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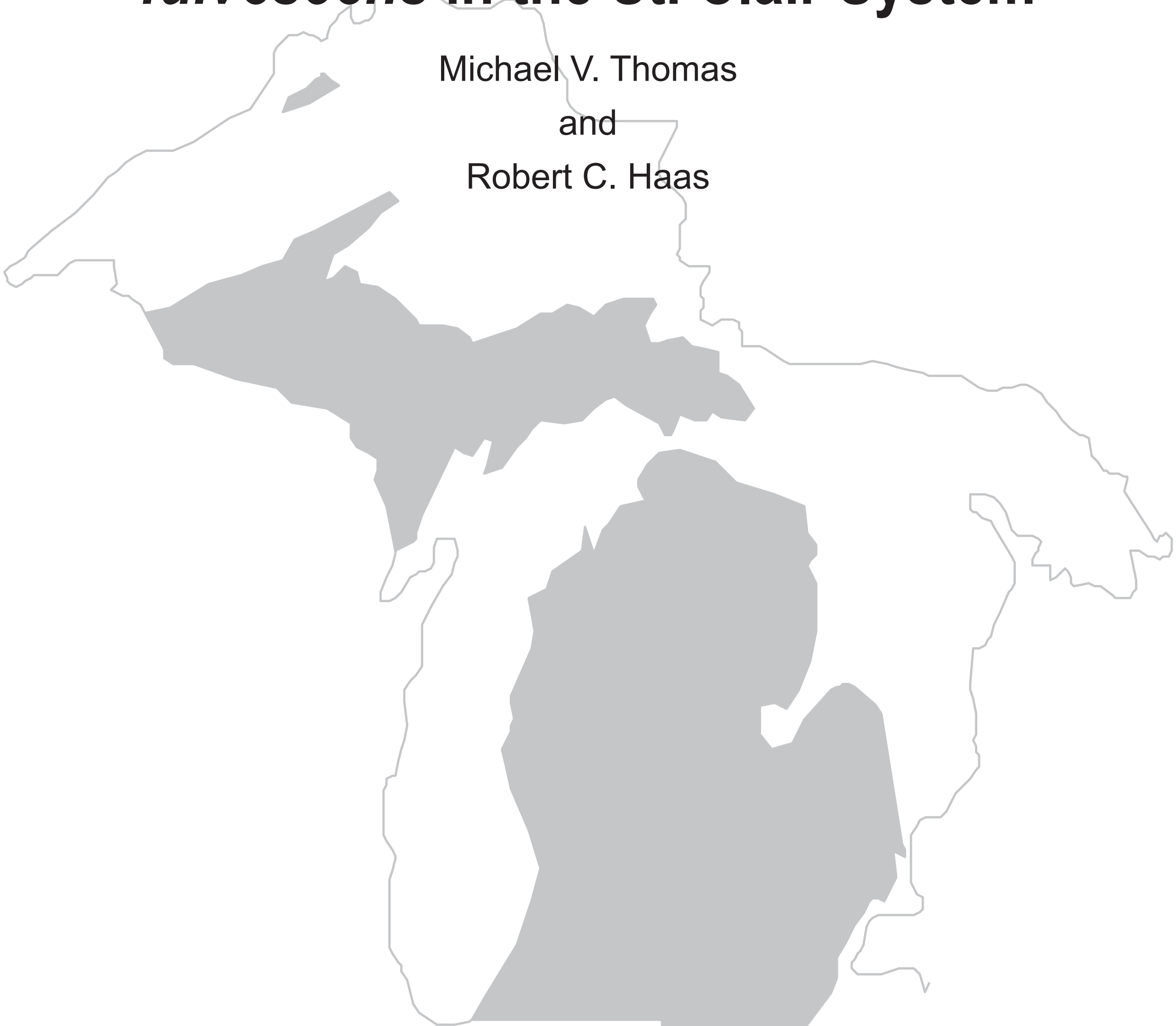

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RESEARCH REPORT

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Abundance, age structure, and spatial distribution of lake sturgeon *Acipenser fulvescens* in the St. Clair System

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Abstract.−Historically, the St. Clair River and Lake St. Clair supported an abundant lake sturgeon population. Since the early 1900s, the status of lake sturgeon populations within these waters has been unknown, largely due to the demise of the commercial fishery. We initiated a study in 1996 to determine the spawning locations, abundance, age structure, and spatial distribution of lake sturgeon in the St. Clair River and Lake St. Clair. One spawning site was identified in the North Channel of the St. Clair River. The site was unusually deep, 9 to 12 m, with a substrate of coal cinders. A total of 1,238 lake sturgeon were captured with trap nets, setlines, trawls, and gill nets. Nearly all the fish captured were tagged and released. Fifty-six tag recoveries were recorded for all sources (assessment, sport fishing, and commercial fishing). Seven fish were recaptured twice, providing more details on individual movements and growth. Tag recoveries documented movement into southern Lake Huron and Lake Erie. Factors such as the open nature of the St. Clair system, unknown level of fishing mortality, tag loss, and individual fish behavior deterred efforts to use mark-recapture data to estimate population size. Age structure, based on interpretation of pectoral fin ray sections, indicated consistent recruitment during the 1970s and 1980s, but low recruitment prior to 1973 and after 1994. Trawling and sidescan sonar analysis documented an area of consistently high lake sturgeon density in the lake near the St. Clair River delta. We used sidescan sonar to estimate the abundance of lake sturgeon in a 255-ha section of that area of the lake at over 29,000 fish in 1999 and about 5,000 fish in 2000. Results of this study indicate the St. Clair system supports a large number of sturgeon with some movement into Lakes Huron and Erie. During summer, sturgeon are densely aggregated in a small geographic area of Lake St. Clair. This dense aggregation likely represents fish from several different spawning locations, including the one identified on the North Channel of the St. Clair River. Gaining an understanding of the characteristics that make that area a preferred location may enhance environmental protection efforts and assist in habitat restoration efforts in other Great Lakes connecting waters.

Lake sturgeon *Acipenser fulvescens* is the only species of sturgeon endemic to the Laurentian Great Lakes. Within the last century, lake sturgeon populations have been dramatically reduced or extirpated from much of their native range (Harkness and Dymond 1961; Brousseau 1987; Hay-Chmielewski and Whelan 1997). Life history traits, such as long life span, large size, and late sexual maturity have made lake sturgeon particularly vulnerable to exploitation. Physical impacts on nursery and spawning areas, construction of barriers to migration, and the effects of fishing have been cited as contributors to the rapid decrease of Great Lakes lake sturgeon since the late 1800s (Auer 1999; Bogue 2000). Currently, the State of Michigan lists lake sturgeon as a threatened species. Thus it is not surprising that lake sturgeon observations or catches are rare across Michigan. However, the St. Clair River and Lake St. Clair are exceptions.

The St. Clair River, Lake St. Clair, and the Detroit River combine to form the connecting channel between Lake Huron and Lake Erie (Figure 1). Fish movement through these waters is unimpeded. In contrast, the other Great Lakes connecting channels, the St. Marys and Niagara rivers, both contain barriers to fish passage. Early commercial fishery records (Baldwin et al. 2000) indicated that lake sturgeon abundance in the St. Clair River, Lake St. Clair, and the Detroit River declined dramatically by 1895. In addition to commercial exploitation, this decline was accompanied by major habitat perturbations. Dams were constructed on tributary streams that supported sturgeon spawning. Spawning grounds in the Detroit River may have been destroyed when bedrock limestone was blasted to deepen the river for commercial shipping and mining operations removed gravel shoals from the Detroit and St. Clair rivers. Despite these perturbations, lake sturgeon remained in the St. Clair system at lower levels of abundance throughout the 20th century. A limited commercial fishery remained in the Ontario waters of Lake St. Clair through 2003. In recent years, only one licensed sturgeon fisherman has been active, with an annual harvest quota of 1,100 pounds (headed and dressed) or approximately 30 fish (Don MacLennan, Ontario Ministry of Natural Resources [OMNR], Wheatley, personal communication). Baker (1980) reported that a largely illegal snag fishery for mature, spawning, lake sturgeon continued to exist in the Michigan waters of the St. Clair River near Algonac through the 1960s and 1970s, but the clandestine nature of the fishery prevented data collection.

Sport fishing regulations for lake sturgeon in the Michigan waters of the St. Clair system became progressively more conservative after 1970. A minimum size limit (1,067 mm) was first established in 1970, then increased to 1,270 mm in 1974. A closed season was established in 1983 to protect spawning sturgeon in the St. Clair River. The daily possession limit was reduced from two fish per season to one fish per season in 1994. Since 1999, the recreational harvest in Michigan has been further restricted with an open season from July 15 to September 30, a legal harvest size range from 1,067 mm to 1,270 mm, and a mandatory catch registration program. Ontario recreational fishing regulations for the St. Clair system included no minimum size limit, no closed season, and a one sturgeon per day bag limit in 2002.

Because lake sturgeon have been rare across the State of Michigan for nearly a century, fisheries research and management efforts focused on a few inland locations where small spawning groups of sturgeon are readily accessible in shallow rivers. Lake sturgeon abundance, distribution, age structure, genetic structure, and spawning locations in Great Lakes waters are less well known. In recognition of this information gap, the Michigan Department of Natural Resources (MDNR) Lake Sturgeon Rehabilitation Strategy (Hay-Chmielewski and Whelan 1997) recommended an inventory of abundance and age structure for all known lake sturgeon populations in the state. The goal of our study of sturgeon in the St. Clair system was to obtain basic information about the sturgeon population crucial for protecting and managing this unique resource. Specific objectives of this study were to determine (1) spawning period, areal distribution of spawning activity, and spawning habitat for lake sturgeon in the St. Clair River; (2) abundance, age structure, and spatial distribution of lake sturgeon in the St. Clair River and Lake St. Clair; and (3) early (juvenile) life history of lake sturgeon in the St. Clair River and Lake St. Clair, and identify their habitat requirements.

Methods

Study Sites

St. Clair River.−The St. Clair River is a 63-km long strait with an average discharge of 5,100 m^3/sec (Edsall et al. 1988). The river flows north to south from Port Huron, Michigan to Algonac, Michigan before splitting into a series of deltaic channels. River velocity ranges from 6.0 km/hr at Port Huron to 1.1 km/hr at Lake St. Clair (Edsall et al. 1988). The average velocity is 3.5 km/hr. From Port Huron to the delta, depths range from 8 to 21 m. Depths in the delta channels are more variable with maximum depth of 27 m in the North Channel. Sediment deposition at the mouths of delta channels results in water depths less than 3 m and necessitates maintenance dredging for navigational access. Approximately 33% (1,690 m^3/sec) of the St. Clair River discharge passes through the North Channel into Anchor Bay of Lake St. Clair (Edsall et al. 1988). Sampling for this study was focused in the North Channel, near Algonac, Michigan (Figure 2). Sampling locations were determined by trial and error. Locations where sturgeon were captured with setlines were sampled repeatedly, while locations where setlines did not capture sturgeon were seldom sampled again.

Lake St. Clair.−Lake St. Clair has a surface area of 1,114 km^2 with an average depth of 3 m and a maximum natural depth of only 6.4 m (Bolsenga and Herdendorf 1993). A navigation channel, maintained at a depth of 8.2 m, bisects the lake, connecting the South Channel of the St. Clair River with the Detroit River. The hydraulic retention time of Lake St. Clair is short, 2-30 days. Sampling for this study occurred throughout Lake St. Clair. A 2.5-minute latitude by 2.5-minute longitude grid system was established (Figure 2) and each grid was categorized as nearshore (if the grid encompassed the shoreline) or offshore (shoreline not present in the grid). Three sectors were established based on the geography of the lake: northwest, southwest, and southeast. Three nearshore grids and two offshore grids were then randomly selected from each sector for each month from June to October.

Spawning Site Identification

We identified likely sturgeon spawning locations in the St. Clair River delta from conversations with local fishing and scuba diving enthusiasts. Potential spawning sites were then examined by divers and underwater video. The presence of spawning sturgeon and egg deposition was confirmed at only one site. The area of the spawning site was measured by divers and water temperatures were recorded daily.

Early Life History Investigation

Our strategy was to identify juvenile habitat preferences by locating congregations of juveniles, or locations with consistent presence of juveniles, using trap nets, setlines, trawls, small-mesh fyke nets, visual searches with underwater video, and snorkel searches. Once specific locations were identified, we planned to measure various habitat parameters to quantify the conditions at the site. However, our experimental efforts to locate juveniles were not successful. Work on this objective (3) will continue through 2007. Therefore, we do not address this objective any further in this report.

Catch and Abundance

Low numbers of lake sturgeon were captured in trap nets fished in Anchor Bay of Lake St. Clair during late April and May. Trap nets had a 1.8-m deep pot of 5.1-cm stretch mesh, 7.6-cm stretch-mesh heart and wings, and a 91.4-m long lead of 10.2-cm stretch mesh. These nets were targeting yellow perch or smallmouth bass, depending on the year, for jobs included in other MDNR research studies. However, lake sturgeon incidentally captured during these netting efforts were included in this study.

Lake sturgeon were captured with setlines in the St. Clair River during May and June (Thomas and Haas 1999). Each setline consisted of a 91.4-m mother line (0.95-cm diameter, diamond-braid rope) with 25 leaders attached at 3-m intervals. Each leader consisted of an 0.46-m length of #36 tarred nylon twine, a net snap with swivel, and one Kirby sea hook size 4 (10/0), for an overall length of 0.61 m. Anchors (11.4 kg) were attached at each end of the mother line and attached to a surface buoy. Hooks were baited with cut baits or whole fish, previously frozen and thawed. Initially, we used a variety of cut baits including bluegill *Lepomis macrochirus*, Atlantic mackerel *Scomber scombrus*, Atlantic herring *Clupea harengus*, carp *Cyprinus carpio*, white sucker *Catostomus commersoni*, channel catfish *Ictalurus punctatus*, northern pike *Esox lucius*, alewife *Alosa pseudoharengus,* and squid *Loligo spp* (both frozen and pickled). Whole alewife, rainbow smelt *Osmerus mordax*, spottail shiner *Notropis hudsonius*, trout-perch *Percopsis omiscomaycus*, and round goby *Neogobius melanostomus* were also used. We also tried chicken livers and large earthworms *Lumbricus terrestris*. Round goby out performed all other baits.

Trawls were used to capture lake sturgeon in Lake St. Clair from June to October. All sampling took place during daylight hours. Nearshore trawling was conducted from small boats, typically in water depths of 0.6 m to 2 m. Nearshore trawling gear consisted of a 5.3-m headrope otter trawl constructed of 38.1-mm stretched measure mesh with a 9-mm stretched mesh liner in the cod end. All offshore trawling was conducted from the MDNR research vessel *Channel Cat*, in water depths exceeding 2 m. Offshore trawling gear consisted of a 10.66-m headrope otter trawl towed with single warp and a 45.7-m bridle. The trawl was constructed of 76-mm, 38-mm, and 32-mm graded stretched mesh from gape to cod end with a 9-mm stretched-mesh liner in the cod end. Occasionally, a custom built trawl was used offshore to target lake sturgeon. This trawl had a 10.66-m headrope with single warp and 45.7-m bridle. Stretched mesh size ranged from 152 mm at the gape to 76 mm at the cod end. Whenever possible, trawl tows were made on lake bottom, for 10 minutes, and at approximately 2.0 knots. Sometimes tow duration was shortened to avoid heavy plant growth or other physical obstructions. Sturgeon catches were standardized as the number of fish caught per ha by estimating the area swept by the trawl during each tow. Area swept was calculated based on the gape of the trawl and the linear distance between starting latitude and longitude and ending latitude and longitude.

A small number of lake sturgeon were caught in experimental large-mesh gill nets fished in Lake St. Clair during August 2001. Three short daytime sets were made with gangs of nets 1.83 m deep. Two sets were made with a net consisting of nine 15.2-m long panels of 254-mm stretched mesh. One set was made with a net that consisted of three 30.4-m long panels of 203-mm stretched mesh. All nets were deployed on the bottom for 2 hours.

Total length, weight, and any physical abnormalities were recorded for each lake sturgeon captured. The t-test for independent samples was used to test for differences in mean size and age between lake sturgeon captured in the St. Clair River and Lake St. Clair. From 1999 to 2002, fresh lamprey attachment marks were also recorded. All lake sturgeon were tagged with individually numbered, self-piercing, monel cattle ear tags bearing the address for the MDNR Lake St. Clair Fisheries Research Station. The tags were applied to the left opercle from 1996 to June 1998, and thereafter applied to the dorsal fin.

Mark-and-recapture data from the St. Clair River and Lake St. Clair were pooled and analyzed with CAPTURE® software (White et al. 1978). Each year was considered a discrete marking and capture event. Fish marked and recaptured within the same year were not considered recaptures for this analysis. The CAPTURE® program selects the best mark-recapture model with consideration of time, animal behavior, and heterogeneous individual probability of capture. The program indicated the model most appropriate for the data incorporated time effects, behavioral response, and heterogeneity. However, this model produces no population estimate.

Age Analysis

Beginning in 1997, the leading (marginal) ray of the left pectoral fin was removed for age interpretation. We followed the procedures described in Rossiter et al. (1995). Fin ray samples were allowed to dry in a freezer for a period of at least 2 months. The base of the ray was then cross-sectioned into 0.305-mm thick slices with a slow-speed diamond-bladed saw (Isomet). The slices were mounted on microscope slides and examined under a binocular microscope. Various magnifications and lighting conditions were used to optimize the legibility of the growth rings. An age was assigned based on the pattern of clear and opaque zones. Each pair of clear and opaque zones was considered a single year. Each sturgeon was assigned to a year-class by subtracting the estimated age of the fish from the year of capture. Catch by year-class was totaled across sampling years and gear type to assess overall patterns in recruitment. We also used this total cumulative catch distribution by year-class as an approximation of a synthetic catch curve. This approach requires assumptions of constant recruitment and constant survival at age over time. We applied a standard catch curve analysis (Quinn and Deriso 1999) to the portion of the right side (descending) of the curve that provided the highest R^2 value.

Spatial Distribution Analysis

Global positioning system (GPS) receivers were used to record geographic location data for setline and trawl sampling sites. Sampling sites and fish capture locations were mapped with ArcView® GIS geographic information system software (version 3.2a, Environmental Systems Research Institute, Inc.). ArcView® was then utilized to map areas of high, medium, and low sturgeon frequency of occurrence in Lake St. Clair based on trawl catch rates.

A Sea Scan PC©, 600 kHz, sidescan sonar (Marine Sonic Technology, Ltd.; Gloucester, VA) was used to map bottom transects through the area of high sturgeon density in Lake St. Clair during August of 1999 and 2000. Computer files containing sidescan images were projected and saved as GEOTIFF files using SonarWeb Pro© (Chesapeake Technology, Inc.) software and loaded into ArcView® for extraction of fish information. Bright fish echoes and dark acoustic shadows, cast by the fish, were digitized on the computer screen as point features for determination of geographic coordinates and enumeration. Obvious fish echoes, assumed to be sturgeon, were also digitized as line features. The length of echo traces (line features) were calculated in ArcView® and compared to lengths of sturgeon caught in trawls. Polygons were created in ArcView® that calculated the lake bottom area covered by each projected sidescan file. The geographic center of fish echoes for each year was determined in ArcView® and used as a central point to create concentric circular polygons at 50-m radial increments (Figure 3). A total of 18 concentric polygons were created for each of the 2 years and then converted to "doughnut" polygons covering only the area between the neighboring concentric doughnuts. Areas within individual doughnuts were determined. Doughnut polygons were used to select all projected sidescan files that they touched. Mean numbers of fish per ha were calculated using those sidescan files intersecting each doughnut. These mean fish density values were expanded by the total area for that doughnut and summed across all doughnuts to estimate the total fish population within the area circumscribed by the largest doughnut.

Results

Spawning Site Identification

We identified a sturgeon spawning site in the North Channel of the St. Clair River near Algonac, Michigan (Figure 4). Sturgeon spawning on the site was verified with underwater video, capture of ripe fish with setlines placed on the site, and collection of fertilized eggs from the substrate at the site. The site was characterized by water depths of 9 m to 12 m, flow rates of 1 m/s, and substrate composed of coal cinders ranging in size from 0.5 cm to 12 cm in diameter. The cinder bed measured approximately 25 m by 54 m and roughly paralleled the shoreline. Photographs of the coal cinder substrate at the site were published by Manny and Kennedy (2002). Sturgeon spawned on the site on June 13 and 14, 1997. Water temperature at the peak of spawning in 1997 was 13.2°C. In 1998, water temperatures reached 13°C and sturgeon began spawning on the site on May 18. In 1999, water temperatures were 12°C on May 20, when ripe sturgeon were first captured. An underwater video system was used to record nearly 80 hours of video of fish activity on the spawning site. Numerous sturgeon spawning events were recorded, as well as the feeding behavior of sturgeon, redhorse spp., and round goby.

Efforts to map the spawning site with sidescan sonar in 1998 and 2000 were largely unsuccessful. Fairly good sidescan images of the site were captured by the Seascan system, but signal returns from the cinder substrate were not obviously different from surrounding clay and gravel substrates. We also found that river currents tended to make the towfish unstable, producing considerable image distortion. Further, steep bottom contours typical of the St. Clair River shorelines made it difficult to use the sidescan sonar effectively. Therefore, we were unable to use the sidescan system to quickly search for other potential spawning locations in the river, as we had originally envisioned.

Catch and Effort Totals

From May 1996 to October 2002, MDNR assessment efforts captured 1,238 lake sturgeon. A total of 489 fish were captured with 434 setline lifts in the St. Clair River. In Lake St. Clair, a total of 1,290 trawl tows captured 721 sturgeon. Additionally, 28 more sturgeon were caught with trap nets (17 fish in 56 net lifts) and gill nets (11 fish in 3 net lifts) in Lake St. Clair. In total, 1,201 lake sturgeon caught with assessment gear were tagged and released. Sturgeon caught with setlines in the St. Clair River were significantly older, longer, and heavier (α=0.05) than those caught with trawls from Lake St. Clair (Table 1).

Lamprey Marks

Fifty-nine percent (59%) of the lake sturgeon examined between 1999 and 2002 bore lamprey attachment marks. The incidence of lamprey attachment marks was much higher for sturgeon captured in Lake St. Clair, 75%, than for those captured in the St. Clair River, 36%. No trend in lamprey mark incidence was apparent across years. All attached lampreys were identified as silver lampreys *Icthyomyzon unicuspis*. Individual sturgeon often had multiple fresh attachment marks. Most attachment marks were superficial with very little bleeding and no penetration of the musculature. The highest number of marks recorded on a single lake sturgeon was 23. During this study, no lake sturgeon were captured with attached sea lampreys *Petromyzon marinus*.

Age Structure and Estimates of Survival

Ages for 1,106 sturgeon collected during the assessment, based on interpretation of pectoral fin ray sections, ranged from 1 to 74 years. A total of 55 year-classes were represented. A general pattern of higher frequency of occurrence was evident for cohorts produced since 1973. The 1977, 1985, and 1993 year-classes appeared to be the strongest cohorts produced (Figure 5). Conversely, the 1981, 1987, and 1992 year-classes appeared to have been weak.

Catch curve analysis of the cumulative catch for each year class (summed across all years) provided estimates of annual mortality and survival. The strongest linear relationship (R^2 = 0.8494) was found when the analysis was limited to the 1979 to 1963 year classes (Figure 6). For those cohorts, annual survival (S) was estimated at 0.91. However, expanding the analysis to include the 1979 to 1957 cohorts produced an S estimate of 0.86 and a linear relationship only slightly weaker (R^2 = 0.841).

Tag Recoveries

From a total of 1,201 fish tagged and released, 56 tag recoveries were reported through 2002 (Table 2). This total includes 27 recoveries with assessment gear (setlines, trawls, and gill nets combined), 27 recoveries by sport and commercial fishing, and 2 recoveries from dead, floating, fish. Although 58% of all sturgeon tagged during this study were originally caught with trawls in Lake St. Clair, recaptures of those fish were disproportionately low. From a total of 56 recaptures only 10 (18%) of the fish were originally captured with trawls in Lake St. Clair. A total of 21 lake sturgeon were recaptured with setlines, and only five were recaptured with trawls. All 21 fish recaptured with setlines were originally captured with setlines in the St. Clair River. Two of the five sturgeon recaptured in Lake St. Clair with trawls were originally captured with a trawl, two were originally captured with setlines, and one was first caught in a gill net.

Recreational or commercial fishers reported catching a total of 27 tagged lake sturgeon. Seven tag recoveries were reported by Michigan recreational anglers from the North Channel of the St. Clair River. All of these fish were caught during the closed season and were reportedly released. All seven were fish that were originally captured with setlines in the North Channel. Eight tag recoveries were reported from the Ontario commercial fishery in southern Lake Huron, strong evidence of lake sturgeon movement northward out of the St. Clair system. Six of the commercial fishery recoveries were fish originally caught with setlines, two were originally captured with a trawl.

More than half of all recoveries (30) were reported from the St. Clair River (Table 3). Lake Huron recoveries were the second most common, accounting for 30% of the total. Only eight fish were recovered from Lake St. Clair, and one recovery was reported from Lake Erie. In total, 49 individual fish were recaptured, including 7 fish that were recaptured twice. A more detailed history of the tagging and recapture events for those seven fish is provided below.

Tag Loss

Two fish recaptured with survey gear appeared to have shed the original tag. Both of these fish bore scars on the opercle and left pelvic fins lacked the leading ray, however, because the original tag had been shed, it was not possible to determine where, or with which gear type, the fish was initially captured. Since evidence of tag loss has only been observed in 2 out of 29 recaptures, the estimate of tag loss is 6.9%.

Individual Histories for Fish with Multiple Recaptures

Fish #1106 was a female originally caught with a setline in the North Channel of the St. Clair River, near the spawning site close to Sassy Marina, on May 30, 1997. At initial capture, the fish was 1,397 mm in total length (TL), 16.3 kg total weight, and estimated to be 21 years old (1976 year-class). The fish was recaptured by a sport angler 630 days later, on February 19, 1999, about 4 km downstream from the original tagging location, near Deckers public access site (PAS). The fish was recaptured again by a sport angler 34 days later at the same location near the Deckers PAS. Neither angler obtained length or weight information.

The sex of fish #1107 was undetermined when it was originally caught on May 30, 1997 on the same setline in the North Channel as fish #1106. At initial capture the fish was 1,045-mm TL, 7.1-kg total weight, and estimated at 14 years old (1983 year-class). It was caught a second time on a setline just 12 days later, on June 11, 1997, at the original tag site near Sassy Marina. After another 373 days-at-large (June 19, 1998), the fish was recaptured by a sport angler fishing from a dock on the St. Clair River, just upstream from Algonac, about 5 km upstream from the two 1997 recaptures. The angler reported the TL was 1,219 mm. This would represent an increase in TL of 174 mm in just over 1 year. We suspect that the TL reported by the angler was inaccurate.

Fish #1330 was originally caught on a setline in the North Channel of the St. Clair River, just above the Sni Bora, on May 27, 1998. At initial capture the fish was 1,024 mm TL, 6.8 kg total weight, estimated at 15 years old (1983 year-class), and sex was undetermined. The fish was recaptured with a setline 366 days later (May 28, 1999), about 1.5 km upstream near the cinder pit spawning site by Sassy Marina. The fish had grown 30 mm in TL, and increased in weight by 0.3 kg. On May 30, 2001, the fish was recaptured again, after 733 days-at-large. It was caught in the North Channel, between the original tag site and the location of the first (1999) recapture event. The fish increased 84 mm in TL and 1.6 kg in total weight during the 2-year interval between recaptures. So, over the 3-year interval between the original capture and the second recapture, fish #1330 increased in TL by 114 mm, for an average annual growth rate of 38 mm per year.

Fish #1334 was originally caught on a setline in the Middle Channel of the St. Clair River, just downstream of the confluence with the St. Clair River North Channel, on May 27, 1998. At initial capture the fish was 1,610 mm TL, 27.9 kg total weight, estimated at 35 years old (1963 year-class), and sex was undetermined. The fish was recaptured with a setline 730 days later (May 26, 2000), in the North Channel on the spawning site near Sassy Marina, approximately 2 km downstream of the Middle Channel–North Channel division. The fish had grown 28 mm in TL, and increased in weight by 9.6 kg. On June 4, 2002, the fish was recaptured again, after an additional 739 days-at-large. It was caught in the North Channel on the spawning site near Sassy Marina, the same location as the first (2000) recapture event. The TL of the fish had not changed, but it weighed 1.3 kg less than at the first recapture. During the 4-year interval between the original capture and the second recapture, fish #1334 increased in TL by only 28 mm, for an average annual growth rate of 7 mm per year.

On May 25, 1999, fish #1736 was caught on a setline in the North Channel of the St. Clair River, just upstream from the Middle Channel confluence. At initial capture the fish was 866-mm TL, 3.7-kg total weight, estimated at 6-years old (1993 year-class), and sex was undetermined. The fish was recaptured with a setline 353 days later (May 12, 2000) in the North Channel, less than 0.5 km below the spawning site near Sassy Marina and approximately 3 km downstream from the original tag site. The fish had grown 41 mm and 0.1 kg. On June 6, 2002, the fish was recaptured again, after an additional 755 days-at-large. It was caught near the original tag site above the Middle Channel–North Channel confluence. The fish had increased another 27 mm and 0.1 kg. During the 3-year interval between the original capture and recapture, fish #1736 increased in TL by only 61 mm, for an average annual growth rate of 20.3 mm per year.

Fish #1770 was originally caught on a setline in the North Channel of the St. Clair River near the MDNR North Channel PAS at Algonac, on June 2, 1999. At initial capture the fish was 734 mm TL, 1.9 kg total weight, estimated at 7 years old (1992 year-class), and sex was undetermined. The fish was recaptured in a commercial fishing net in southern Lake Huron in 2000. The first recapture date, location, length, and weight of the fish were unrecorded, but the fish was released alive in the St. Clair River, at Sarnia. The fish was recaptured again in 2001 in southern Lake Huron with a commercial net. Again, the exact recapture date and location were not recorded, but TL was measured at 771 mm. So, over the 2-year interval between the original capture and the second recapture, fish #1770 increased by 37 mm, for an average annual growth rate of 18 mm per year.

Fish #8120 was originally caught on a setline in the North Channel of the St. Clair River near the MDNR North Channel Public Access Site at Algonac, on June 5, 2001. At initial capture the fish was 1,316-mm TL, 15.9-kg total weight, estimated at 19 years old (1982 year-class), and sex was undetermined. The fish was recaptured with a setline 360 days later (May 31, 2002), in the North Channel on the spawning site near Sassy Marina, about 7.5 km downstream from the original tag site. The fish had grown only 4 mm in TL, and decreased in weight by 0.2 kg. Eleven days later (June 11, 2002), the fish was recaptured a second time with a setline, about 0.8 km downstream of the first recapture event.

Spatial Distribution

Trawl catches of lake sturgeon in Lake St. Clair revealed several interesting aspects of lake sturgeon distribution within the lake. First, no lake sturgeon were captured during nearshore trawling on the lake. Over the course of the study, a total of 383 nearshore trawl tows, sweeping an estimated total area of 32.6 ha, collected no lake sturgeon. Secondly, when lake sturgeon were captured within a grid, they tended to be captured repeatedly within that grid. Lake sturgeon were captured in 12 of the 63 grids sampled (Figure 7), and in 10 out of 12, sturgeon were captured more than once. Finally, lake sturgeon sometimes occurred in highly localized groups, resulting in high trawl catch rates. Individual trawl catch rates of 10 or more sturgeon per ha were recorded in 5 of the sturgeon grids. Trawl catch rates in grid 24 often exceeded 10 sturgeon per ha and included 12 trawls with catch rates exceeding 20 sturgeon per ha. While sampling in grid 24, sturgeon were often seen breaching and jumping in the vicinity of the research vessel. The highest catch rate for a single trawl tow was 62 sturgeon per ha, in grid 24.

Fish echoes and shadows were plotted, counted, and measured from projected sidescan files made in August of 1999 and 2000. It was evident from the ArcView® maps of fish echo distribution that they tended to be concentrated in a small area. The centroids of fish geographical distribution were only 150 m apart between the 2 years. Eighteen concentric doughnut polygons were created around the centroid for each year ranging in area from 0.8 ha for the innermost doughnut to 27.5 ha for the outermost doughnut. The entire area within the doughnuts was 255 ha, which fell almost entirely within the north half of grid 24. In 1999, the innermost doughnut had an estimated fish echo density of 253/ha (versus 146/ha in 2000) and the outermost doughnut had an estimated 66/ha (versus 0/ha in 2000). Estimates of lake sturgeon size and density were made within polygons and summed to get total estimates each year for the 255-ha area (Table 4). Based on the sidescan analysis, the number of lake sturgeon present was 29,262 in 1999, and 5,038 in 2000, when densities of were much lower. Mean lengths of fish echoes were calculated from the line segments digitized in ArcView®. Mean echo length was 940 mm in 1999 and 1,200 mm in 2000. Mean length of sturgeon captured with trawls in the area of the sidescan sonar sampling was 1,178 mm in 1999 and 1,252 mm in 2000.

Discussion

Spawning Site Identification

Some features of the North Channel spawning site are atypical of known lake sturgeon spawning locations. First, there is no natural or man-made barrier on the St. Clair River, thus upstream and downstream access to the site is open for fish from lakes Huron and Erie. Secondly, the site depth (9 m) is much greater than that previously reported for lake sturgeon spawning locations in smaller rivers (Scott and Crossman 1973; Kempinger 1988; LaHaye et al. 1992). However, the depths of two other lake sturgeon spawning locations recently identified in the Detroit-St. Clair waterway are even greater (Manny and Kennedy 2002). Thus, lake sturgeon spawning is likely not depth limited, but limited by other factors such as temperature regime, flow velocity, and substrate characteristics.

Most documented lake sturgeon spawning locations have been characterized by natural gravel, cobble, or rubble substrates. Thus, the coal cinder substrate at the North Channel site is unusual, but not unique. Lake sturgeon spawning on coal cinders has been reported from at least two other locations (Kempinger 1988; Caswell et al. 2004). The coal cinders at the North Channel site are believed to have been deposited during the late 1800s when coal-burning vessels moored to load salt from a nearby factory and emptied their cinders into the river. The cinder substrate is now zebra mussel encrusted, and the three-dimensional structure of the cinders combined with the zebra mussel layer provide a complex system of interstitial spaces that appears to provide excellent protection for deposited eggs and fry. However, other site features were recently identified that could be limiting spawning success and recruitment. These features include too few spawners, poaching, low egg retention on the reef, and low hatch rate (Nichols et al. 2003).

Movement Patterns

Recaptures of lake sturgeon tagged in the St. Clair River and Lake St. Clair indicated that fish moved between the St. Clair River and lakes Huron and Erie. In some cases these movements may represent spawning migrations of adult Lake Huron or Erie fish to and from natal spawning sites in the St. Clair River. However, in many cases juvenile or apparently non-spawning adult fish were involved. The stimulus for movements by non-spawning condition fish are unknown, but could include seasonal movements to better foraging locations.

The low recapture rate for fish originally caught with trawls in Lake St. Clair is interesting. These fish may have experienced high mortality due to stress from capture with trawls during the warmest months of the year. However, only two dead sturgeon bearing tags have been found, so high mortality seems unlikely. One was originally captured on a setline, while the other was originally caught with a trawl. The lack of setline recaptures for fish originally caught with trawls in Lake St. Clair is striking (Table 2), especially considering the high number of setline recaptures of fish previously caught with setlines in the North Channel. We consider this evidence that Lake St. Clair is used by lake sturgeon from a broad geographic area and the local North Channel spawning group represents a small portion of the total population in the system. This scenario is supported by telemetry study results for the St. Clair River (Boase 2003) and the Detroit River (Caswell 2003), which documented co-mingling of adults from the two rivers in Lake St. Clair during the summer. Thus, we surmise lake sturgeon caught with trawls during the summer in Lake St. Clair tend to remain in the lake, or move up the St. Clair River and northward into Lake Huron. Since no Lake St. Clair tagged fish have been recaptured on setlines or by sport anglers in the North Channel of the St. Clair River, it would appear that most movement northward from the lake occurs through the South Channel.

The distribution of tag recoveries is a function of the distribution of both fish and fishing effort (assessment and non-assessment). We suspect the high proportion of recaptures from the St. Clair River (Table 3) is a product of fish densities magnified by the narrow confines of the St. Clair River accompanied by an intense recreational fishery. Walleye tag recovery data from tagging sites in western Lake Erie and Lake St. Clair also suggest an intensive sport fishery is present in the St. Clair River (Robert Haas, Michigan Department of Natural Resources, Mt. Clemens, personal communication). In contrast, the low lake sturgeon recapture rate for Lake St. Clair may be a reflection of lower fishing pressure and lower fish densities (on a per unit area basis) due to its comparatively large area. In fact, we observed few anglers fishing in the area of high lake sturgeon density during our trawl surveys on Lake St. Clair.

The seven fish that were recaptured twice provided additional insight into the movements of lake sturgeon in the St. Clair system. All seven fish were originally captured with setlines in the St. Clair River. Six of those (including three mature adults and three younger fish) were subsequently recaptured twice in the St. Clair River, predominantly in the North Channel near the spawning site. Two of the fish were recaptured twice by sport anglers, while the other four were recaptured twice on setlines. We believe these multiple recapture events in the St. Clair River support our theory that fishing effort is fairly intensive on this water body. It is also interesting that the one fish recaptured twice outside the St. Clair River was a juvenile that moved northward into southern Lake Huron, and was recaptured there in commercial nets during two consecutive years.

While sturgeon captured in the St. Clair River were older and larger than those collected in Lake St. Clair, the difference may have been a function of differing selectivity of the sampling gear rather than a difference in locale. Since both gear types have not been used at the same location at the same time, their relative age or size bias has not been evaluated. However, both juvenile and adult sturgeon were captured with both gear types. This suggests juvenile and adult lake sturgeon are present in the St. Clair River, near the spawning site, during the spawning period. It also indicates juvenile and adult lake sturgeon are present in Lake St. Clair during the summer months in waters over 2 m deep.

Spatial Distribution

Fish echoes in sidescan sonar images, presumably from lake sturgeon, were approximately five times more abundant in 1999 than in 2000. The big difference between years probably reflects a real difference in concentration rather than error in density estimation. The factors behind such a substantial difference in densities in a particular area of the lake are unclear. It is possible that the fish were more widely dispersed, or that the timing of migratory movements differed between the two years. In any case, we are convinced that the density did in fact differ considerably between years in the region surveyed with sidescan sonar. In 1999, we towed an underwater video camera while making sonar transects and only sturgeon were seen. We also hit two sturgeon with the video camera, so we are certain that sturgeon density was very high that year. The 1999 estimate of 29,262 sturgeon agrees very well with our earlier mark-recapture population estimate of 45,506 and lower confidence bound of 24,230 sturgeon (Thomas and Haas 2002), if a large share of the Lake St. Clair sturgeon population in August of 1999 was concentrated in that area of the lake. In 2000, at times we used the sidescan sonar to look for large fish echoes as targets for trawling. Random trawls often did not produce sturgeon, but trawls in areas where sidescan showed large fish echoes routinely produced sturgeon catches. Mean fish echo lengths estimated from the sonar traces in 2000 were only slightly different from mean length measurements taken from trawl caught sturgeon in the same area of Lake St. Clair. We think this gives credence to our assumption that the fish echoes in sonar files were predominantly reflections from lake sturgeon.

The highest densities of lake sturgeon, as indicated by trawl catches and sidescan sonar, occurred in Lake St. Clair grid 24. Habitat characteristics that make grid 24 so attractive to lake sturgeon are unclear. Bathymetric maps of Lake St. Clair suggest that an old, natural channel of the St. Clair River passes through grids 17 and 24. Flow studies by Ayers (1964) indicated that under prevailing westerly winds, strong currents sweep through both grids from north to south. Hydraulic studies of the St. Clair River reported that 53% of total St. Clair River volume passes through the shallow Anchor Bay area of Lake St. Clair from the North and Middle Channels (Edsall et al. 1988). Knights et al. (2002) documented that Mississippi River lake sturgeon preferred habitats characterized by transition from high current velocities to lower velocities. These areas were also typified by depositional substrates (silt-containing). Interestingly, Boase (2003) noted that sites where lake sturgeon were found in Lake St. Clair had significantly higher densities of burrowing mayflies (*Hexagenia* spp.) than sites without lake sturgeon. Burrowing mayflies require depositional substrates, high in silt, clay, or marl that are soft enough to enable burrowing, but cohesive enough to prevent burrow collapse (Hunt 1953). We speculate that a combination of river and lake morphology and water currents results in a depositional zone off the deltaic channels, which lake sturgeon find attractive, perhaps due to abundant food resources in the form of burrowing mayflies. Further quantification and analysis of flow, substrate, benthos, and aquatic plants could provide additional insight. For whatever reason, grid 24 of Lake St. Clair clearly serves as an important summer and fall habitat for both juvenile and adult lake sturgeon. Gaining an understanding of the characteristics that make it a preferred location may enhance environmental protection efforts and assist in habitat restoration efforts in other waters.

Synthesis of a Seasonal Pattern of Movement and Distribution

Since 1996, several studies have collected information about seasonal patterns of movement and distribution for lake sturgeon in the connecting waters of southeast Michigan. Specifically, our study and contemporary telemetry studies on the Detroit River (Caswell 2003) and the St. Clair River and Lake St. Clair (Boase 2003) provided complimentary data. Both telemetry studies attempted to describe movements of spawning adults, but ultimately documented seasonal movements by both spawning and non-spawning individuals, because sturgeon captured near the spawning sites were often immature, or mature but not in spawning condition. For the Detroit River, Caswell (2003) identified a spawning location near Zug Island, about halfway between Lake Erie and Lake St. Clair. One-third (7/21) of the lake sturgeon captured and implanted during the spawning period migrated upstream into Lake St. Clair as summer progressed. Meanwhile, a downstream migration of lake sturgeon into Lake Erie was also observed during the summer and fall. The magnitude of this movement seemed to be less than the upstream movement of Detroit River spawning fish into Lake St. Clair. Caswell (2003) noted a return of at least some of the fish from Lake St. Clair and Lake Erie into the Detroit River the following spring. Two spawning locations were identified on the St. Clair River: the North Channel site near Algonac and the Bluewater Bridge site at Port Huron. The St. Clair River telemetry study (Boase 2003) found that nearly 70% (11/16) of sturgeon implanted near the North Channel spawning site during spawning season subsequently migrated downstream into Lake St. Clair for the summer. An upstream migration by some fish towards, and presumably into, Lake Huron was also apparent. Fish from both the Detroit River and St. Clair River studies co-mingled in the area of Lake St. Clair identified as a zone of high sturgeon density during summer months, based on trawling and sidescan sonar results from our study. Tag recoveries from our study, which occurred over a longer time span than the telemetry studies, support the downstream and upstream movements documented by Boase (2003) and Caswell (2003). However, individual movement from the St. Clair River spawning area as far downstream as Lake Erie was also noted (Table 3). Our tagging also revealed a substantial movement of fish captured and tagged during the summer in Lake St. Clair upstream into Lake Huron, where they were recaptured in the Ontario commercial trap net fishery during subsequent years. In summary, available evidence suggests that lake sturgeon movements in the connecting waters are complex and defy a simple qualitative description. Several other studies have documented similar complexity in lake sturgeon movement patterns (Knights et al. 2002; Rusak and Mosindy 1997; Fortin et al. 1993). Much of this complexity has been attributed to lake sturgeon life history characteristics (late maturity, intermittent spawning, differing maturity and spawning periodicity between sexes).

Population Abundance

Mark-recapture estimates of population abundance are tenuous for this system for several reasons. The St. Clair system is an open system, which violates important mark-recapture assumptions. Lake sturgeon movements between Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, and Lake Erie appear to occur frequently.

Fishing mortality was an additional complicating factor in our efforts to use mark-recapture data for estimating the population abundance in the St. Clair system. The total annual sturgeon harvest within the St. Clair system is unknown. A commercial fishing license with a quota of about 30 lake sturgeon is still valid for Lake St. Clair, but hasn't been active in several years (Don MacLennan, Ontario Ministry of Natural Resources, Wheatley, personal communication). Recreational or tribal harvest in Ontario waters of the St. Clair system is unmeasured. No tag recoveries were reported by tribal fishers or the Ontario Lake St. Clair commercial fishery during this study. No legally harvested lake sturgeon were registered in 1999 or 2000 under the mandatory registration system for Michigan recreational anglers. Three legal lake sturgeon were registered in 2001 and six in 2002. During this same time period, Michigan Conservation Officers apprehended several poachers with illegal lake sturgeon in possession. However, the number of sturgeon illegally harvested from Michigan waters is unknown.

A low recapture rate further impeded mark-recapture population estimates during this study. Tag loss can be a contributing factor in a low recapture rate. However, the practice of removing a pectoral fin ray for age determination resulted in a second mark on all fish tagged after 1996, so even a fish that had shed the monel tag would be recognized as having been previously captured. Based on assessment gear recaptures, we estimated tag loss at 6.9% during this study. This would contribute to overestimation of population abundance with typical mark-recapture estimation methods.

Fish behavior may also have influenced mark-recapture population estimates during this study. Although trawls have accounted for 58% of the sturgeon captured, tagged, and released during this study, only 10 of 56 recaptures (20%) were fish originally caught with a trawl. The factors in this disparity are not entirely clear. We speculate that lake sturgeon abundance in Lake St. Clair is much higher and possibly more transient than in the St. Clair

River. However, another alternative explanation is that lake sturgeon captured with trawls become "trawl shy," or learn to avoid trawls. Such behavior would further confound mark-recapture population estimation procedures.

Thomas and Haas (2002) estimated lake sturgeon abundance in the St. Clair system was over 45,000 fish, based on mark-recapture methods. In light of the numerous difficulties and assumption violations with the use of mark-recapture techniques for estimating population abundance in the St. Clair system, we now consider it impractical to generate accurate population estimates with those techniques. However, we believe that the low recapture rates documented in our assessment gear is a strong indication that the population of lake sturgeon in these waters is substantial, 20,000-40,000 fish. Historically, the standing crop was estimated at 10.3 kg/ha (Hay-Chmielewski and Whelan 1997), which would represent a population of about 100,000 lake sturgeon based on the size structure of the present population. Thus, the present population is about 30% of the historic level.

Individual Growth

Several of the double-recapture fish provided a measure of individual growth rates over a period of 1 to 4 years. The greatest average annual growth increment was 38 mm per year for a 15 year-old fish. The lowest average annual growth increments were 4 mm per year for a 19 year-old fish and 7 mm per year for a 35 year-old fish, both likely mature adults. A pattern of lower annual growth increments for mature fish is not unexpected, since those individuals would be investing more energy into gonadal tissue production and less into somatic growth (Diana 1995).

Age Structure

Since the mid-1970s, lake sturgeon recruitment in the St. Clair system has been relatively consistent. Low representation of earlier cohorts may be a reflection of poor recruitment prior to the mid-1970s, or alternatively, a result of higher exploitation rates at some time on those older cohorts. Both possible scenarios have some merit. The St. Clair River experienced industrial and municipal waste pollution during the 1950s and 1960s, possibly impairing recruitment. Water quality improved after the Clean Water Act became law in 1972. We suspect improved water quality strengthened recruitment by the mid-1970s. Prior to 1982, Michigan fishing regulations were liberal and spawning sturgeon were illegally harvested by snagging on the spawning grounds near Algonac. This activity most likely resulted in elevated exploitation rates for the mature portion of the population. The spawning closure likely resulted in much lower exploitation on the Algonac spawning stock after 1983.

Recruitment since 1995 appears to have been poor. There are several possible explanations. The presence of our sampling gear on and near the spawning location could be a factor in the decline through some disruption in the spawning behavior at the site. Alternatively, the colonization of the St. Clair River by round gobies in the early 1990s (Jude et al. 1995) may have resulted in reduced egg and fry survival through goby predation. A third possibility is that some environmental factor, perhaps related to declining water levels has been involved. Finally, it is possible that the gear used in this study may not be effective in sampling the youngest cohorts due to size selectivity or spatial distribution of young lake sturgeon in the St. Clair system.

Catch curve analysis of the mature 1979 to 1963 cohorts produced an annual survival estimate of 0.91 that compared favorably to values reported for other lake sturgeon populations. Threader and Brousseau (1986) estimated annual survival was 0.87 and annual exploitation was 0.023 for the lake sturgeon population in the Moose River, a Hudson Bay tributary. The Moose River population was exploited by native and commercial fisheries. Bruch (1999) reported Lake Winnebago lake sturgeon annual survival at 0.814 and adult exploitation of 0.032 for males and 0.060 for females. The Winnebago sturgeon population supported a large recreational fishery. We suggest that our survival estimate of 0.91 should be considered a maximum value since inclusion of six additional older cohorts resulted in a lower estimate of S (0.86), which is more similar to survival estimates for the other two exploited populations.

Management Implications

1. Inter-jurisdictional cooperation is crucial in managing lake sturgeon in the Great Lakes and connecting waters due to short- and long-term movements that routinely cross state and international boundaries.

2. Spawning sites are limited in number and spatial area, and thus should be afforded the greatest habitat protection possible.

3. Continued monitoring of the Michigan recreational harvest is necessary to ensure the harvest remains at conservative levels. The mandatory registration system provides a minimum estimate of the actual harvest from the system.

4. Increased enforcement and public education could help reduce or minimize mortality from poaching.

Future Research Needs

1. Identification of nursery and juvenile habitats is needed to facilitate habitat protection.

2. Better quantification of the geographical bounds and habitat characteristics of summer core-use areas, such as Grid 24, would also facilitate habitat protection.

3. Diet data for all lake sturgeon life stages in the St. Clair system is needed to enable better understanding of the habitat requirements, seasonal movement patterns, and ecological significance of lake sturgeon in these waters.

4. Application of new population estimation procedures is needed to better quantify the numbers of lake sturgeon in the connecting waters. It would be desirable to attempt a joint population estimation effort with the OMNR assessment efforts for southern Lake Huron.

Acknowledgments

This study was supported by funds from the Sport Fish Restoration Act. Numerous MDNR employees were instrumental in field collections. Boat captains Larry Shubel, Jack Hodge, and Roy Beasley developed the gear and technique used in the setline surveys in the St. Clair River and the trawling for sturgeon in the Lake St. Clair “sturgeon hole”. Ken Koster, Fisheries Research Technician interpreted the fin ray sections for ages. Graduate student Jim Boase often assisted with field collections. Professional scuba divers, Greg Lashbrooke and Kathy Johnson were instrumental in our efforts to pinpoint the spawning sites in the North Channel near Sassy Marina and the Bluewater Bridge site at Port Huron. The ROV from the USGS Great Lakes Science Center provided valuable underwater video observations of suspected spawning locations. The USFWS Alpena Fisheries Resource Office provided an underwater video system with a custom built frame for stationary recording of spawning activity on the cinder pit. Finally, the Maslanka family generously allowed us access and use of their dock, located at the cinder pit, for various efforts associated with this study.

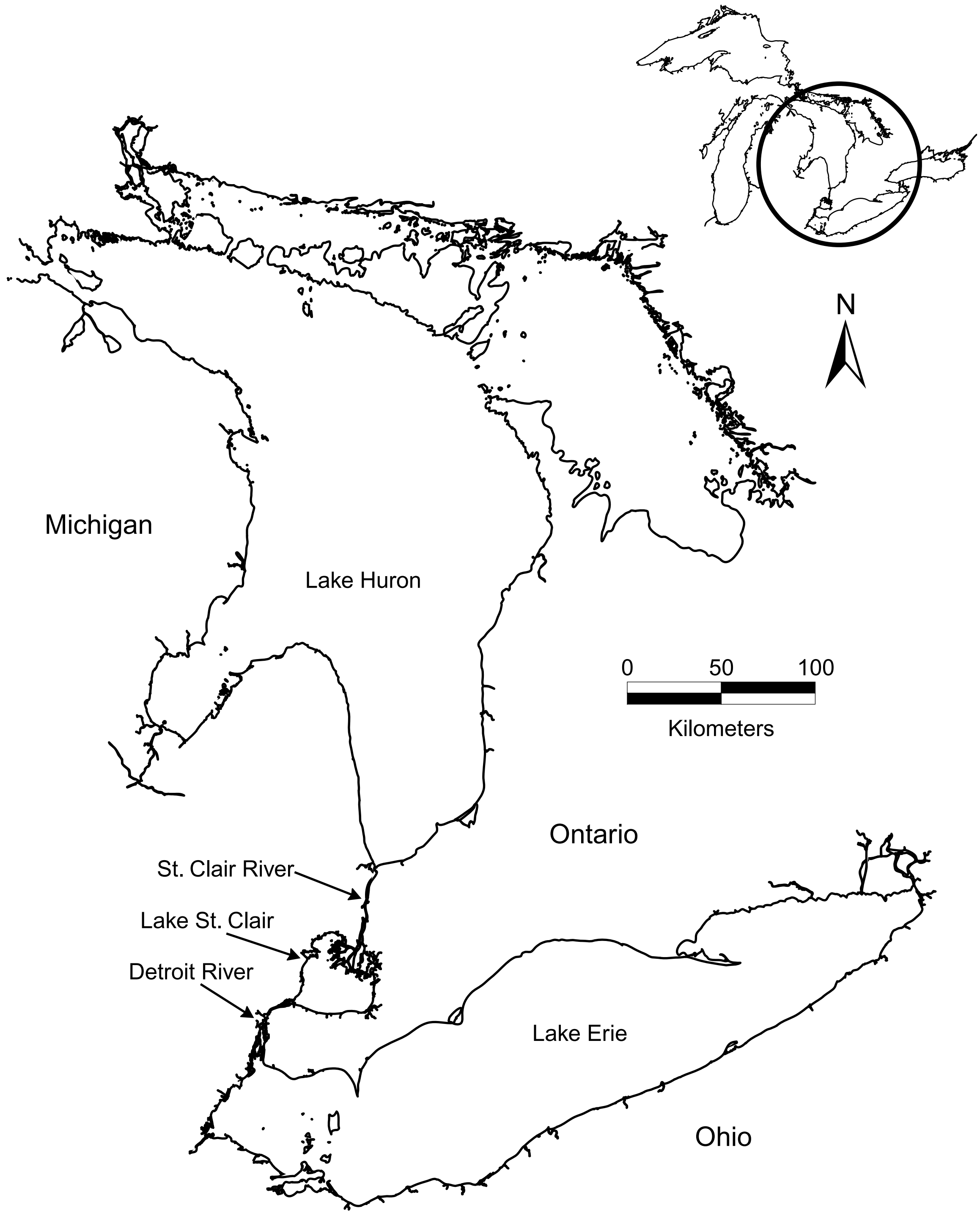

Figure 1.−Location of Lake St. Clair, the St. Clair River, and the Detroit River in the Laurentian Great Lakes.

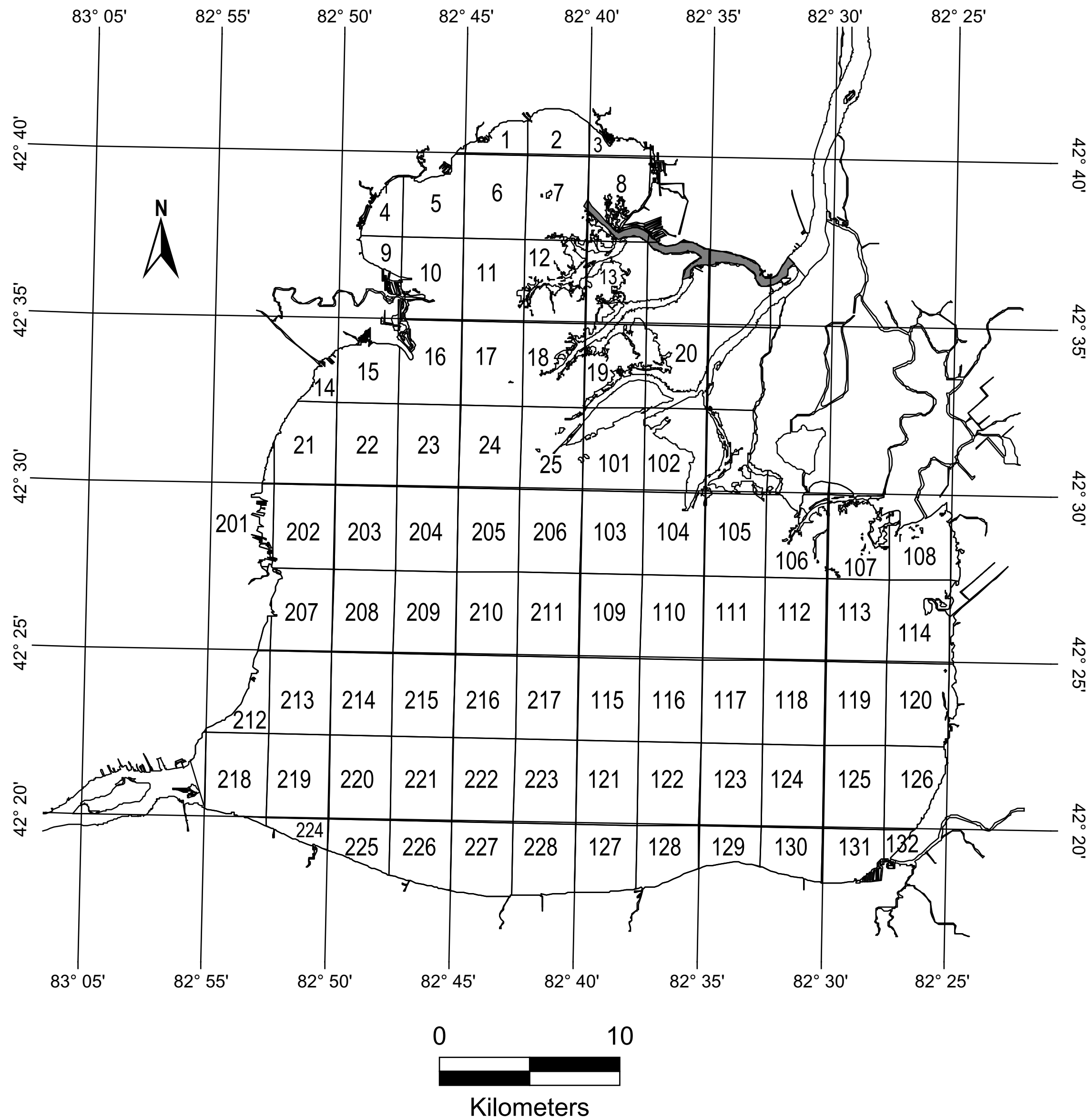

Figure 2.−Map of Lake St. Clair and the St. Clair River showing grid system used to stratify sampling with trawls on Lake St. Clair. The area of the St. Clair River sampled with setlines is shaded.

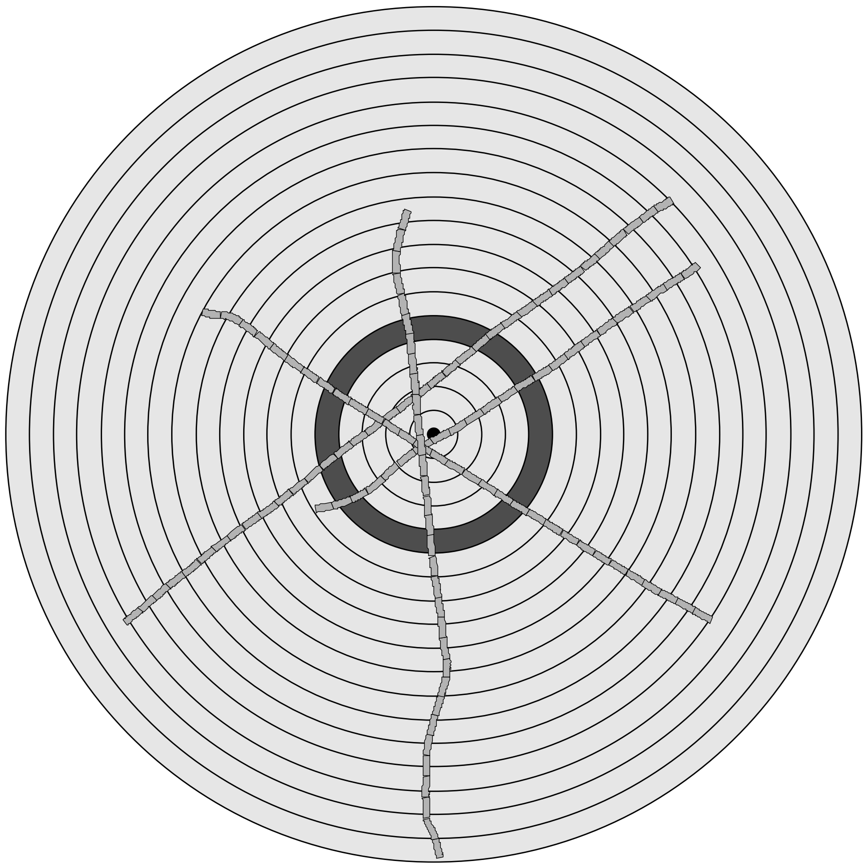

Figure 3.−Illustration of donut polygons used to estimate lake sturgeon abundance from sidescan sonar images for a selected area in Lake St. Clair. Sidescan sonar tracks, each composed of a series independent files, are shown as lines crossing the concentric donut polygons. Densities of lake sturgeon were estimated from the mean lake sturgeon density for all sidescan sonar files located within a particular donut. The fifth donut polygon is darkened for illustrative purposes.

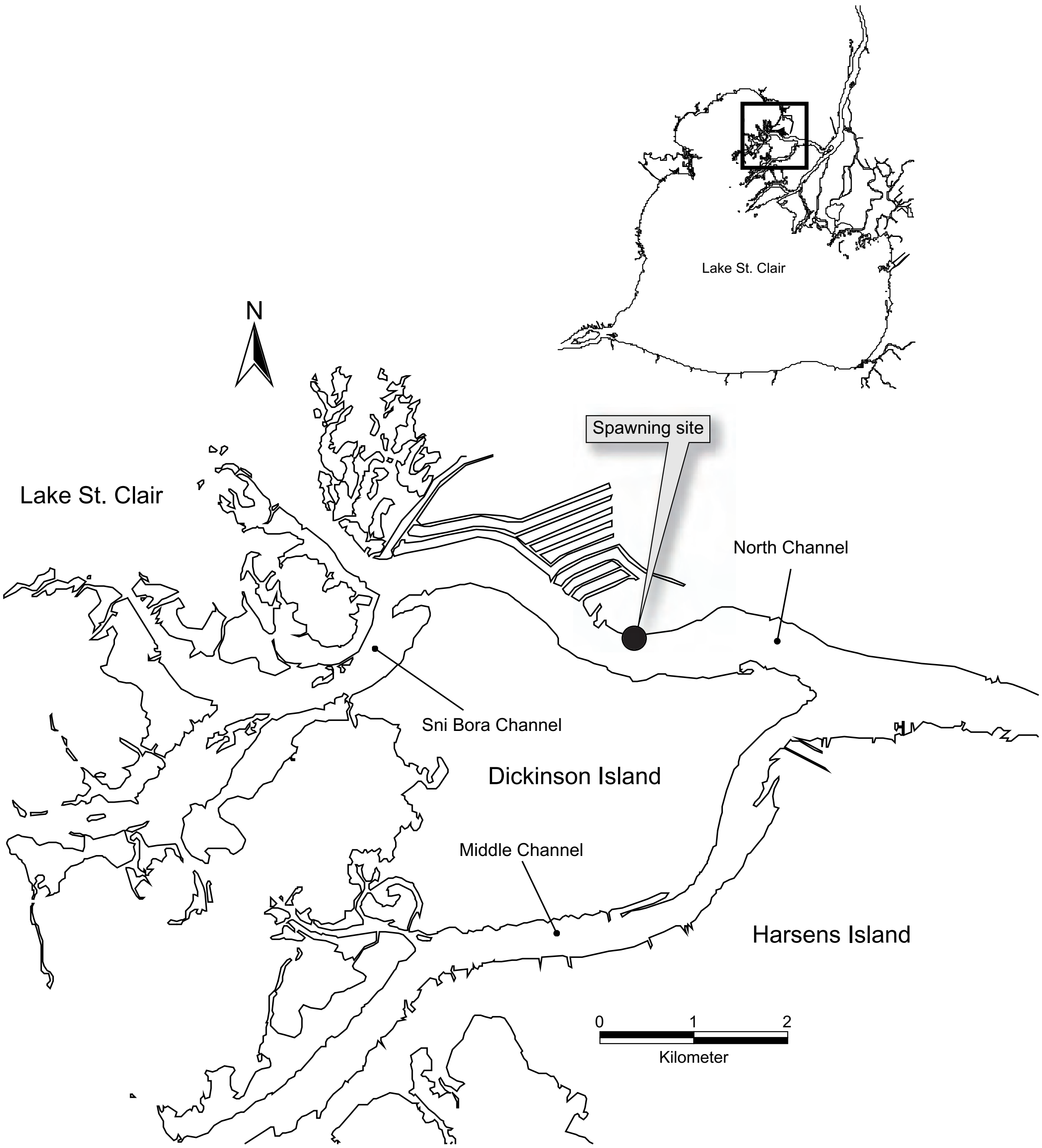

Figure 4.−Map of sturgeon spawning site in the North Channel of the St. Clair River.

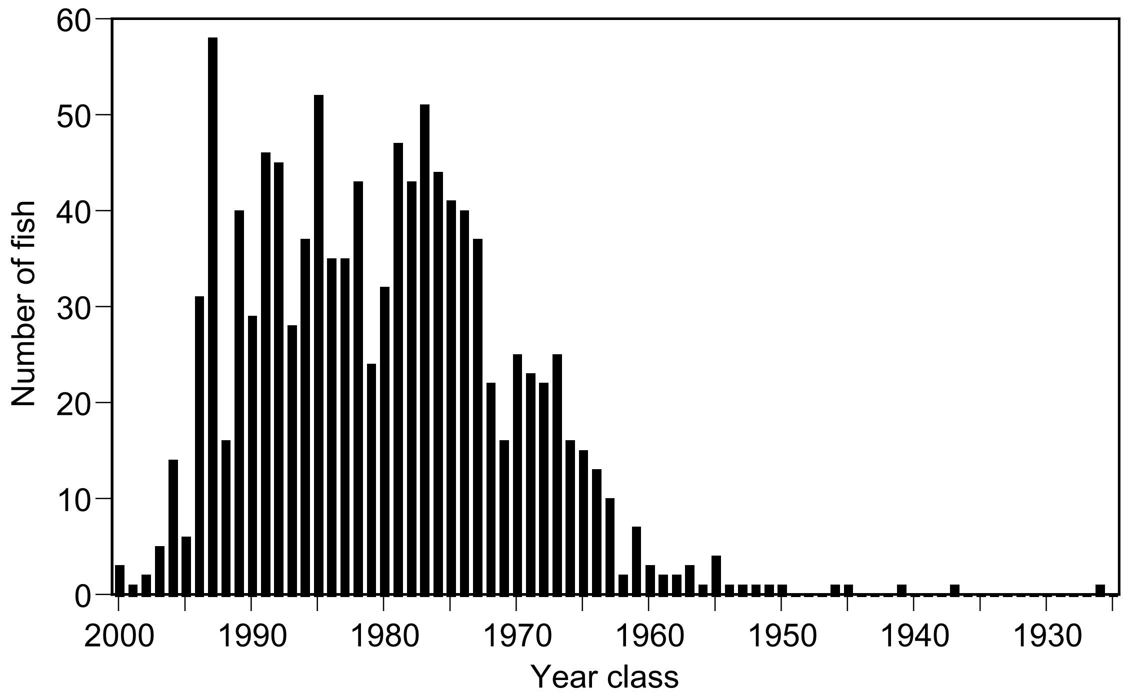

Figure 5.−Number of lake sturgeon from each year-class caught with assessment gear (combined total for all gear types across survey years 1997-2002) in the St. Clair system (Total 1,106).

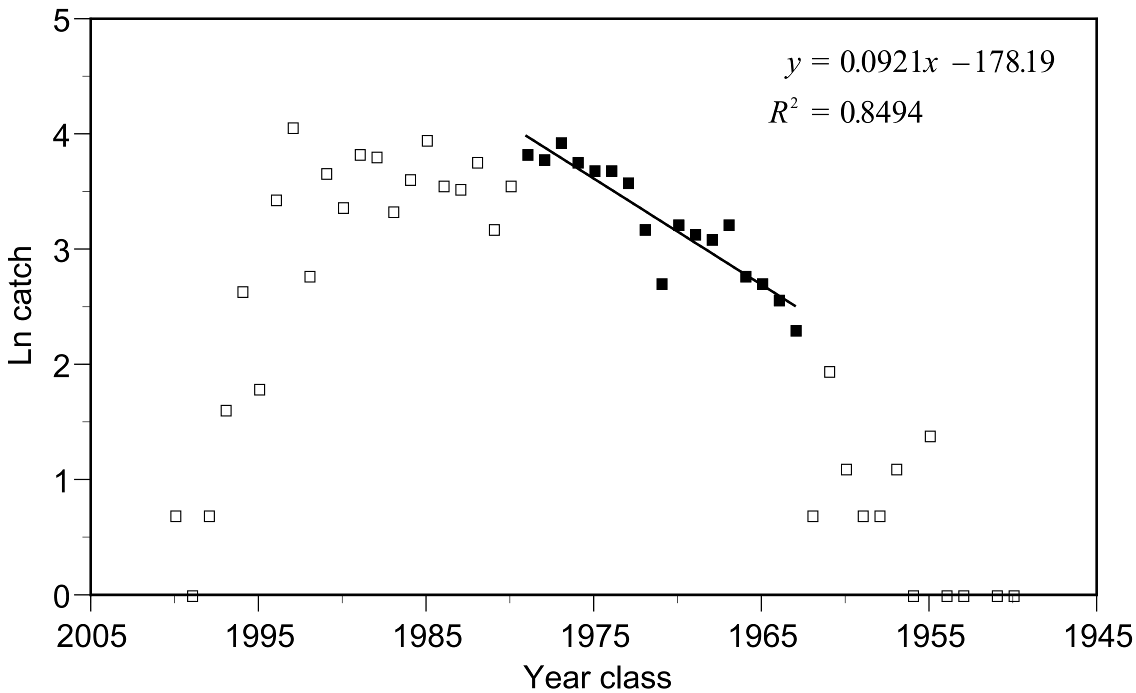

Figure 6.−Natural log of the cumulative catch by year-class (combined for 1997 to 2002) for lake sturgeon in the St. Clair system. Only solid points were used in the linear regression formula to estimate annual survival at 91%.

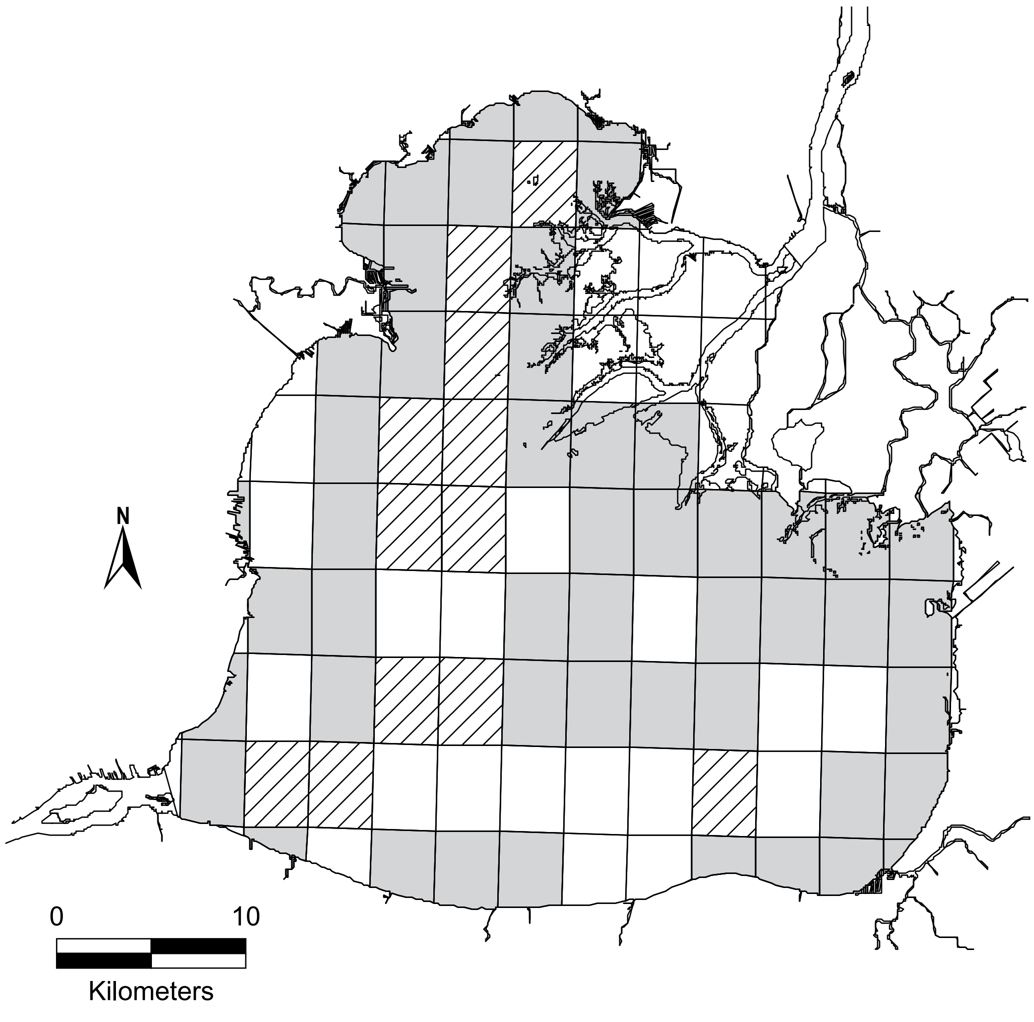

Figure 7.−Grid map of Lake St. Clair: Gray color indicates grids where trawling failed to capture lake sturgeon. Cross-hatched grids were those where lake sturgeon were captured with trawls. Uncolored grids were not sampled during this study.

Table 1.–Mean length, weight, girth, and age for sturgeon collected from the St. Clair River and Lake St. Clair, from 1996 to 2002.

	St. Clair River (Setline)	Lake St. Clair (Trawl)
Total number caught	489	721
Mean length	1,235 mm	1,198 mm
Length range	546 mm – 1,887 mm	244 mm – 1,849 mm
Mean weight	14.6 kg	13.0 kg
Weight range	0.8 kg – 53.6 kg	0.2 kg – 44.0 kg
Mean age	20.0	18.7
Age range	3-74	1-59

Table 2.–Number of lake sturgeon tagged and released by gear type, and mode of recapture for tag recoveries from 1996 to 2002, including seven fish with multiple recoveries.

		Mode of recapture						
Capture gear	Number tagged	Setline	Trawl	Gill net	Sport fishing	Commercial fishing	Found dead	Total
Setline	464	21	2	1	10	10	1	45
Trap net	17	0	0	0	0	0	0	0
Trawl	714	0	2	0	0	7	1	10
Gill net	10	0	1	0	0	0	0	1
Total	1188	21	5	1	10	17	2	56

Table 3.–Original tag location and subsequent recapture locations for tag recovery reports from 1996 to 2002, including seven fish with multiple recoveries.

	Recapture location				
Tag location	Lake Erie	Lake St. Clair	St. Clair River	Lake Huron	All waters
Lake St. Clair	0	4	0	7	11
St. Clair River	1	4	30	10	45
Total	1	8	30	17	56

Table 4.–Lake sturgeon estimated length and density (fish per ha) within 255-ha area in Lake St. Clair, estimated from georeferenced sidescan files for 1999 and 2000.

Measurement	1999	2000
Number of transects	4	5
Number of sidescan files	122	205
Mean file area (ha)	0.061	0.056
Mean fish per file	12.1	4.0
Mean shadows per file	–	3.8
Mean fish density per hectare	115	20
Mean shadow density per hectare	118	15
Estimate of fish population size	29,262	5,038
Mean echo length (m)	0.94	1.20

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