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[Article]

Evaluation of Sampling Techniques for Age-0 Lake Sturgeon in a Lake Michigan Tributary

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Abstract.—Rehabilitation of lake sturgeon *Acipenser fulvescens* in the Great Lakes would benefit from a greater understanding of early life stage attributes. The objectives of this study were to determine the efficacy of active and passive sampling gears for capturing age-0 lake sturgeon and evaluate whether the most effective gear types were size selective. Fish were collected by means of active (i.e., wading, haul-seine, backpack electrofishing, snorkeling surveys, and bottom trawls) and passive (i.e., gill nets, set lines, and fyke nets) sampling gears from June to November of 2002 and 2003 in the lower Peshtigo River, Wisconsin, and nearshore waters of Green Bay. Mean catch per unit effort (CPUE) was greatest for day wading (0.036 fish/min), followed by day haul-seine surveys (0.029 fish/min), night wading (0.020 fish/min), and night haul-seine surveys (0.015 fish/min). Night wading surveys captured the greatest number of fish (N = 118). Day and night electrofishing (CPUE = 0.008 and 0.013 fish/min, respectively), snorkeling (CPUE = 0.010 fish/min), and gill nets (CPUE = 0.026 fish/d) were less effective gear types, while bottom trawls, set lines, and fyke nets did not capture fish. Smaller fish were captured during day wading and haul-seine surveys (median = 71 and 68 mm, respectively) than during night wading and haul-seine surveys (median = 120 and 133 mm, respectively). Based on these results, we recommend the use of wading and haul-seine surveys to collect age-0 lake sturgeon in shallow lotic and lentic systems, such as the lower Peshtigo River and Green Bay, that are characterized by low current velocity and high water clarity.

Lake sturgeon *Acipenser fulvescens* were once abundant throughout the Great Lakes, Mississippi River, and Hudson Bay drainages (Harkness and Dymond 1961). This species was commercially harvested until overexploitation, habitat loss, and industrial pollution led to large declines in population abundance during the late 1800s (Harkness and Dymond 1961; Scott and Crossman 1973; Organ et al. 1978; Hay-Chmielewski and Whelan 1997; Auer 1999). Currently, lake sturgeon are imperiled in U.S. waters of the Great Lakes, and estimates indicate that population abundance is approximately 1% of historical levels (Hay-Chmielewski and Whelan 1997; Elliott 1998). Rehabilitation efforts would benefit from an increased understanding of lake sturgeon early life history characteristics, particularly for age-0 fish (Elliott 1998; Holey et al. 2000). As a result, determination of effective methods for capturing these life stages will facilitate the collection of necessary biological information.

The capture of lake sturgeon has primarily relied on the use of set lines, boat electrofishing, bottom trawls, gill nets, and hoop nets (Thuemler 1997; Thomas and Haas 1999; Hughes 2002; Knights et al. 2002). While age-1 and older juvenile lake sturgeon have been captured by use of these gears, age-0 fish are typically not collected, perhaps because of their small size (Noakes et al. 1999; Hughes 2002). For example, gill nets, trawls, and

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set lines have been used to capture age-1 and older lake sturgeon in the Wolf River, Wisconsin, but age-0 fish in this system have only been successfully captured by scuba, haul seines, boat electrofishing, and to a lesser extent, bottom trawls (Kempinger 1996). Age-0 lake sturgeon have also been captured from the Sturgeon River, Michigan, by use of visual wading surveys (Holtgren and Auer 2004). Although age-0 Gulf of Mexico sturgeon *A. oxyrinchus desotoi* have been captured in bottom trawls and gill nets, visual surveys have also been successfully used in the Suwannee River, Florida (Sulak and Clugston 1999). Because sampling gears used to capture lake sturgeon have been generally unsuccessful for consistently capturing age-0 fish, it is necessary to examine alternative collection methods to characterize the biological attributes, habitat preferences, and movement patterns of these life stages (Kempinger 1996; Schram et al. 1999; Holey et al. 2000).

The lack of known gear types for effectively sampling early life stages has been identified as a limitation for assessing lake sturgeon populations in the Great Lakes (Holey et al. 2000). Further, a standardized method of sampling is necessary to facilitate comparisons within and among systems. The objectives of this study were to: (1) assess the catch per unit effort (CPUE) of various gear types used to capture age-0 lake sturgeon in the lower Peshtigo River, Wisconsin, and nearshore waters of Green Bay; and (2) determine whether gear types that are effective for collecting age-0 lake sturgeon (e.g., wading and haul-seine surveys) are size selective. Based on the results of this study, we will recommend a sampling protocol for the collection of age-0 lake sturgeon from nursery areas to facilitate standardization of status assessment surveys in shallow, low-flow, high-clarity systems, such as the lower Peshtigo River and nearshore waters of Green Bay.

Study Area

The study area for this research was the 19-km lower Peshtigo River from the Peshtigo Dam to the nearshore waters of Green Bay (Figure 1). Based on general morphology and substrate type, the study site was divided into the following five sections: (1) a wide (75 m) and shallow (1 m or less) riffle that extended 1.0 km downstream from the Peshtigo Dam and contained large gravel and small cobble substrates; (2) a wide (97 m) and shallow (up to 1.3 m), gravel–sand run that extended 5.5 km; (3) a narrow (55 m), deep (up to 2.5 m) run that extended 6.5 km and contained predominantly sand substrate; (4) a relatively wide (75 m), shallow (up to 1.3 m), straight run that extended 6.0 km, ending at the river's mouth, where it flowed into Green Bay and contained sand substrate; and (5) the shallow (6 m or less), nearshore waters of Green Bay that contained sand substrate within 1.5 km east, west, and south of the river's mouth. The riparian area of the river had limited development and consisted primarily of a maple *Acer* spp. and American beech *Fagus grandifolia* forest for sections 1–3 and a cattail *Typha* spp. and bulrush *Scirpus* spp. wetland for section 4. The average discharge of the river was 34 m^3/s in 2002 (range = 9–120 m^3/s) and 29 m^3/s in 2003 (range = 6–107 m^3/s), as measured by the U.S. Geological Survey gauging station located immediately downstream from the Peshtigo Dam.

Methods

Age-0 lake sturgeon were captured from the lower Peshtigo River and nearshore waters of Green Bay from June to November of 2002 and 2003. Fish were collected by means of a suite of active (i.e., wading, haul seines, backpack electrofishing, snorkeling, and bottom trawls) and passive (i.e., gill nets, set lines, and fyke nets) sampling gears. Shallow-water sampling methods, such as wading, haul seining, backpack electrofishing, snorkeling, and fyke-netting, were used in river and bay areas less than 2 m in depth to compare capture efficiency in these locations. In contrast, bottom trawls, gill nets, and set lines were used at depths up to 7.6 m to evaluate capture efficiency in deeper areas. A stratified random sampling schedule was employed such that active sampling gears were used at least once each week; sampling periods were distributed among two 4-h daytime periods (0900–1300 and 1300–1700 hours) and two 4-h nighttime periods (2000–2400 and 2400–0400 hours). All captured age-0 lake sturgeon were measured for total length to the nearest 1 mm to allow for comparisons of size selectivity among selected gear types. Captured age-0 fish were implanted with individually coded passive integrated transponder tags (14 mm long, 2.1 mm diameter, 125-KHz; Biomark, Inc., Boise, Idaho) below the second and third dorsal scutes by use of a 12-gauge needle.

Wading surveys.—Day and night wading surveys were conducted in study sections 1–5 from June to September of 2002 and June to November of 2003 at depths (<1 m) where the bottom was clearly visible. Day wading surveys were con-

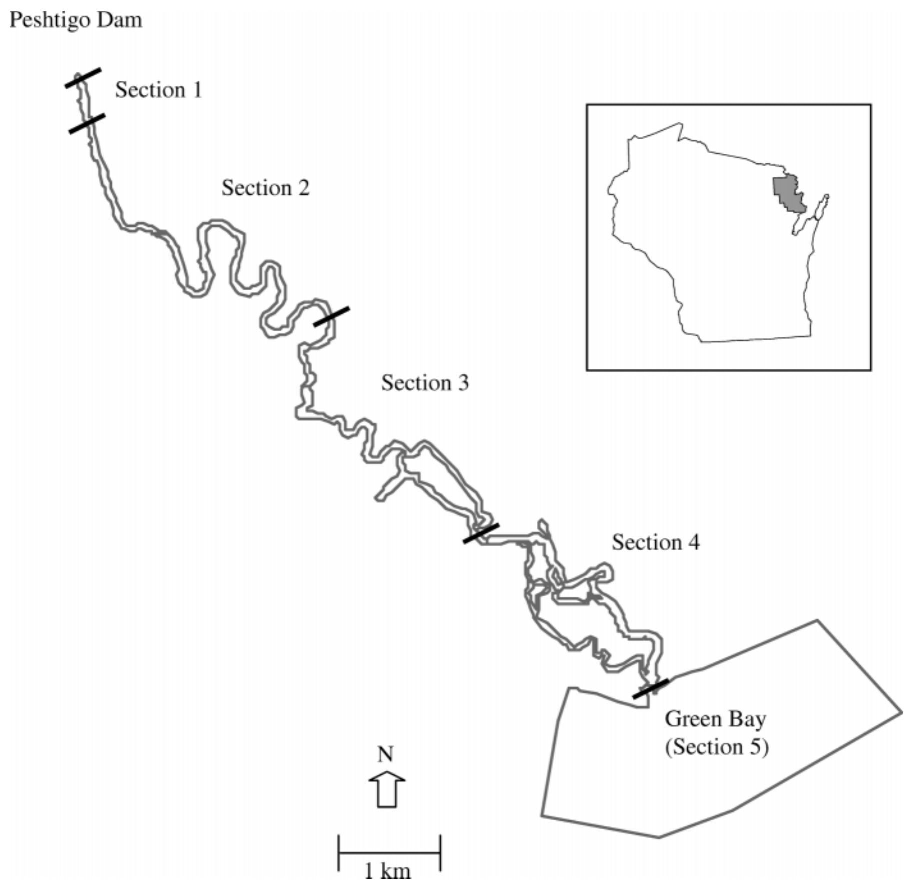

FIGURE 1.—Map of the lower Peshtigo River, located in northeastern Wisconsin, and nearshore waters of Green Bay.

ducted from 0900 to 1700 hours when the sun was sufficiently high that shadows from the riparian zone were not cast on the water surface. In contrast, surveys at night were conducted at full dark and employed a spotlight. During all surveys, netters were distributed equidistantly across the river and moved upstream while scanning the river bottom.

Electrofishing surveys.—Day and night electrofishing surveys were conducted in study sections 1–4 from June to September of 2002 and 2003. Surveys were carried out at water depths less than 1 m and used a model ABP-3 backpack electrofishing unit (Engineering Technical Services, Madison, Wisconsin; Figure 1). Each survey was conducted in an upstream direction along a single transect for 45 min. For night sampling, a spotlight was used to illuminate stunned fish.

Snorkeling surveys.—Snorkeling surveys were conducted in study sections 1–5 from June to September of 2003. Surveys were completed in either an upstream or downstream direction along transects spaced equidistantly across the river at depths less than 2 m. One person snorkeled each transect in a single pass while carrying a handheld dip net to capture fish. Surveys were conducted during daylight hours when shadows from the riparian zone were not cast on the water surface.

Haul seines.—Day and night haul-seine surveys were conducted in study sections 1–5 from June to September of 2002 and 2003. The seine was 1.8 m high and 4.9 m long and had 6.3-mm bar mesh. A 4.9-m tickler chain was attached immediately in front of the lead line to displace fish from the bottom into the water column, where they could be captured by the seine. Haul seines were pulled in an upstream direction at water depths that were 0.9 m or less.

Bottom trawls.—Bottom trawls were only conducted throughout study section 5 from June to August of 2002 and 2003. A 2.4-m shrimp trawl (3.5-cm-bar-mesh body and 3.1-cm-bar-mesh bag) and a 3.6-m shrimp trawl (3.8-cm-bar-mesh body and 3.1-cm-bar-mesh bag) were used to capture fish. Paired otter doors (2.4-m trawl: 22.9 cm high × 40.6 cm long; 3.6-m trawl: 30.5 cm high × 61.0 cm long) were attached to each trawl by use of two 30-m ropes. Bottom trawls were conducted with a 4.9-m boat powered with a 35-hp outboard motor; trawl speeds ranged from 3.0 to 3.5 km/h. Tow times did not exceed 5 min and were conducted at water depths ranging from 0.6 to 7.6 m.

Set lines.—Set lines were deployed in study sections 1–5 from July to September of 2002 and 2003 at depths ranging from 0.6 to 3.0 m. The main line was 91 m long and had 0.6-m snews attached at 3-m intervals. All snews in 2002 had a size-1/0 single barbed hook; half of the hooks were baited with cut white suckers *Catostomus commersonii* and the other half were baited with night crawlers (Oligochaeta). In 2003, half of the snews had a size-1/0 single barbed hook, and the other half had a size-8 single barbed hook. All hooks were baited with night crawlers in 2003, and all set lines during both years were checked at 24-h intervals.

Fyke nets.—Modified fyke nets were used in sections 1–5 from July to September of 2002. Fyke nets had 3.1-cm bar mesh, were 5.5 m in length, had two rectangular frames (1.2 m high × 2.0 m long), and had a 15.2-m lead. Nets were set oblique to the current; the net mouth faced downstream, and the lead was tied to the riverbank or bay shoreline. Two nets were set each day and were checked at 24-h intervals. Fyke nets were deployed at depths greater than 1.0 m but less than 1.2 m to prevent mortality of aquatic reptiles, such as northern water snakes *Nerodia sipedon*, common snapping turtles *Chelydra serpentina*, and painted turtles *Chrysemys picta*.

Gill nets.—Monofilament gill nets were used in sections 1–4 from July to September of 2002. Each gill net had four panels (15.2 m wide × 1.2 m deep) of 1.3–5.1-cm stretch mesh at 1.3-cm increments. One or two nets were set parallel to the current for an average of 2 d/week in the river and were checked at 24-h intervals. Gill nets were set in both shallow (0.5 m) and deep (3 m) water to allow for comparisons between the shallow and deep areas.

Statistical analyses.—A Kruskal–Wallis nonparametric test was used to determine differences in CPUE among gear types. The CPUE of age-0 lake sturgeon was measured as the number of fish caught per minute (active gears) or per day (passive gears). Size selectivity of fish captured during day and night wading and haul-seine surveys was evaluated by use of a Mann–Whitney test to determine differences in the median size of captured fish. Because June and July of 2003 were the only months when fish were captured by both survey approaches, these were the only months used in this analysis. A Tamhane's T2 multiple comparison test was used to determine whether gear types captured different sizes of lake sturgeon because the size distributions had unequal variances (Tamhane 1979). All statistical analyses were analyzed by use of the Statistical Package for the Social Sciences, version 11.0.1 (SPSS, Inc., Chicago, Illinois), and methods of statistical testing followed those outlined in Zar (1999). Unless stated otherwise, all statistical analyses were considered significant at P-values less than 0.05.

Results

Age-0 lake sturgeon were captured by wading, snorkeling, electrofishing, and haul-seine surveys (Table 1) and by gill nets (Table 2) over the two sampling years. No fish were captured in set lines, fyke nets, or bottom trawls (Table 2). There were no significant differences in CPUE among the sampling gears that successfully captured age-0 lake sturgeon in 2002 (H = 3.512, df = 2, P = 0.173) and 2003 (H = 9.405, df = 6, P = 0.152).

The use of active sampling gears resulted in the capture of age-0 lake sturgeon (Table 1). In 2002, six lake sturgeon were captured during day wading surveys (CPUE = 0.004 fish/min) and seven fish were captured during night wading surveys (CPUE = 0.003 fish/min). In 2003, 82 lake sturgeon were captured during day wading surveys (CPUE = 0.036 fish/min) and 118 fish were captured at night (CPUE = 0.020 fish/min). Day and night backpack electrofishing, snorkeling, and haul-seine surveys successfully captured age-0 lake sturgeon in 2003 but not in 2002. Two lake sturgeon were captured by use of day electrofishing surveys (CPUE = 0.008 fish/min), and four fish were captured by electrofishing at night (CPUE = 0.013 fish/min). Seven lake sturgeon were captured during snorkeling surveys (CPUE = 0.010 fish/min). Twenty fish were captured during day haul-seine surveys (CPUE = 0.029 fish/min), and nine fish were captured at night in haul seines (CPUE = 0.015 fish/min). No fish were captured in bottom trawls during either year.

Only passive sampling gears captured age-0 lake sturgeon during 2002 (Table 2). During that year,

TABLE 1.—Mean CPUE (SE in parentheses) of age-0 lake sturgeon collected by use of active gear types in 2002 and 2003 from the lower Peshtigo River and nearshore waters of Green Bay, Wisconsin. The abbreviation NA denotes gears that were not used during that field season.

	2002			2003		
Active gear types	CPUE (fish/min)	Effort (min)	Number of fish	CPUE (fish/min)	Effort (min)	Number of fish
Day wading	0.004 (0.003)	3,930	6	0.036 (0.018)	5,692	82
Night wading	0.003 (0.001)	1,800	7	0.020 (0.004)	9,583	118
Snorkeling	NA	NA	NA	0.010 (0.009)	2,300	6
Day electrofishing	0	20	0	0.008 (0.005)	434	2
Night electrofishing	NA	NA	NA	0.013 (0.008)	318	4
Day haul seines	0	660	0	0.029 (0.010)	593	20
Night haul seines	NA	NA	NA	0.015 (0.009)	673	9
Bottom trawls	0	55	0	0	620	0

a single lake sturgeon was captured by means of gill nets (CPUE = 0.026 fish/d). No age-0 fish were captured by fyke nets or set lines during either sampling year.

Size selectivity was observed for age-0 lake sturgeon captured during day and night wading and haul-seine surveys (Figure 2). Median total length was significantly smaller for fish captured by wading surveys during the day (median = 71 mm; range = 40–173 mm) than at night (median = 120 mm; range = 42–154 mm; $Z = -3.531$; $P < 0.001$; Table 3). Similarly, the median total length of lake sturgeon captured during day haul-seine surveys (median = 68 mm; range = 52–98 mm) was significantly smaller ($Z = -2.444$; $P = 0.012$) than that of fish collected at night with this sampling gear (median = 133 mm; range = 54–156 mm).

Discussion

Previous studies have utilized various sampling methods to capture age-0 lake sturgeon (Kempinger 1996; Hughes 2002; Holtgren and Auer 2004). However, these sampling efforts were often ineffective at capturing fish in sufficient numbers to determine biological attributes and to adequately characterize habitat preferences and movement patterns. In the lower Peshtigo River and nearshore waters of Green Bay, active sampling gears were more successful at capturing age-0 lake sturgeon than were passive gears. Wading and haul-seine surveys had the highest CPUEs among all gear types. Because no fish were captured by bottom trawls, set lines, or fyke nets, these sampling gears were classified as ineffective in our study area. Variation in catch rates between years may have been caused by differences in river conditions (i.e., the river was shallower and had lower flows in 2003 than 2002), greater capture efficiency of field crews, and a greater abundance of age-0 lake sturgeon in 2003 than 2002.

Night wading surveys captured the greatest number of age-0 lake sturgeon during both study years. During night surveys, fish were visible because they were actively swimming and the light color of the ventral body surface provided contrast against the river bottom. Further, lake sturgeon eyes have a tapetum lucidum, which reflects light from a spotlight. Night wading surveys were effective for capturing fish as long as the river bottom was visible. In addition, the success of night wading surveys required there to be little to no wind or fog. Similar sampling has also been used to capture age-0 lake sturgeon in the Manistee River, Michigan (M. Holtgren, Little River Band of Ottawa Indians, personal communication).

The use of day wading surveys resulted in the

TABLE 2.—Mean CPUE (SE in parentheses) of age-0 lake sturgeon collected by use of passive gear types in 2002 and 2003 from the lower Peshtigo River and nearshore waters of Green Bay, Wisconsin. The abbreviation NA denotes gears that were not used during that field season.

	2002			2003		
Passive gear types	CPUE (fish/d)	Effort (d)	Number of fish	CPUE (fish/d)	Effort (d)	Number of fish
Gill nets	0.026 (0.020)	38	1	NA	NA	NA
Set lines	0	16	0	0	98	0
Fyke nets	0	63	0	NA	NA	NA

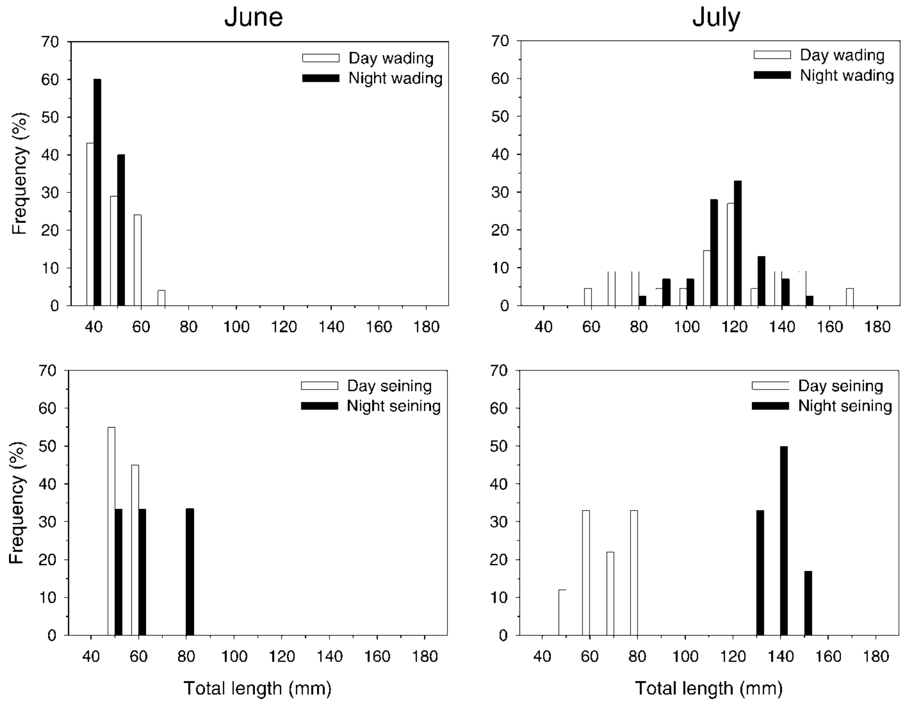

FIGURE 2.—Length-frequency distributions of age-0 lake sturgeon during June and July 2003 in day and night wading surveys and haul-seine surveys in the lower Peshtigo River, Wisconsin, and nearshore waters of Green Bay.

capture of the second largest number of age-0 lake sturgeon. The effectiveness of these surveys depended on direct sunlight, the absence of shadows, and the presence of little to no wind. Although fish typically remained immobile and were difficult to locate because of their cryptic coloration, this method had one of the highest CPUEs among the active gear types used in this study. Similar stationary behaviors by juvenile lake sturgeon during the day have also been observed in the Wolf River, Wisconsin, and the lower Niagara River, New York (Kempinger 1996; Hughes 2002). Day wading surveys have also been used to capture age-0 lake sturgeon in the Sturgeon River, Michigan (Holtgren and Auer 2004).

TABLE 3.—Differences in size selectivity of age-0 lake sturgeon captured by day and night wading and haul seine surveys in the lower Peshtigo River and nearshore waters of Green Bay, Wisconsin, in 2003.

Gear type	Number of fish	Median total length (mm)	Total length range (mm)
Day wading	33	71	40–173
Night wading	59	120	42–154
Day haul seine	18	68	52–98
Night haul seine	9	133	54–156

Haul-seine surveys have previously been used to capture age-0 lake sturgeon (Kempinger 1996). In the Wolf River, small age-0 lake sturgeon (range = 29–97 mm in total length) were collected by use of haul-seine surveys during the day, and this method most effectively captured fish less than 79 mm (Kempinger 1996). Haul seines were also effective for capturing age-0 lake sturgeon in the lower Peshtigo River during June and July, when fish were small (<160 mm) and unable to avoid the net. After July, fish had become stronger swimmers and could more easily avoid capture. Although fewer fish were captured during haul-seine surveys than wading surveys, the former method had the second highest day and fourth highest night CPUEs in 2003. Day haul-seine surveys were more effective than night haul-seine surveys because debris on the river bottom was easier to detect and avoid during the daytime. When haul seines became snagged on debris during night surveys, fish were presumably able to escape and avoid capture. Therefore, haul seines are most appropriate for sampling in areas with little to no debris on the river bottom. Based on these results, haul seines would be most effective at capturing age-0 lake sturgeon early in the year, when fish are small and difficult to locate visually.

Backpack electrofishing captured only six age-0 lake sturgeon over both sampling years. Because fish were always observed prior to being shocked, this method could be used in conjunction with wading surveys to allow fewer fish to escape capture. Although backpack electrofishing has not been previously used to capture juvenile lake sturgeon, boat electrofishing has been used to collect age-0 fish in the Menominee River (Priegel and Wirth 1974). Kempinger (1996) found that boat electrofishing was the most effective gear type for capturing age-0 fish larger than 79 mm in length. Similarly, juvenile Gulf of Mexico sturgeon in the Suwannee River have also been captured by use of boat electrofishing surveys (Sulak and Clugston 1998).

Snorkeling surveys captured six age-0 lake sturgeon. While snorkeling upstream against the current, snorkelers usually observed age-0 fish but were unable to capture them because the fish were startled and swam to deeper water. In contrast, when snorkelers passively drifted downstream, fish were not startled and could be collected by dip net. Snorkeling surveys have also been used to capture age-0 Gulf of Mexico sturgeon in the Suwannee River (Carr et al. 1996). In rivers too deep for snorkeling, such as the lower Niagara River, scuba surveys have proven effective for capturing juvenile lake sturgeon (Hughes 2002). While snorkeling surveys are not as effective as wading or haul-seine surveys, they do provide an opportunity to observe the behavior of fish in their natural habitats with minimal disturbance.

Bottom trawls did not capture age-0 lake sturgeon in the study area. This sampling gear has been used in Lake Winnebago, Wisconsin, for capturing larger juvenile lake sturgeon (range = 267–749 mm total length; Kempinger 1996). Similarly, age-0 Gulf of Mexico sturgeon in the Suwannee River have been captured in bottom trawls (Sulak and Clugston 1999). In the lower Peshtigo River and nearshore waters of Green Bay, the capture of age-0 fish in haul seines in shallow areas outside the mouth of the river indicated that the fish were using these areas as nursery habitats. Therefore, bottom trawls may have been ineffective in our study area because the locations where age-0 fish were captured with haul seines were typically too shallow to sample effectively with bottom trawls.

Gill nets were the only passive gear type that captured age-0 lake sturgeon. However, the one fish that was captured was found dead in the net. Gill nets have been used successfully in the Suwannee River for capturing age-0 Gulf of Mexico sturgeon (Sulak and Clugston 1999). To minimize mortality of fish, particularly during summer months and at higher water temperatures, this gear type should be used for shorter durations (i.e., less than 4-h set intervals). Although set lines have been used to capture age-0 lake sturgeon in the Sturgeon River (Holtgren and Auer 2004), fyke nets have not been noted as an effective sampling gear.

Differences in body size of age-0 lake sturgeon were observed for day versus night wading and haul-seine surveys. For both gear types, night surveys captured larger fish than day surveys. This difference may be a result of greater wariness of fish during the day and the fact that larger individuals could swim faster and avoid capture more easily than smaller fish. In contrast, age-0 fish were less wary at night and were easier to approach. Large fish were often inactive during the day, whereas small individuals were typically swimming to maintain their position in the current, which made them more visible. Peake (1999) observed the active swimming of small age-0 lake sturgeon in a laboratory study and found that fish were more active during early morning and late evening. As a result, disparities in age-0 lake sturgeon size at capture may be the result of differences in fish behavior between light and dark periods and the ability to evade capture.

Based on this study, active gear types were the most effective methods for capturing age-0 lake sturgeon in low-flow, high-clarity, shallow systems, such as the lower Peshtigo River and nearshore waters of Green Bay. River depth was variable in this system and largely determined which sampling method(s) would be most successful. Environmental conditions (i.e., wind, fog, sunlight, and river surface agitation) also influenced gear effectiveness and must be accounted for when choosing the most appropriate sampling gear. Determination of an efficient capture method for each habitat type that is also comparable within and among systems is essential for successful characterization of age-0 lake sturgeon population attributes. Future research efforts should focus on determining effective capture methods for age-0 lake sturgeon in riverine systems with different characteristics (i.e., deeper water depths, lower water clarity, etc.) to better understand early life stage attributes of this species in other Great Lakes tributaries.

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