collected as larvae from the Big Manistee River with D-framed drift nets following the methods of Auer and Baker (2002). Larval drift nets were deployed at rkm 44 in 2007 and 2008. In 2008, in addition to larvae, lake sturgeon eggs were collected for rearing. Collection occurred by placing egg mats at rkms 37.2 and 42.6 in areas of known sturgeon spawning (Chiotti et al. 2008). Egg mats were made from cinder blocks wrapped in a furnace filter with marker buoys attached (Chiotti et al. 2008) and were checked every 3 to 7 d. Filters with eggs attached were removed from cinder blocks and taken to the SRF where eggs were removed and placed in hatching jars (Mini Egg Hatching Jar, Aquatic Eco-systems).

Length measurements.—Lake sturgeon in the SRF were reared in two types of paired fiberglass raceways, depending on size (a small tank 100 cm long × 52 cm wide × 25 cm deep, or larger model LS-700 tank 2.13 × 0.61 × 0.58 m, Frigid Units) (Holtgren et al. 2007) and were separated by collection date. During the study, fish were fed a diet of brine shrimp *Artemia franciscana* and chironomid larvae using 24-h automatic feeders. Lake sturgeon from raceways were measured weekly for total length (TL) to the nearest millimeter. Small aquarium dip nets (15 cm wide, 1.5 mm mesh) were used to sample fish from each raceway. In 2007, measurements were taken from 19 June to 18 September, slightly less than 4 weeks after the first larvae were collected. With the exception of the first week, all fish were measured every week owing to the small sample size; *n* ranged from 29 to 39 fish. In 2008, both eggs and larvae were collected from two different spawning locations, captured within 6 d of one another, and were grouped together during measurements. Similar to the previous year, measurements were taken weekly and performed between 1 July and 16 September 2008. Measurements began 6 weeks after the first fish was collected owing to lower than average water temperatures and slow fish growth.

Wild lake sturgeon, used to compare length to that of SRF sturgeon, were collected during nighttime visual surveys conducted from a boat on the Big Manistee River between July and October 2007 and from August to September 2008. Surveys began at dusk and were completed within 3 h. Halogen Q-beam lights (Nite Tracker, 1.5–2 million candlepower [1 candlepower = 0.981 cd]) were used to scan the river to locate sturgeon visually (Chiotti 2004). Once a fish was located, attempts were

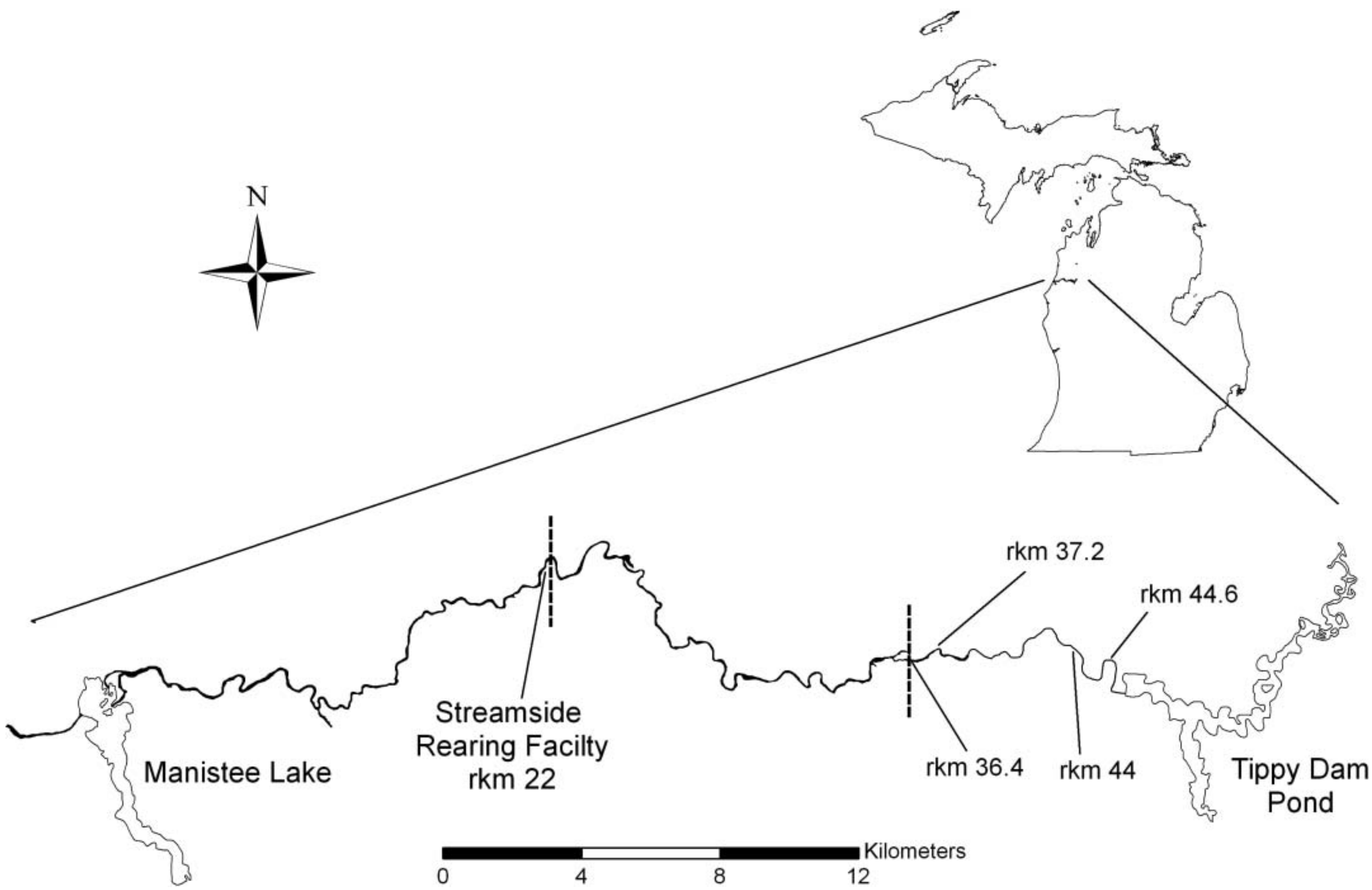

FIGURE 1. Locations on the Big Manistee River at which eggs and larval lake sturgeon were collected in 2007 and 2008. Dashed lines indicate where streamside-reared and wild fish were released during radiotelemetry surveys.

made to capture it with dip nets. Each age-0 fish captured was measured for TL and received a passive integrated transponder (PIT) tag for future identification. A total of five nighttime visual surveys were conducted during the final week of SRF rearing in 2007, while in 2008 three surveys were conducted. Only wild fish captured within 5 d of when fish were released from the SRF were used to compare lengths between groups; collection methods prevented capture of small fish earlier in the year. In 2007 and 2008, 24 and 22 wild sturgeon, respectively, were captured and subsequently measured within the final 5 d of SRF rearing respectively. All SRF and wild fish were pooled each year within their respective group (SRF or wild), and compared within year but not between years.

Water temperatures, collected daily (Hobo, Water Temp Pro v2) from both the SRF and the Big Manistee River were compared to determine whether lake sturgeon in the SRF were being reared in similar temperatures as those occurring in the wild. In 2007, water temperatures were recorded only from 4 June to 2 July owing to failure of the logger. In 2008, temperature loggers recorded data for 135 d from 5 May to 20 September.

Movement.—Radio-telemetry surveys were conducted in 2007 and 2008 to determine locations and assess movement of both SRF-reared and wild lake sturgeon. In 2007, nine SRF and nine wild fish received external transmitters (Advanced Telemetry Systems [ATS], model F1926) on 21 September. In 2008, eight SRF and eight wild fish received transmitters between 19 and 23 September. Previous work suggests transmitter weight should not exceed 1.25–4% of a fish's body weight (Sutton and Benson 2003; Zale et al. 2005) to avoid affects on movement and performance. Over the course of the study, transmitter weight, including attachment hardware, did not exceed 3.4% of a fish's body weight. The transmitters used in this study were 0.95 g in weight and had a battery life of approximately 30 d. Wild lake sturgeon to be used for transmitter attachment were taken to the SRF and, after transmitters were attached, held for 1 to 2 d. All sturgeon, SRF and wild, were then released on the same day, 2 d before tracking began. On 21 September 2007, wild fish with transmitters were released at their capture location, between rkms 22 and 36, while streamside fish were released between rkm 22 and 36.4. Water temperatures on the day of release ranged between 17.4°C and 18.0°C. On 20 September 2008 six wild fish were released at rkm 36.4 while two, which were captured and released 3 d later, were released at rkm 24. Streamside-reared sturgeon were released similar to the previous year between rkms 22 and 36.4. Water temperatures on 20 September ranged between 16.3°C and 17.0°C while on 23 September temperatures ranged between 16.6°C and 17.2°C. Water temperatures on the day of fish release were taken from data recorded at the U.S. Geological Survey (USGS) water gauging station located at rkm 46 in the Big Manistee River. Tracking was conducted during daylight hours within the 46 rkm section of river every other day beginning on 24 September and continuing until 20 October in 2007, and 22 September until 29 October in 2008 when tracking was conducted 3 d/week. Average weekly movement comparisons between groups were based on a 7-d week. Tracking was performed with an ATS receiver (model R2000) combined with a three-arm Yagi antenna. A fish location was determined when the maximum signal strength for a frequency was achieved, and the river bottom was scanned for a visual confirmation. Not all fish were visually located; however, fish were located multiple times to ensure that signals were not from dropped tags. Two stationary ATS receivers (model R4500S) were deployed; one at the mouth of the Big Manistee River where it empties into Manistee Lake and the other at the mouth of the river channel that empties into Lake Michigan. Both receivers were programmed with the frequencies of all transmitters within the river. When a fish came within range of the receiver, frequency number, date, time, and signal strength were logged. A fish was determined to have passed by the receiver when signal strength increased, peaked, and began to decline. At the peak of signal strength, the date was recorded and distance traveled was calculated from the previous contact. Stationary receivers were used as an additional measure to determine travel distance in case sturgeon that were close to the mouth of the river were not located during a survey with the portable receiver. Before the radio-telemetry study, the stationary receivers were tested with an extra transmitter pulled behind a boat. The tests were conducted in the confined channel at both the maximum channel depth (1.5 m) and distance (50 m). The number of positive signals (hits) and the strength of the signal were used as a baseline to compare with data collected during the surveys. When a receiver recorded a frequency corresponding to a tag, those data were compared with the test results and then classified as a positive or negative hit. Both receivers did record hits that were classified as negative, potentially due to heavy boat traffic throughout the area. Records that were classified as negative tended to be far less complex and lengthy than those classified as positive. Owing to the small transmitter size, battery life was limited (estimated at approximately 30 d) and, on occasion, batteries failed during the course of the study. When a fish was no longer able to be located, the batteries were assumed to have failed or the fish was removed by outside forces (predation, fishing), and the fish was removed from further analysis. Stationary receivers were checked weekly to determine whether a frequency missed during a survey had passed by. Total distance traveled and average weekly distances were calculated from global positioning system (GPS) points with geographic information system (GIS) software (ArcMap 9.1).

Habitat association.—Water depth, velocity, and substrate were characterized at each telemetry contact location for both SRF and wild lake sturgeon. In 2007, at each lake sturgeon location a 3 × 3-m grid was established and nine underwater substrate photos were taken in a 12 × 12-m square. In 2008, five photos were taken in a 12 × 12-m "X" pattern with the fish located at the center. Mann–Whitney U-tests showed no statistical difference between values when measuring five versus nine photos so the methods were changed between 2007 and

2008 to reduce photography and analysis time. Substrate photos were taken with an underwater video camera (SplashCam, model Deep Blue Pro Color) mounted on a pole (Chiotti et al. 2008). Water velocity was collected with a Marsh–McBirney (model 2000) flowmeter attached to a long pole; measurements were taken 0.25 m off the bottom. Water depth was calculated from the river bottom to the water's surface and determined by marking and measuring the depth on the pole.

Particle size composition was classified based on the Wentworth Classification System modified by Cummins (Wentworth 1922; Cummins 1962) and calculated for each substrate photo with SigmaScan software (Chiotti et al. 2008). To establish substrate composition for the Big Manistee River, cross-sectional river profiles were collected every 500 m on transects from the mouth of the river upstream to Tippy Dam in 2007. Five substrate photos were collected along each of 94 transects. The two transect sections between which a lake sturgeon was found during telemetry contacts were pooled together to estimate the substrate availability for that particular fish location. Each fish location was then compared with the section in which it was found to determine selectivity. The Strauss index of selectivity (L), calculated as follows, was used to calculate whether lake sturgeon showed a preference for any particular substrate type (Strauss 1979; Benson et al. 2005):

$$L = r_i - p_i,$$

where the proportion of habitat (i) that is being used by fish is represented by r_i with p_i representing the proportion of habitat that is available in each river section in which a fish was found. Strauss selectivity values range between −1, which indicates strong avoidance, and +1, which indicates strong selection. Values close to 0 are within a neutral range and indicate an individual has no strong avoidance or selection for a particular substrate type in proportion to its availability (Matthews 1996). For the purpose of this study, a median Strauss index value equal to or greater than 0.25 indicated moderate selection and equal to or greater than 0.5 indicated strong selection for a substrate type. Only Strauss values for sand, gravel, and pebble were calculated owing to the high prevalence of these substrates in the river (92.5%) compared with remaining substrate types. The remaining four substrate types—cobble, boulder, macrophytes, and debris—accounted for less than 8% of the total substrate sampled combined.

Data analysis.—Student's t-tests, with an α of 0.05, were used in all analyses throughout this study to compare SRF and wild lake sturgeon for length, movement (km/week), and habitat type, as well as to compare water temperatures within the river to those within the SRF. When data were found to have a nonnormal distribution or unequal variances, Mann–Whitney U-tests with an α of 0.05 were used.

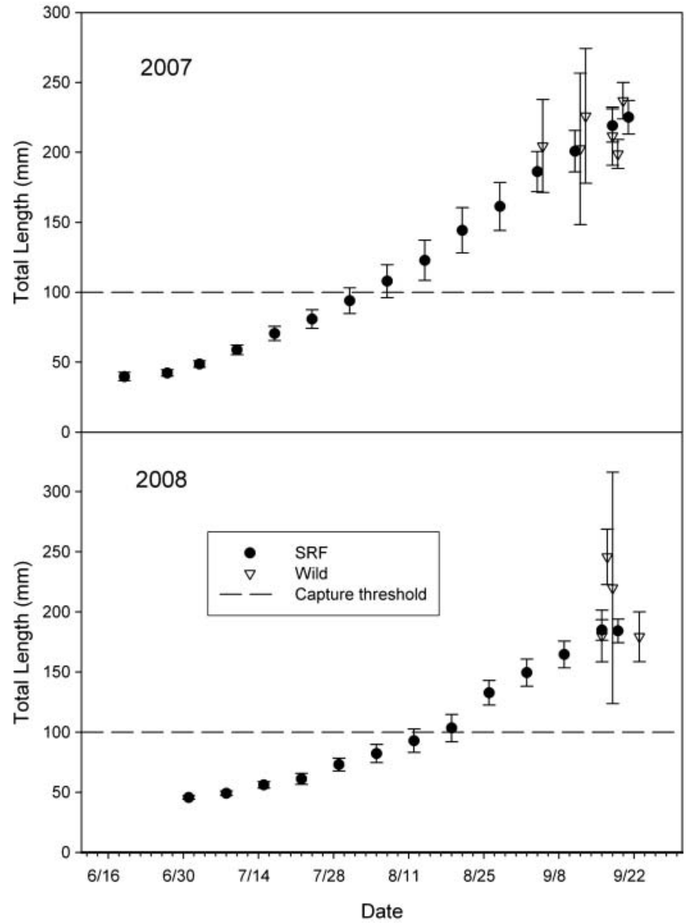

FIGURE 2. Weekly average lengths for streamside-reared (SRF) and wild lake sturgeon in 2007 and 2008.

RESULTS

Length Measurements

In 2007, 107 lake sturgeon larvae were captured for rearing within the streamside facility but no eggs were collected that year. In 2008, 76 lake sturgeon larvae along with approximately 300 eggs were collected and reared within the SRF. Age-0 lake sturgeon less than 100 mm TL are poorly detected and avoid capture during nighttime visual survey capture methods and only become subject to sampling gear at sizes greater than 100 mm TL (Figure 2). Wild sturgeon ($n = 24$) in 2007 were slightly longer than SRF sturgeon ($n = 28$) early in the sampling period (July–August), but at the time of release (21 September) no significant difference was detected ($t = 1.065$, df $= 50$, $P = 0.292$); wild fish averaged 220 mm TL and SRF fish averaged 228 mm TL (Figure 2). Wild fish ($n = 22$) in 2008 were slightly longer than SRF fish ($n = 47$) early in the sampling period (July–August), but by the time of release (20 September) no significant difference was detected ($U = 827.5$, $n_1 = 22$, $n_2 = 47$, $P = 0.16$; Figure 2); wild fish averaged 196 mm TL and SRF fish averaged 183 mm TL.

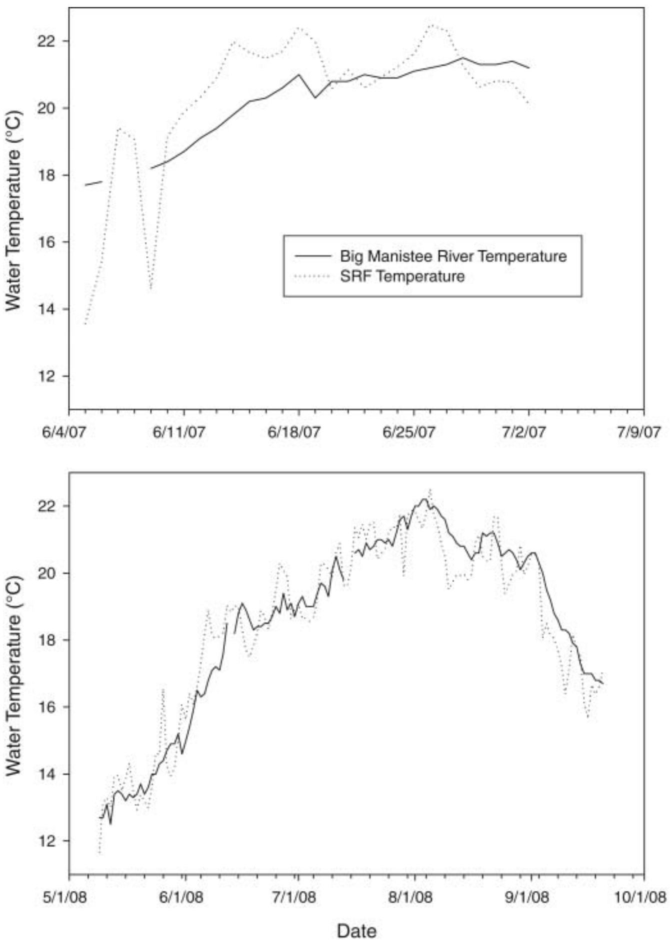

FIGURE 3. Water temperatures in the Big Manistee River and at the streamside-rearing facility (SRF) in 2007 (upper panel) and 2008 (lower panel).

TABLE 1. Average weekly movements of age-0 streamside-reared (SRF) lake sturgeon and wild lake sturgeon in the Big Manistee River in 2007 and 2008. Within years, different letters indicate statistically significant differences between the two types of fish (Student's t-tests; Mann–Whitney U-tests; $P \leq 0.05$).

Week	Number		Average weekly distance traveled (km)		P-value
	SRF	Wild	SRF	Wild	
	N	N			
		2007			
22–29 Sep	9	9	1.25	2.36	0.37 z
29 Sep–6 Oct	8	9	0.57	0.24	0.19 z
6–13 Oct	6	6	0.44	0.04	0.04 y
13 Oct-20 Oct	5	3	0.05	0.54	0.57 z
		2008			
20–27 Sep	8	8	2.28	2.81	0.66 z
27 Sep–4 Oct	8	7	0.74	0.10	0.28 z
4–11 Oct	5	6	1.67	0.35	0.02 y

Water temperature data collected from both the SRF and Big Manistee River during the rearing seasons showed no significant differences. Mann–Whitney U-test results showed no difference between the water temperatures within the river and in the streamside facility in either 2007 ($U = 707.5$, $n_1 = 29$, $n_2 = 29$, $P = 0.313$) or 2008 ($U = 18010$, $n_1 = 132$, $n_2 = 135$, $P = 0.610$) (Figure 3).

Movement

During this 2-year study 34 lake sturgeon were tagged with transmitters but only 23 of those produced signals during the entire study. It is possible some lake sturgeon were lost to predators or sport fishers, or were undetected as they moved out of the river system, or the transmitters malfunctioned. In 2007, lake sturgeon that were reared streamside and received external transmitters averaged 240 mm TL (range, 219–250 mm) and 55.9 g (28.1–66.9 g) at release, while wild sturgeon that received transmitters averaged 239 mm TL (206–262 mm) and 52.3 g (34.3–71.2 g). At the completion of the 4-week telemetry period 8 of the original 18 transmitters were operational; five of the eight remained attacheded to SRF sturgeon and three to wild sturgeon. The total number of telemetry contacts for each SRF and wild fish ranged from 5 to 12 and from 7 to 13, respectively. In 2007, SRF fish averaged 9.7 contacts per fish while wild fish averaged 10.3 contacts per fish. The total distance traveled for SRF fish ranged from 0.68 to 18.44 km while for wild fish ranged between 0.54 and 31.32 km. The total average linear distance traveled from the release sites for SRF fish was 8.68 ± 7.34 km (mean ± SD) while wild fish averaged 9.96 ± 12.83 km. In 2007, average weekly movements of SRF fish were not significantly different from those for wild fish over the 4-week study except during the third week when SRF fish moved farther than wild fish for that week ($U = 52$, $n_1 = 6$, $n_2 = 6$, $P = 0.041$; Table 1). Regarding the total distance traveled for wild and SRF fish in 2007, Mann–Whitney U-tests showed that neither SRF nor wild lake sturgeon traveled significantly farther than the other ($U = 92$, $n_1 = 9$, $n_2 = 9$, $P = 0.596$).

In 2008, streamside-reared lake sturgeon that received transmitters averaged 215 mm TL (range, 198–232 mm) and 42.8 g (35.8–51.5 g) at release while wild sturgeon averaged 235 mm TL (212–261 mm) and 49.9 g (36.5–62.2 g). In 2008, 11 of the original 16 transmitters were operational, and after 3 weeks five remained attached to SRF sturgeon and six to wild sturgeon. The total number of telemetry contacts for each SRF and wild fish ranged from 6 to 14 and from 4 to 14, respectively. The total average linear distance traveled from the release sites for all SRF fish was 18.28 ± 14.21 km, while the total distance traveled ranged between 0.75 and 39.57 km. The total average linear distance traveled from the release sites for all wild fish was 14.91 ± 13.53 km and the total distance traveled ranged between 0.20 and 33.88 km. In 2008, average weekly movements of SRF fish were not significantly different than those for wild fish over the 3-week study except during the third week when

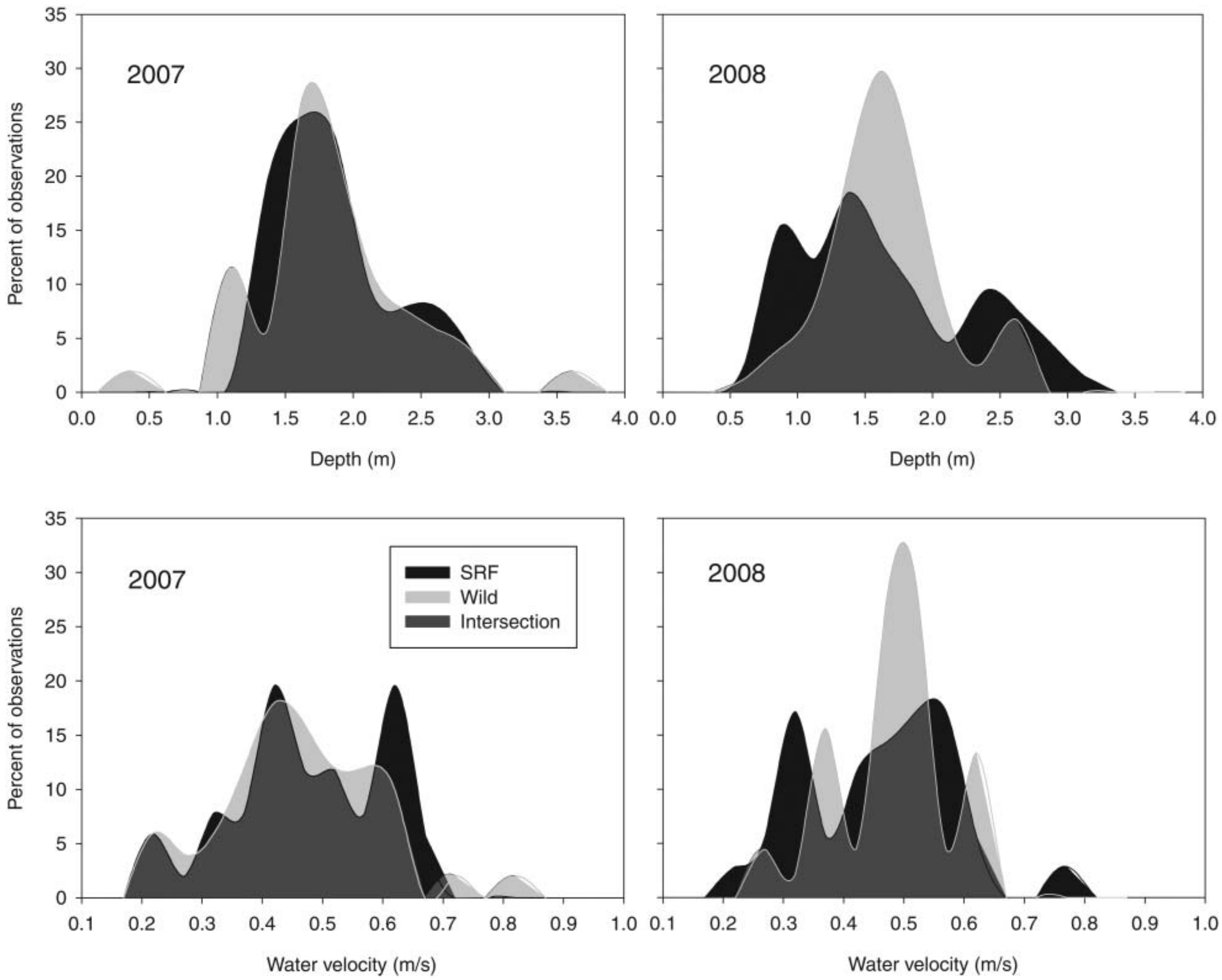

FIGURE 4. Distributions of telemetry contacts with streamside-reared (SRF) and wild lake sturgeon on the Big Manistee River in 2007 and 2008, by water depth and velocity. Depth measurements are grouped into 0.5-m increments and velocity measurements into 0.1-m/s increments.

SRF sturgeon were documented traveling farther than wild fish ($t = 3$, df $= 9$, $P = 0.015$; Table 1). In 2008, *t*-tests showed similar results to those of 2007 in that neither SRF nor wild lake sturgeon traveled significantly farther than the other when considering their overall distance traveled ($t = 0.486$, df $= 14$, $P = 0.635$).

In 2007, at the end of the 4-week tracking period, five of the nine SRF transmitters were still operational, while only three of the nine wild transmitters were. One SRF lake sturgeon was confirmed to have passed by the stationary receiver near the river mouth, but no wild sturgeon passed the receiver. In 2008, after the 3-week tracking period, five of the eight SRF transmitters and six of the eight wild transmitters were still operational. Two SRF fish and two wild fish were documented passing a stationary receiver in 2008.

Habitat Associations

In 2007, streamside-reared lake sturgeon were found in water depths averaging 1.83 m (range, 1.10–2.79 m) and wild fish were found in depths averaging 1.83 m (0.32–3.70 m) showing no difference ($U = 1416$, $n_1 = 35$, $n_2 = 44$, $P = 0.878$). In the same year, SRF fish were found in waters where the velocity averaged 0.47 m/s (range, 0.21–0.68 m/s); the velocity of water where wild fish were found averaged 0.47 m/s (0.22–0.80 m/s) showing there was no difference between the two groups ($t = -0.119$, df $= 76$, $P = 0.905$). In 2008, SRF lake sturgeon were found in water depths averaging 1.63 m (range, 0.60–3.00 m) and wild fish were found in water depths averaging 1.66 m (0.70–2.69 m). Similar to the previous year, groups showed no difference in the water depths in which they were found ($U = 4343$, $n_1 = 65$, $n_2 = 74$, $P = 0.383$). Fish reared streamside were located in waters having an average velocity of 0.45 m/s (range, 0.24–0.75 m/s) and wild fish were found in waters having an average velocity of 0.48 m/s (0.26–0.64 m/s); there was no significant difference between the two groups ($U = 1305$, $n_1 = 35$, $n_2 = 45$, $P = 0.277$). All recorded depths in both 2007 and 2008 for both groups ranged between 0.32 and 3.7 m, while water velocities ranged between 0.21 and 0.80 m/s (Figure 4).

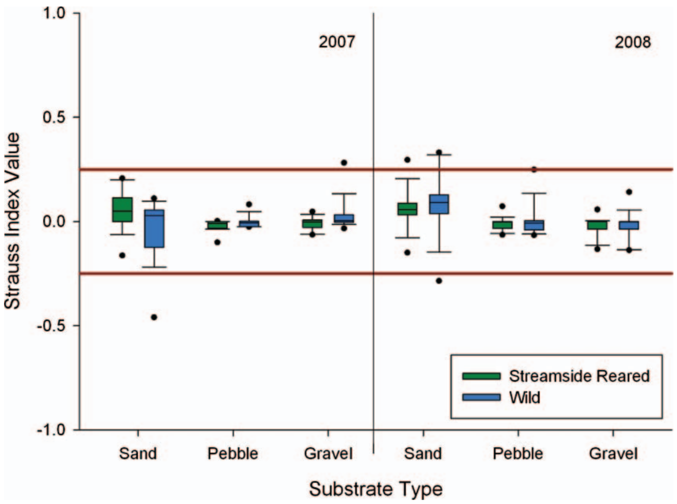

FIGURE 5. Strauss index values for streamside-reared and wild lake sturgeon in the Big Manistee River in 2007 and 2008. The error bars represent the 5th to 95th percentiles. The horizontal bars represent +0.25 and −0.25 selection thresholds based on Matthews (1996).

Overall substrate availabilities in the 46 km of Big Manistee River for sand, gravel, and pebble substrates were 82.8, 4.8, and 4.9%, respectively, and other substrate types accounted for 7.5%. Age-0 fish telemetry in 2007 showed that SRF-released lake sturgeon had the highest median Strauss selectivity index value for sand ($L = 0.05$) while wild fish had the highest value for gravel ($L = 0.03$) (Figure 5). In 2008, median Strauss index values for both SRF and wild sturgeon were highest for sand ($L = 0.06$ and $L = 0.09$, respectively) over both other substrate types (Figure 5). During 2007 and 2008, no median Strauss index values or 25th or 75th percentiles exceeded the threshold of 0.25 for selection for either the SRF or wild groups (Figure 5). Sturgeon were observed over sand, gravel, and pebble substrates in proportion to their availability; therefore, SRF and wild groups did not display differences of habitat selection as reflected in the Strauss selectivity index.

DISCUSSION

Determining the success of any artificial rearing technology for a long-lived, late-maturing species that is known to imprint, such as lake sturgeon, is a challenge. Streamside facilities were first developed for salmonids (Salmonidae) and walleye *Sander vitreus* and are now being used for lake sturgeon recovery in the Great Lakes because they reduce the "artificial" nature of the rearing environment. While an obvious measure of success of such facilities will be recruitment to the spawning stock and preservation of wild genotypes, this will not be seen for at least 20 years in most sturgeon populations. To that end we wanted to detect whether lake sturgeon reared in a SRF showed any significant differences in size, movement, or habitat preference from their wild counterparts immediately after release.

Length Measurements

In this study, total lengths of wild lake sturgeon and those from the SRF were similar. Because little difference was observed in water temperature no large differences in TL between wild and SRF fish were expected. Water temperatures in the Big Manistee River closely matched those in the SRF during the 2 years of rearing, which indicated that temperature did not influence metabolic processes. Kempinger (1996) found that wild age-0 lake sturgeon captured in the Wolf River, Wisconsin, (212 mm mean length at 125 d old) were dramatically longer than those raised at the conventional Wild Rose Fish Hatchery (123 mm mean length at 123 d old); however, water temperatures were cooler and fish were reared at much higher densities at the hatchery than those within the Wolf River (Steve Fajfer, Wisconsin Department of Natural Resources). Ćzeskleba et al. (1985) also found that lake sturgeon reared within the Wild Rose Hatchery at a constant 17°C in 1983 were much smaller, approximately 100 mm TL less at 120 d posthatch, than wild age-0 fish captured from the Wolf River. Rearing densities were not recorded, but this study was one of the first to attempt to rear lake sturgeon on live food and their low growth compared with wild fish may be due to difficulties in determining quality live foods (Ćzeskleba et al. 1985). Fish within the Wolf River were subject to more natural fluctuating water temperatures than were those in the hatchery. The natural and fluctuating temperature regimes within an SRF may allow reared fish to experience a similar environment as wild fish. The results for length of SRF sturgeon and wild sturgeon from our study indicate that temperature and density in the SRF may contribute to a more natural growth than what has historically been observed in traditional hatchery settings.

Movement

In five of the seven telemetry weeks wild lake sturgeon did not travel significantly different distances than did the SRF fish. Few studies have been conducted regarding the movement patterns of age-0 lake sturgeon (Auer and Baker 2002) and no previous studies have compared streamside reared and wild age-0 lake sturgeon for movement patterns. In 2007, during the 4 weeks of our study, only in the third week did any difference between SRF fish and wild fish occur. Similarly, in 2008 only during the third and final week of the study were differences found between the linear distances traveled for each group. Slight differences that were found between the groups may be explained by the length of the study and small sample size. Other studies involving larger juvenile sturgeon have had extended tracking periods owing to larger and longer lasting transmitters (Holtgren and Auer 2004; Smith and King 2005; Jordan et al. 2006).

Small differences in movement between SRF and wild lake sturgeon may be attributed to small sample sizes. As the study progressed, fewer fish were located each week (owing to transmitter battery life loss, fish removal by predators, or possible unreported loss to sport fishers), which then created small sample sizes for statistical comparison. The only differences witnessed between groups were seen during the final weeks of the study each year when fewer fish were located. Fish movement was calculated on a weekly basis instead of on overall movement for the entire study. This may have also accounted for some of the differences witnessed in movement between groups. By evaluating groups on a weekly basis, fish were then compared with only those that were still found within those same weeks and never against fish found over shorter or longer periods. This type of comparison allowed us to evaluate fish over similar periods but resulted in smaller samples sizes as the study progressed, potentially affecting the power of the tests.

Habitat Association

The purpose of rearing fish in a streamside facility is to produce fish that exhibit similar characteristics to wild individuals, and this was exhibited in similar habitat associations by wild and SRF lake sturgeon. In this study, substrate Strauss selection values between groups of streamside-reared and wild lake sturgeon showed little variation in either 2007 or 2008. In 2007 SRF sturgeon were located on sand substrates slightly more often than were wild fish, and wild fish were located on gravel and pebble substrates slightly more often than SRF fish. Yet in 2008, no group was found to be using any one of the three substrate types more than any other. The Strauss selectivity indices calculated show that no substrate type was selected for more often than any other; however, other studies have shown a preference. A laboratory study involving hatchery-reared lake sturgeon (12.9–25.7 cm fork length) showed that, given the choice of four different substrate types, fish preferred sand over gravel, large rocks, and a plastic bottom (Peake 1999). Our findings indicate that within the 46-km reach of Big Manistee River sampled, sand, gravel, and pebble comprised 92.5% of the substrate type, and wild and SRF sturgeon were encountered in these three habitats equally.

This study reported similar results to those of previous age-0 lake sturgeon studies regarding water depths and velocities in which lake sturgeon juveniles were observed. In our study age-0 lake sturgeon were found over mixed sand and gravel substrates that ranged from 0.6 to 3.3 m deep and in velocities of 0.3–0.8 m/s. Holtgren and Auer (2004) found juvenile sturgeon at depths less than 1 m and in water velocities between 0.4 and 0.5 m/s while Kempinger (1996) found age-0 lake sturgeon at depths of less than 0.75 m.

Rearing lake sturgeon in a streamside facility and releasing them into their natal water source is a feasible management option. This study found that age-0 lake sturgeon attained similar size as wild cohorts by September with similar movement patterns and were observed over similar substrate types. This indicates that streamside rearing is an appropriate and beneficial technique that maintains early life history growth, movement, and habitat association. This is one of the first comparisons of wild versus streamside-reared lake sturgeon and suggests that the use of such facilities for species that imprint is a viable restoration management option.

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