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Reintroduction of Lake Sturgeon in the St. Louis River, Western Lake Superior

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Abstract.—Lake sturgeon *Acipenser fulvescens* declined in abundance in Lake Superior's St. Louis River during the late 1800s and were eliminated from the river during the early 1900s because of the combined effects of exploitation, pollution, and habitat alteration. Since then, exploitation in the river and in Lake Superior has been reduced. Furthermore, water quality in the St. Louis River has improved, and its upper-estuary spawning habitat has remained relatively unchanged and adequate. Lake sturgeon have been stocked annually in the St. Louis River since 1983; from 1983 to 1994 stockings included 736,000 fry, 128,000 fingerlings, and 500 yearlings of the Lake Winnebago strain. Relative abundance, distribution, and growth were determined by sampling marked fish in the St. Louis River estuary and western Lake Superior with graded-mesh gill nets and bottom trawls. During 1983–1998, 644 lake sturgeon were caught in 15,486 m of gill net, and 196 were caught in 1,200 trawl tows. Lake sturgeon were sampled most frequently near channelized portions of the St. Louis River and stayed in the estuary up to 5 years before entering Lake Superior. Lake sturgeon were not captured in western Lake Superior prior to stocking, but abundance increased dramatically after 1985. Of 582 lake sturgeon sampled along the Wisconsin shore of Lake Superior from 1985 through 1998 (347,000 m of gill nets), 93% were captured in less than 30 m of water. A total of 93 lake sturgeon were reported from assessment netting conducted along the Minnesota shore of Lake Superior from 1992 through 1997. The current range of stocked lake sturgeon extends from the St. Louis River 145 km east to the Apostle Islands in Wisconsin and 110 km northeast to Little Marais in Minnesota. Increases in lake sturgeon abundance were directly attributed to the stocking program. We recommend stocking a minimum of 20 year-classes and the use of a Lake Superior egg source, if possible. Final evaluation of the project will be detection of tagged lake sturgeon successfully spawning at historical spawning areas.

Lake sturgeon *Acipenser fulvescens* are indigenous to Lake Superior but declined in abundance during the late 1800s or early 1900s because of the combined effects of exploitation, water pollution, and habitat alteration (Slade 1996). The St. Louis River historically supported a lake sturgeon spawning population (Kaups 1984), but the species was eliminated from the river during the early 1900s. Habitat alteration in the lower St. Louis River estuary has included dredging for commercial shipping, wetland filling for dock construction and discharge of untreated effluents from industrial and residential sources. Despite this, lake sturgeon spawning habitat in the upper estuary has remained relatively unchanged (Kaups 1984).

Exploitation has been reduced through conservative commercial and sport fishing regulations. In 1928, Minnesota and Wisconsin closed the commercial lake sturgeon fishery. Minnesota has a closed season for Lake Superior and the St. Louis River. Wisconsin closed the season for the St. Louis River in 1992 and currently has a Lake Superior possession limit of one per year, a minimum length limit of 127 cm, and mandatory registration of harvested fish.

Water quality improved after the Western Lake Superior Sanitary District began treating domestic and industrial effluent in 1979 (Doucette et al. 1985; Schram et al. 1992). Soon after, the Wisconsin Department of Natural Resources (WDNR)

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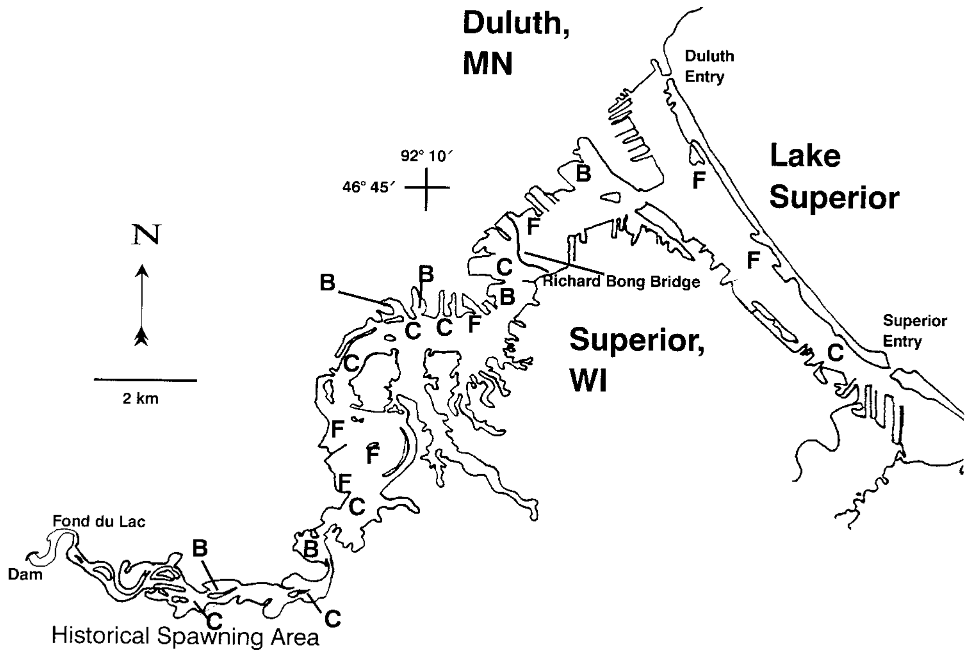

FIGURE 1.—St. Louis River estuary between Minnesota (MN) and Wisconsin (WI), showing 1986–1998 gill-net sampling locations: C = dredged channel, F = open flat, and B = sheltered bay.

and Minnesota Department of Natural Resources (MDNR) became interested in reestablishing a spawning population of lake sturgeon in the St. Louis River. Although lake sturgeon may have recolonized the river naturally, their life history characteristics of slow growth, late age at maturity, and an intermittent spawning cycle indicated that the process might have taken centuries. Therefore, a management alternative to begin stocking was initiated in 1983. The only potential Lake Superior egg source available in the early 1980s was from the Bad River in Wisconsin. However, the adult population size was unknown and the logistics of obtaining eggs proved difficult. Therefore, we used eggs from the Lake Winnebago strain (Lake Michigan watershed; Ceskleba et al. 1985) to propagate and release sturgeon into the St. Louis River from 1983 through 1994.

The St. Louis River lake sturgeon reintroduction program was consistent with agency goals for reestablishing depleted stocks of native species such as lake sturgeon (Blust et al. 1988; Busiahn 1990, Schreiner 1995; Auer 1998a). In this study we evaluated the lake sturgeon stocking program by using existing fisheries assessments. We were able to assess relative abundance, document distribution, and monitor growth. We believed that relative abundance should increase over time and that lake sturgeon should remain near the estuary through much of their lives. We were also able to monitor growth by following a specific year-class for 7 years. These findings provide new information concerning reintroduction of lake sturgeon in the Great Lakes.

Study Area

The St. Louis River is the largest United States tributary entering Lake Superior, having a mean discharge of 73.2 m^3/s (Sather and Johannes 1972). The estuary consists of the lower 40 km of river and has a surface area of 4,600 ha (Figure 1). Most of the estuary, which forms the border between the states of Minnesota and Wisconsin, is less than 3 m deep, except for a 6–12-m dredged navigational channel. A power dam constructed in 1924 upstream from Fond du Lac, Minnesota, prevents upstream migration of fish. Prior to 1924, the natural boundary to upstream migration of fish was a rapids near the present location of the dam. The rapids extend from the dam downstream to Fond du Lac (2 km). From Fond du Lac to the Richard Bong Bridge, the river takes on the character of an estuary with numerous bays, small islands, emergent vegetation, and shallow water. Downstream from the bridge, the river is characterized by shipping channels and waterfront de-

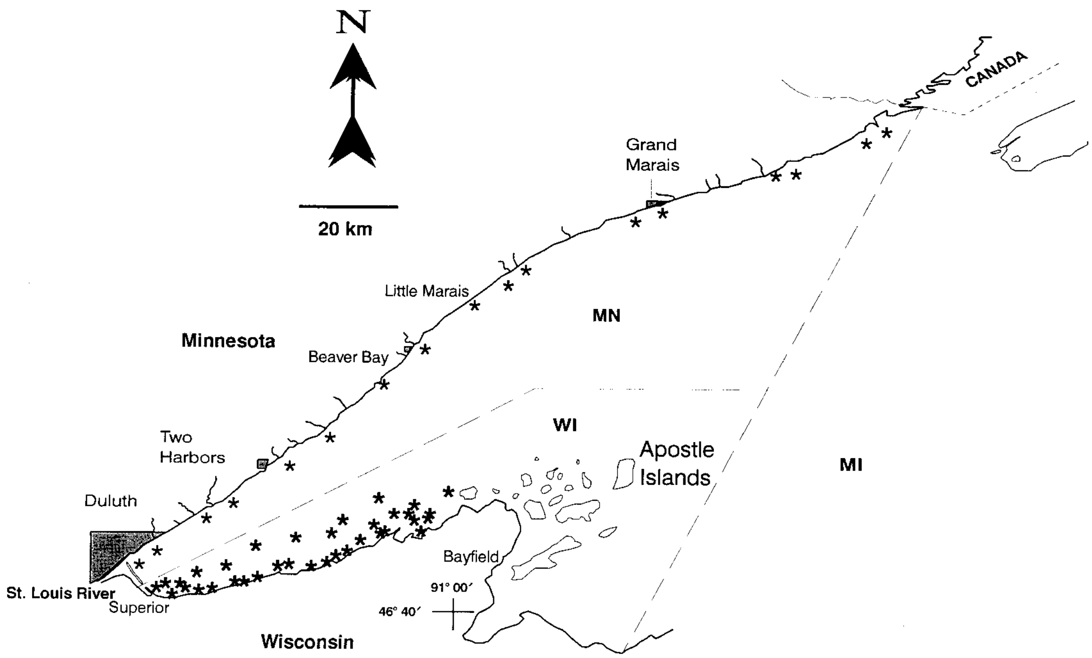

FIGURE 2.—Western Lake Superior showing lake sturgeon sampling locations from summer assessments in Wisconsin (WI), 1970–1997, and summer assessments in Minnesota (MN), 1992–1997. Asterisks denote gill-net stations; Michgan (MI) and Canadian waters were outside the sample area.

velopment. Substrate throughout the estuary consists of red clay, sand, muck, detritus, and isolated areas of fine gravel. Over 50 fish species have been documented using the estuary as a spawning, nursery or feeding area (Schram et al. 1992).

The portion of Lake Superior we sampled extended from the mouth of the St. Louis River (Superior Entry) eastward to the western Apostle Islands and from the Superior Entry northeastward to Canada (Figure 2). In this area the Minnesota shoreline of Lake Superior is rocky with depths that drop sharply beyond 200 m. The Wisconsin nearshore waters are relatively shallow and frequently turbid; the clay and sand bottom slopes gradually to 150 m. Summer water temperatures along the Wisconsin shore are warmer than the Minnesota shore, but surface temperatures fluctuate with prevailing winds.

Methods

Lake Winnebago strain of lake sturgeon were stocked in the St. Louis River from 1983 through 1994. Fish released by WDNR were raised at Wild Rose State Fish Hatchery in Wisconsin; fish released by MDNR were obtained from WDNR as fry and reared at various hatcheries in Minnesota. From 1983 through 1994, 736,000 fry, 128,000 fingerlings, and 500 yearling lake sturgeon were released in the St. Louis River (Table 1). Number, size and age of lake sturgeon stocked were not standardized. Wisconsin Department of Natural Resources generally released fry (13–25 mm) in May and fingerlings (102–152 mm) in August and September. Similarly, MDNR released fry in May and fingerlings (127–203 mm) in September and October. Coded wire tags were injected into the snout cartilage of all fingerling year-classes released by MDNR. In addition, the 1991 year-class was double-tagged by injecting an additional coded wire tag under the sixth dorsal scute posterior to the head. Recovery of double-tagged lake sturgeon provided nonlethal age data. Tag loss for 120 double-tagged fingerlings retained in the hatchery for 90 d was estimated to be less than 1%. A wand-type tag detector was used to check for the presence of coded wire tags. No Wisconsin-reared fish received coded wire tags. The majority of fish were released just downstream from the Fond du Lac Bridge. This area had gravelly shoals and pools and was in an area where lake sturgeon historically spawned. The remaining fish were released upstream from the Richard Bong Bridge.

Four separate fisheries assessments, designed for other management programs, were used to in-

TABLE 1.—Lake sturgeon stocked in the St. Louis River by the Minnesota Department of Natural Resources and Wisconsin Department of Natural Resources from 1983 through 1994. All fingerlings stocked by Minnesota received a coded wire tag.

	Minnesota		Wisconsin		Total	
Year	Fry	Fingerling[a]	Fry	Fingerling[b]	Fry	Fingerling
1983			102,000	2,700	102,000	2,700
1984			162,000	18,000	162,000	18,000
1985		4,900	59,000	2,700	59,000	7,700
1986		400[c]				400
1987						
1988		18,200		6,000		24,300
1989		7,200	50,000	100[c]	50,000	7,300
1990		10,300	25,000		25,000	10,300
1991		5,500	96,000	4,500	96,000	10,000
1992	83,000			13,500	83,000	13,500
1993			7,000	19,300	7,000	19,300
1994			151,000	14,500	151,000	14,500
Total	83,000	46,500	652,000	81,300	735,000	128,000

[a] Fall fingerlings (127–203 mm).
[b] Late-summer fingerlings (102–152 mm).
[c] Yearlings stocked in October.

dex relative abundance of sturgeon. Sturgeon relative abundance within the estuary was indexed by MDNR with catch per unit effort (CPUE) or the number per 1,000 m of experimental gill net. Assessments were conducted during July from 1983 through 1998 using a 76.3-m-long, 1.8-m-deep, five-panel, multifilament nylon experimental gill nets with bar mesh sizes of 19.1, 25.4, 31.8, 38.1 and 50.8 mm. Nets were set for 24 h on the bottom and in varying habitat types between the Superior Entry and the upper estuary (Figure 1). Depths at sample sites ranged from 1.5 m to 8.2 m overall and in habitat types as follows: 1.5–8.2 m for habitats classified as channel, 1.5–3.1 m for flats, and 1.5–2.7 m for bays.

Relative abundance of lake sturgeon was determined during May through October from 1989 through 1998 by U.S. Geological Survey bottom trawling conducted at randomly chosen locations within the St. Louis River estuary, which included habitat types classified as channel (7.6–12.2 m), undredged (3.1–7.3 m), and flats (0–3.1 m). The 120 stations extended from a point 2 km downstream from Fond du Lac to the Superior Entry. The trawl was a 5.2-m bottom trawl with a 2.5-cm-mesh body and a 6.3-mm-mesh cod end, and it was towed at 2.3 km/h for 5 min.

In western Lake Superior, sturgeon relative abundance was indexed biannually by WDNR with gill nets fished on the bottom at 35 locations along the Wisconsin shoreline during July and August, 1970–1997 (Figure 2). Multifilament nylon nets were used from 1970 through 1990, and monofilament nylon nets were used from 1991 through 1997. Twenty-six stations were intended to sample all species and were in water depths ranging from 3.7 to 115 m. These nets totaled 1,092 m and contained twelve 91-m nets of different stretch meshes: 38–178 mm in 12.7-mm increments. Nine nearshore stations were set specifically for walleye *Stizostedion vitreum* but also caught lake sturgeon. These multifilament nylon nets totaled 540 m (six 30-m nets each with stretch measures of 102, 114, and 127 mm) set in water depths of 3.7–15.2 m. All nets were lifted after 24 h.

Additional sturgeon were collected along the Minnesota shoreline of Lake Superior by commercial assessment fishers and by MDNR. Data on sturgeon were reported on forms submitted by commercial fishers near Duluth and Beaver Bay, Minnesota, and we did not report them as a CPUE. Lake sturgeon were also sampled during annual spring lake trout *Salvelinus namaycush* assessments conducted by WDNR during May, 1987–1998. These multifilament nylon gill nets totaled 823 m, contained 114-mm stretch mesh, and were set in water depths of 16–49 m.

Lake sturgeon collected during the spring and summer by WDNR in Lake Superior were marked with Floy anchor tags (FD68BC) along the side of the dorsal fin and released. Movement patterns and distribution were determined by recovering tagged lake sturgeon. Sources of recapture included MDNR and WDNR assessment netting and commercial fishers.

Results

We collected 1,515 lake sturgeon during 1983–1998 in all gear types in the St. Louis River estuary

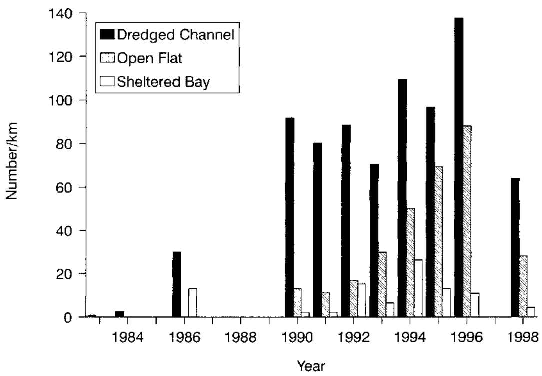

FIGURE 3.—Variable-mesh gill-net catch per unit effort (number/km) of lake sturgeon in the St. Louis River estuary by habitat type. Habitat type was not classified in 1983 or 1984.

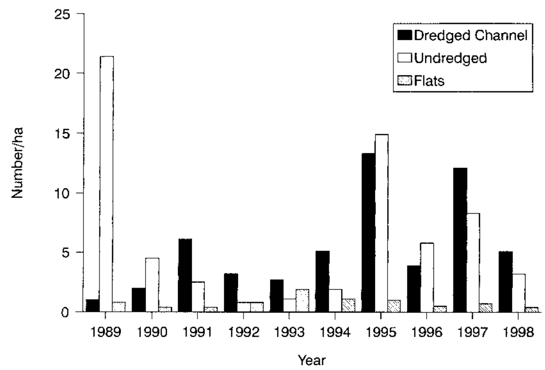

FIGURE 4.—Mean density (number/ha) of lake sturgeon in the St. Louis River estuary by habitat type, 1989–1998, based on bottom trawling. Mean yearly effort for dredged channel, undredged, and flats was 25, 19 and 76 tows, respectively.

and western Lake Superior, of which 644 were captured in 15,486 m of gill nets in the estuary. Relative abundance in the estuary was greatest along the edge of dredged channels where water depths were 1.5–8.2 m (Figure 3). Relative abundance was low in the open flats but steadily increased from 1992 to 1996 before declining in 1998. Shallow sheltered bays had the lowest relative abundance throughout the study period. Lake sturgeon captured in 1,080 trawl tows were found in the same habitats as those caught in gill nets. Mean density of 196 lake sturgeon captured in trawls was greatest in dredged and undredged channels and least in open flats (Figure 4). Effort remained equal in all three areas.

Abundance of lake sturgeon in western Lake Superior increased dramatically after initiation of the rehabilitation program in 1983. Lake sturgeon from this program were first sampled by WDNR along the Wisconsin shoreline of Lake Superior in 1985, two years after the first fish were released. Gill-nets captured 346 sturgeon in 347,000 m of net set during WDNR summer assessments from 1985 to 1997, CPUE increasing from 0.1 fish/km in 1985 to 2.9 fish/km in 1997 (Figure 5). The larger variable-mesh gill nets set in Lake Superior caught larger sturgeon than the trawl or estuarine gill nets (Figure 6). An additional 236 sturgeon were collected during the spring. Although no information is available from netting conducted along the Minnesota shoreline prior to 1992, 93 lake sturgeon were collected from 1992 through 1997.

Length at capture for the 1991 double-tagged year-class of lake sturgeon was determined for 65 fish recaptured from 1992 through 1998 (Table 2). We assumed an estuary residence time of up to 5 years based on the number of double-tagged fish caught and by comparing length at capture data to the length frequency of lake sturgeon captured in the St. Louis River (Figure 6). In addition, no double-tagged sturgeon were captured in the estuary in gill nets or trawls in 1998.

The percentage of coded-wire-tagged lake sturgeon caught in assessment nets was greater than the percentage of tagged fish released. Only 36% of the 128,000 fingerlings released were coded-wire-tagged; however, 42% of 872 lake sturgeon captured and checked with the tag detector contained a coded wire tag. Coded-wire-tagged lake sturgeon accounted for 58% of the fish caught in trawls in 1997 and 1998, 35% of the fish caught in estuary gill nets between 1991 and 1998, and

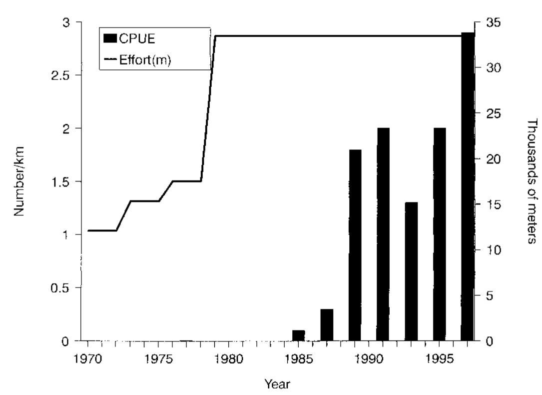

FIGURE 5.—Total effort (m of gill net) and catch per unit effort (CPUE; number/km) of lake sturgeon from variable-mesh gill nets in western Lake Superior, 1970–1997.

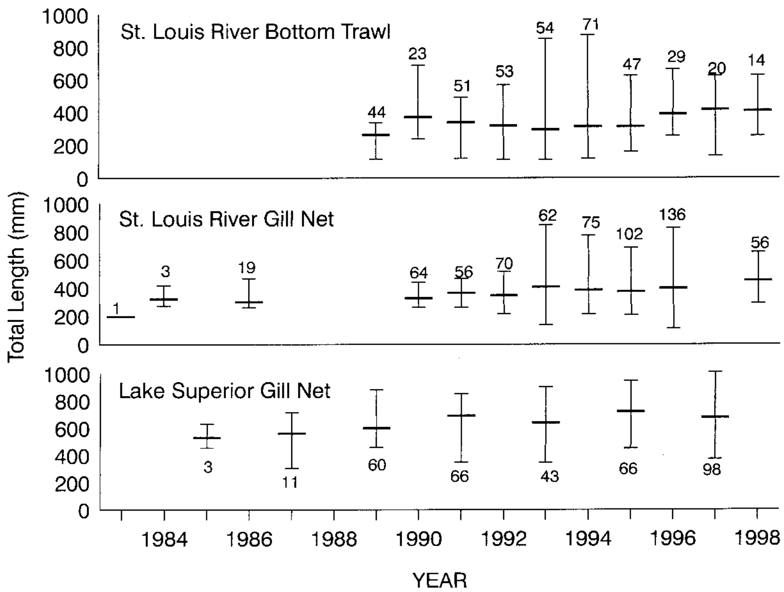

FIGURE 6.—Mean length and range (mm) of lake sturgeon taken by trawls (upper panel) and gill nets (middle) in the St. Louis River and by gill nets in Lake Superior (lower). Sample sizes are above or below bars.

TABLE 2. Mean length at capture for known-age lake sturgeon stocked in the St. Louis River representing the 1991 double-tagged year-class. Fish ages 1–5 were captured in the St. Louis River, and fish ages 6 and 7 were captured in Lake Superior.

Length (mm)	Age							
	0	1	2	3	4	5	6	7
Number of fish								
175–200	5							
201–225								
226–250								
251–275								
276–300		1	1					
301–325		1	1					
326–350		2		2				
351–375			4	1				
376–400				4				
401–425				2				
426–450				1	1	3		
451–475					1		2	
476–500						2	1	
501–525					1	1		
526–550							3	1
551–575							3	4
576–600							2	3
601–625							5	3
626–650							1	1
651–675								1
676–700							1	
Total	5	4	6	10	3	6	18	13
Characteristics								
Mean length (mm)	186	320	340	386	464	467	572	594
Minimum length (mm)	175	290	300	333	441	427	457	536
Maximum length (mm)	200	340	363	447	501	511	681	660

TABLE 3. Catch per unit effort (number/km) of stocked lake sturgeon sampled from variable-mesh gill nets set during summers, 1985–1997, along the Wisconsin shore of Lake Superior, stratefied by distance from the Superior Entry (DSE). Sample sizes are given in parentheses.

	Catch per unit effort (number/km) in:						
DSE (km)	1985	1987	1989	1991	1993	1995	1997
10	0.1 (4)	0.1 (3)	1.3 (42)	0.9 (30)	0.4 (14)	0.7 (22)	2.0 (66)
20		0.2 (6)	0.2 (6)	0.4 (12)	0.1 (5)	0.7 (24)	0.4 (13)
30		<0.1 (1)	0.1 (3)	0.5 (16)	0.2 (6)	0.4 (12)	0.2 (8)
40			0.1 (4)	0.1 (3)	0.1 (4)	0.2 (6)	<0.1 (1)
50					0.1 (4)	<0.1 (1)	0.1 (3)
60		<0.1 (1)	0.1 (2)	0.1 (5)	0.2 (8)	<0.1 (1)	0.1 (5)
70					<0.1 (1)		<0.1 (1)
80					<0.1 (1)		<0.1 (1)

49% of the fish caught in Lake Superior between 1993 and 1998.

Although stocked lake sturgeon have been expanding their range eastward since 1983, relative abundance along the Wisconsin shoreline has remained highest within 30 km of the estuary (Table 3). Sampling in western Lake Superior indicated that lake sturgeon were staying within an area from the Apostle Islands along the Wisconsin shore to Little Marais along the Minnesota shore. The longest known movement of lake sturgeon from this population came from two tagged fish recaptured on the north side of the Apostle Islands, a distance of approximately 145 km from the stocking location.

Bathymetric distribution of lake sturgeon in Lake Superior varied little between spring and summer sampling. Lake sturgeon caught along the Wisconsin shoreline generally inhabited waters less than 30 m deep but were sampled in waters as deep as 60 m (Table 4). Lake sturgeon sampled along the Minnesota shore were captured from depths between 3 and 55 m.

TABLE 4.—Catch per unit effort (CPUE; number/km) and total effort (meters of gill net) by depth interval for stocked lake sturgeon in Lake Superior, taken in the summer (variable-mesh gill nets, 1985–1997) and spring (114-mm gill nets, 1987–1998). Blanks represent depths not sampled in the spring.

Depth interval (m)	Summer		Spring	
	CPUE	Effort (m)	CPUE	Effort (m)
0–15	3.0	110,277		
16–30	0.2	46,086	5.4	36,206
31–45	<0.01	46,086	0.9	40,597
46–60	<0.01	23,043	0.7	6,034
61–75	0.0	7,681		
76–90	0.0	15,362		
91–105	0.0	7,681		
106–120	0.0	7,681		

Discussion

Initial efforts to reintroduce lake sturgeon in the St. Louis River and western Lake Superior have been successful. Increases in lake sturgeon abundance were directly attributed to the stocking program in the St. Louis River. Assessment work in the estuary prior to the stocking program did not capture lake sturgeon. These assessments could not be incorporated into this study because of gear differences and sampling locations.

Lake sturgeon were first collected in Lake Superior in 1985, or 2 years after the stocking program began. By following the double-tagged year-class, we were able document fish remaining in the St. Louis River estuary up to 5 years. Wild lake sturgeon reported from the Kaministiquia River, Ontario, exhibited a similar estuarine residency time (Cullis et al. 1987). Cullis et al. (1987) captured lake sturgeon 9–18 km upstream from the mouth of the Kaministiquia River that had a mean age of 5.1 years and mean total length of 46 cm. Conversely, Slade (1996) documented wild lake sturgeon in the Bad River, Wisconsin, moving downstream at an early age. Juvenile fish (21–86 cm total length) were captured in the lower Bad River and in the adjacent shallow waters of Lake Superior. Juvenile lake sturgeon were also found moving out of the Sturgeon River, Michigan, at an early age (Slade 1996; Auer 1998b). Age-1 and age-2 fish composed 67% of the fish captured in the shoal areas within 16 km of the Sturgeon River river mouth (Slade 1996). Thuemler (1988) released yearling Lake Winnebago-strain lake sturgeon into the Menominee River, Wisconsin. Nine of 10 radio-tagged yearling fish moved rapidly downstream, and 7 of them were eventually found in a flowage type environment. Behavioral differences between hatchery and wild fish and the estuary size could account for the differences in juvenile abundance and residency compared to the Sturgeon and Bad rivers.

Lake sturgeon in the St. Louis River were generally found in waters 3–12 m in depth within the estuary and to 30 m deep in Lake Superior, although we did sample a few lake sturgeon as deep as 60 m. Lake sturgeon are usually found in waters 4–9 m deep, but have been taken at depths up to 43 m (Scott and Crossman 1973). In Black Lake, Michigan, lake sturgeon avoided areas less than 3 m deep but traveled extensively throughout the rest of the lake (Hay-Chmielewski 1987).

Recaptured fish from the 1991 double-tagged year-class allowed us to monitor growth from 1992 to 1998. Lake sturgeon were collected in the estuary from May through October; therefore, we were unable to determine length at age. Data for fish ages 1–5 were only available from the estuary, whereas data for ages 6 and 7 were only available from Lake Superior. Mean length increased over time for all age-classes. Lengths among individuals of the same age at time of capture were more variable after they entered Lake Superior.

The current range of lake sturgeon stocked in the St. Louis River extends from the St. Louis River 145 km east to the Apostle Islands in Wisconsin and 110 km northeast to Little Marais, Minnesota. Auer (1995) found mature adult lake sturgeon moved 165 km to the east and 170 km to the west after spawning in the Sturgeon River. Similarly, lake sturgeon from the Bad and Sturgeon rivers, which are approximately 220 km apart, exhibited some range overlap, based on tag recaptures (WDNR, unpublished data).

In Wisconsin, fingerlings were released at a rate of 0.6–4.2 fish/ha (based on estuary size) and a mean of 2.2 fish/ha; fry were released at a rate of 1.5–35.2 fish/ha and a mean of 17.7 fish/ha. In Minnesota, fingerlings were released at a rate of 1.1–4.0 fish/ha and a mean of 2.0 fish/ha. The increased capture rate of coded-wire-tagged fish released in Minnesota suggests that larger fish survived better. Coded-wire-tagged fish were released at a rate of 1.2 fish/ha; tagged fish were 127–203 mm long when released and untagged fish were 102–152 mm. The stocking of different life stages in the same year complicated this analysis.

Management Recommendations

Because of slow growth rates and late age-at-maturity and based on known spawning characteristics (Scott and Crossman 1973; Auer 1995) we recommend stocking a minimum of 20 lake sturgeon year-classes in the St. Louis River. If possible, a Lake Superior-strain egg source should be developed, although the Lake Winnebago strain should be considered the alternative source. We recommend all fingerlings stocked be coded-wire-tagged with a year-class specific mark. Stocking of fry and fingerling lake sturgeon should be alternated between years to identify differences in survival between life stages. If adequate survival of stocked lake sturgeon fry is documented, program costs may be minimized and imprinting may be maximized.

We assume historical spawning sites in the St. Louis River are adequate for use by mature lake sturgeon. The project will be judged successful if tagged lake sturgeon spawn at these historical sites and reproduce. Current harvest regulations will be maintained and reevaluated if a self-sustaining population is established. Future stocking and evaluation of the St. Louis River lake sturgeon reintroduction project should be closely coordinated among agencies.

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