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Age, growth, mortality, and abundance of lake sturgeon in the Grasse River, New York, USA

By D. G. Trested[1] and J. J. Isely[2]

[1]*Normandeau Associates Inc., Bedford, NH, USA;* [2]*South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, SC, USA*

Summary

An increased understanding of lake sturgeon (*Acipenser fulvescens*) population dynamics is a key requirement for successful management efforts. Little is known regarding the Grasse River population of lake sturgeon except that it is one of a few populations in New York State where spawning has been documented. Thus our purpose was to assess the current status of lake sturgeon in the Grasse River system, including age, growth, mortality, and abundance. Age was determined for 196 of 211 lake sturgeon by examination of sectioned pectoral fin rays. Ages ranged from 0 to 32 years and the annual mortality rate for fish between ages 7 and 14 was 16.8%. The weight (W, g) to total length (TL, mm) relationship was $W = 1.281 \times 10^{-6}\mathrm{TL}^{3.202}$. The von Bertalanffy growth equation was $\mathrm{TL} = 1913(1-e^{-0.0294(t+9.5691)})$. While the range of observed ages was similar to that of nearby St. Lawrence River populations, mean weight at age for an individual at 1000 mm TL was lower than that observed for lake sturgeon within Lake St. Francis of the St. Lawrence River. Predicted growth based on von Bertalanffy parameters was similar to that observed for the nearby Lake St. Francis. An open population estimator using the POPAN sub-module in the Program MARK produced an abundance estimate of 793 lake sturgeon (95% CI = 337–1249).

Introduction

The lake sturgeon (*Acipenser fulvescens*) is native to larger river and lake systems throughout the northeastern and central United States, including the Laurentian Great Lakes and Hudson Bay drainage (Scott and Crossman, 1973; Peterson et al., 2006). This species is present within the St. Lawrence River (Scott and Crossman, 1973; Smith, 1985; Carlson, 1995) where commercial landings constituted one of the most important sturgeon fisheries in North America (Dumont et al., 1987, 2004).

Construction of Beauharnois (1942) and Moses-Saunders (1960) Generating Stations altered the hydrology of the St. Lawrence River (Morin and Leclerc, 1988) and created an impounded section of river known as Lake St. Francis (Fig. 1). The population of lake sturgeon isolated in Lake St. Francis has been negatively impacted by dam construction along with overfishing (Dumont et al., 2004) and was considered depleted during the 1960s, 1970s, and 1980s (Cuerrier and Roussow, 1951; Jolliff and Eckert, 1971; Dumont et al., 1987). Recent assessment in the Quebec portion of the lake suggests the lake sturgeon population remains depressed (Dumont et al., 2004). Commercial and recreational fisheries management within Lake St. Francis is shared by Quebec, Ontario, New York, and the Mohawk Government of the Akwesasne. Commercial fisheries for lake sturgeon in Lake St. Francis were closed in New York State during 1976, in Ontario during 1984 and in Quebec during 1987. An unquantified commercial harvest of lake sturgeon from Lake St. Francis remains on the Akwesasne Reservation.

The Grasse River is one of three major tributaries entering the upper end of Lake St. Francis near the Moses-Saunders Generating Station in Massena, New York. Limited spawning habitat was located below a low-head weir located at river kilometer 12.9 (Jolliff and Eckert, 1971), as measured from the confluence of the Grasse River with Lake St. Francis. Under certain flow conditions, lake sturgeon could perhaps move past that obstruction and into the upper reaches of the Grasse River (Carlson, 1995). However the low-head weir was breached during a flood in 1997.

Little is currently known about Grasse River lake sturgeon age structure, growth, condition, mortality, and abundance. This population of lake sturgeon is one of a few populations in New York State where spawning has been documented, and the population appears to include both resident and migratory individuals (Carlson, 1995). Therefore, a greater knowledge of Grasse River lake sturgeon would be valuable towards enhanced management within the Grasse River and potentially the management of lake sturgeon in Lake St. Francis. In this study, we assess the current status of lake sturgeon in the Grasse River system. Specifically, we evaluate age, growth, mortality, and abundance and compare these values with lake sturgeon populations elsewhere.

Materials and methods

Study area

The Grasse River flows northeast for 185 km from its source in the foothills of the Adirondack Mountains to its confluence with the St. Lawrence River where it empties into Lake St. Francis (Fig. 1). Lake St. Francis runs for approximately 80 km between the Moses-Saunders Generating Station and the Beauharnois Generating Station in Valleyfield, Quebec. The Grasse River drains approximately 1702 km^2, has an average annual stream flow of 31.1 m^3 s^{-1} and a median flow of approximately 19.8 m^3 s^{-1} (Parsons Brinckerhoff, 2006). The lower Grasse River (river km 0–11.5, as measured from the confluence with Lake St. Francis) was dredged during the early 1900s and is relatively deep (4.5–7.5 m) compared to the remainder of the system, which typically ranges in depth from 1.5 to 3.0 m. The remains of an old low-head weir breached during 1997 is located at river km 12.9 and is not a barrier to

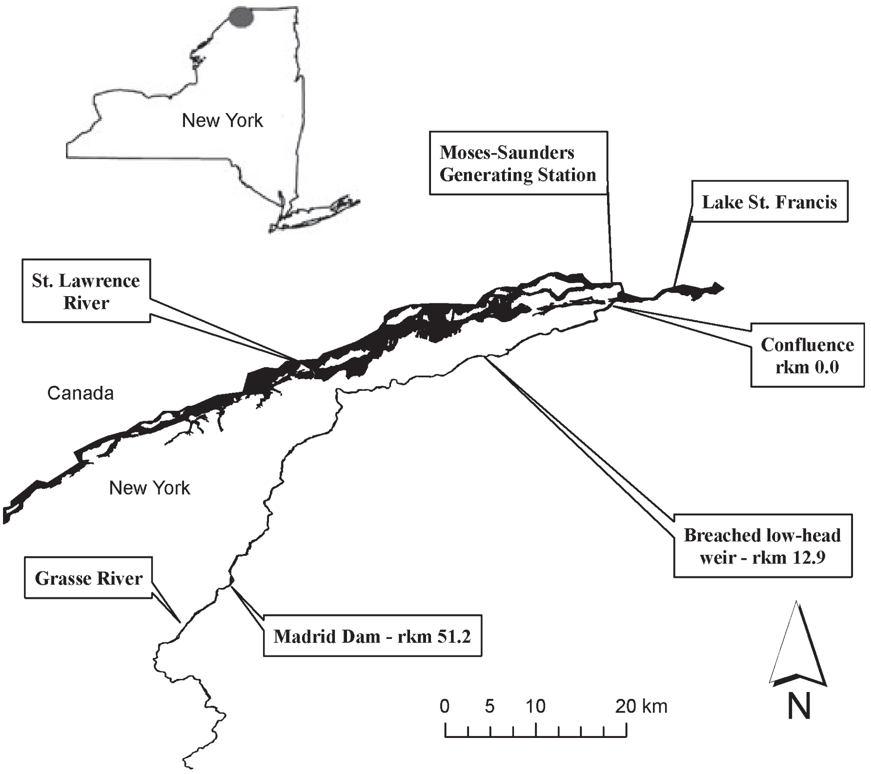

Fig. 1. Grasse River near Massena, New York, showing river reach sampled during 2007 and 2008

migration, except during seasonally low flows. A second low-head dam (Madrid Dam) is located at river km 51.2 and does not have fish passage facilities. All lake sturgeon examined during this study were captured below Madrid Dam and downstream to approximately river km 6.0 of the Grasse River.

Fish capture and sampling

Lake sturgeon were collected monthly from April 2007 through November 2007 and during October 2008 using monofilament gill nets. The three different sinking monofilament gill nets fished were a 38.1 m (length) × 2.4 m (depth) × five 7.6 m wide panels with stretch mesh ranging from 3.8 to 12.8 cm (small-mesh experimental gill net), 45.7 m × 1.8 m × three 15.2 m wide panels of 12.8–17.8 cm stretch mesh (large-mesh experimental gill net), and 45.7 m × 1.8 m with 20.4 cm stretch mesh (single mesh gill net). Gill nets were anchored at the shoreline, set perpendicular to the current, and fished during daylight hours. Sampling was restricted to areas with suitable water depth for boat access. Fixed sample sites were located between river km 6.0–11.3, 12.9–18.5, and at river km 25.7 and 51.0.

Following capture, lake sturgeon were placed in a holding tank on the boat. Total length (TL, nearest mm) and weight (W, nearest 10 g) were recorded. Due to the lack of external distinguishing characteristics, sex was not determined for individuals captured during this study. A passive integrated transponder (PIT) tag (134.2 kHz, 12.45-mm Super Tag II; Biomark Inc., Boise, ID) was injected into the dorsal musculature of each individual.

A section of pectoral spine was removed from the margin using cutting pliers as described by Rossiter et al. (1995). Pectoral spines were sectioned using a low-speed diamond blade saw (Isomet Saw; Buehler Inc., Lake Bluff, IL). Thin (0.5 mm) transverse sections were mounted to glass slides using thermal cement, polished using 600-grit lapidary film and examined under transmitted light using a dissecting microscope at 25× magnification. Age was assigned to each individual as the number of complete opaque bands visible (Rossiter et al., 1995). Spring-collected samples exhibited opaque margins, which were interpreted as annuli. Sections were examined by a single reader on two separate occasions. An estimated age was assigned to a single pectoral spine section from each individual sturgeon. When estimated ages differed, pectoral spine sections were examined a third time by the original reader to assign a final age estimate and reason for disagreement. If agreement with one of the two previous readings did not occur, the section was not included in analysis.

Data analysis

Catch per unit effort (CPUE) was calculated as the total number of lake sturgeon captured per 8-h net set. Samples resulting in zero catch were included in the calculation of mean CPUE values for all gear types. A weight-length relationship ($W = aL^b$) was derived as described by Ricker (1975). A von Bertalanffy growth equation using all length and age data was calculated using TL $= L_\infty[1-e^{-k(t-to)}]$, where L_∞ is the asymptotic length, t is age (years), t_o is the hypothetical age at length 0, and k is the Brody growth coefficient (von Bertalanffy, 1938). This procedure was carried out in Statistical Analysis System using NLIN procedures (SAS, SAS Institute, Cary, NC) using an iterative non-linear least squares procedure.

The total instantaneous mortality rate (Z) was estimated from the slope of the catch curve ($\log_e$ frequency vs age; Ricker, 1975). Early age classes were excluded if they were not abundant in the age frequency due to gear bias and we removed older age classes if they contained fewer than five fish (Ricker, 1975). This analysis assumes that (i) recruitment is constant from year to year, (ii) fishing and natural mortality are constant, and (iii) vulnerability to the fishing gear (gear selectivity) is constant above a given age (Ricker, 1975).

Annual mortality was calculated as: $A = 1-e^{-Z}$, where A is the annual mortality estimate, e is natural log base constant and Z is total instantaneous mortality rate. The annual survival estimate (S) was then calculated as $S = 1-A$.

The population abundance (N) of lake sturgeon within the Grasse River was estimated using the POPAN function (Jolly-Seber model) within the Program MARK (White, 2007). The release-recapture matrix used in this analysis is presented in Table 1 and represents collections between April and November 2007. Sampling dates were pooled within each month to provide a total of eight time intervals. Although this resulted in a minimal loss of within-month recaptures, the decreased number of parameters provided to Program MARK allowed for improved model precision (Cooch and White, 2007). Our estimate of N represents the value obtained using the model averaging function within Program MARK.

Results

A total of 211 lake sturgeon were captured between 1 April 2007 and 9 October 2008. Catch per unit effort for the small-mesh experimental gill nets was 0.4 lake sturgeon per 8-h daytime set (range: 0–7.7; SD = 1.0), for the large-mesh experimental gill nets it was 0.8 (range: 0–1.8; SD = 14.8), and for the single-mesh gill net it was 0.4 (range: 0–0.7; SD = 2.5). A single young-of-year fish (TL = 175 mm; W = 22 g) captured by electrofishing was included in age, growth, and mortality analyses. Total length averaged 796 mm (range: 175–1368 mm; SD = 163.8 mm; Fig. 2) and weight averaged 2757 g (range: 22–13 680 g; SD = 2002 g). The W–TL relationship was $W = 1.281 \times 10^{-6} \times \mathrm{TL}^{3.202}$ ($r^2 = 0.96$; $N = 201$; Fig. 3).

A total of 196 spines were examined for age. Initial agreement in ages between two independent readings was 75.0%. Of the 49 occasions where initial age estimates disagreed, 76% differed by 1 year and 24% differed by 2 years or more. Disagreement in initial age estimates was caused by uncertainty in location of the first annulus and compression of annuli near the margin in samples from older fish. Final age estimates ranged from 0 to 32 years (mean = 8.7 years; Fig. 4). Total lengths ranged from 175 mm at age 0 to 1368 mm at age 32 (Fig. 5). The von Bertalanffy growth equation for length was $\mathrm{TL} = 1913(1-e^{-0.0294(t-9.5691)})$.

The estimate of Z for age 7–14 was 0.184 ($r^2 = 0.74$; 95% C.I. = 0.076–0.291), with a corresponding annual survival rate (S) of 83.2% or an annual mortality rate (A) of 16.8%. Confidence intervals (95%) for A were 7.3–25.2%. Figure 6 presents the length frequency distributions used in the catch curve analysis. The mean TL for individuals captured in the small mesh experimental gill nets was 759 mm while mean TL for individuals captured in the large mesh experimental gill nets was 784 mm. The length frequency distributions of catch from both net types indicated that sturgeon over a wide range of lengths were vulnerable to the sampling gear (Fig. 6). When the mean TL for sturgeon captured by the two experimental gill net gear types are compared to the mean TL at age (Fig. 5) it appears that sturgeon became fully vulnerable to our gill nets at an age of 7 years (Fig. 7). Our added use of the large mesh gill nets allowed for the capture of older and larger year classes if they had been present.

We estimated 793 (95% CI; 337–1249) lake sturgeon inhabited the Grasse River.

Table 1
Release-recapture matrix for lake sturgeon (*Acipenser fluvescens*), Grasse River, occasions 1–8 (April–November 2007)

Release occasion	Number of releases	Recapture occasion 2	3	4	5	6	7	8	Total
1	36	2	0	1	0	0	0	1	4
2	8		1	0	0	0	4	4	9
3	19			0	0	0	0	0	0
4	23				0	0	2	3	5
5	1					0	0	0	0
6	6						0	0	0
7	49							8	8

Discussion

Abundance of lake sturgeon in the Grasse River during our study is comparable to levels observed during previous sampling (Carlson et al., 2001). Although mesh sizes are unknown, previous work reported CPUE values of 1.5 fish per gill net night in the nearby Lake St. Francis (St. Lawrence River) and from 0.2 to 0.5 fish per gill net night

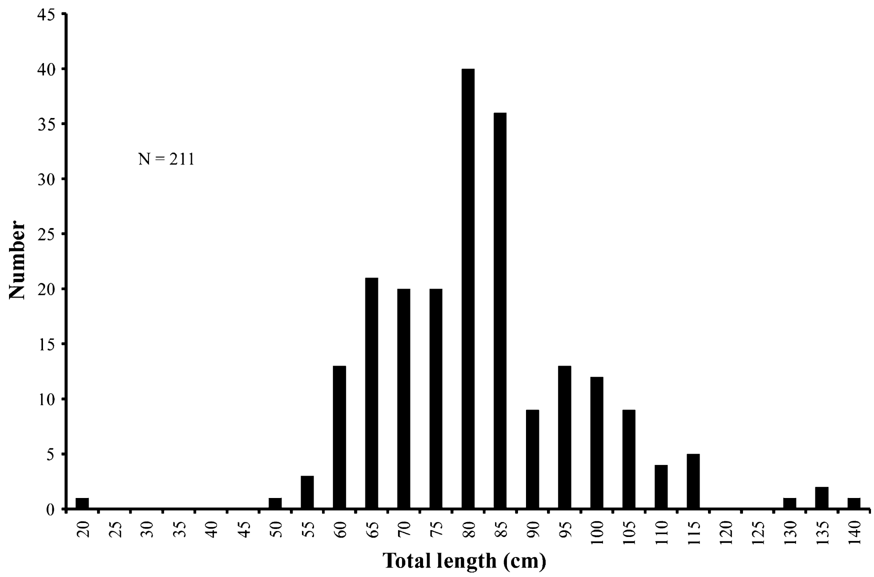

Fig. 2. Length frequency of Grasse River lake sturgeon captured between 1 April 2007 and 9 October 2008

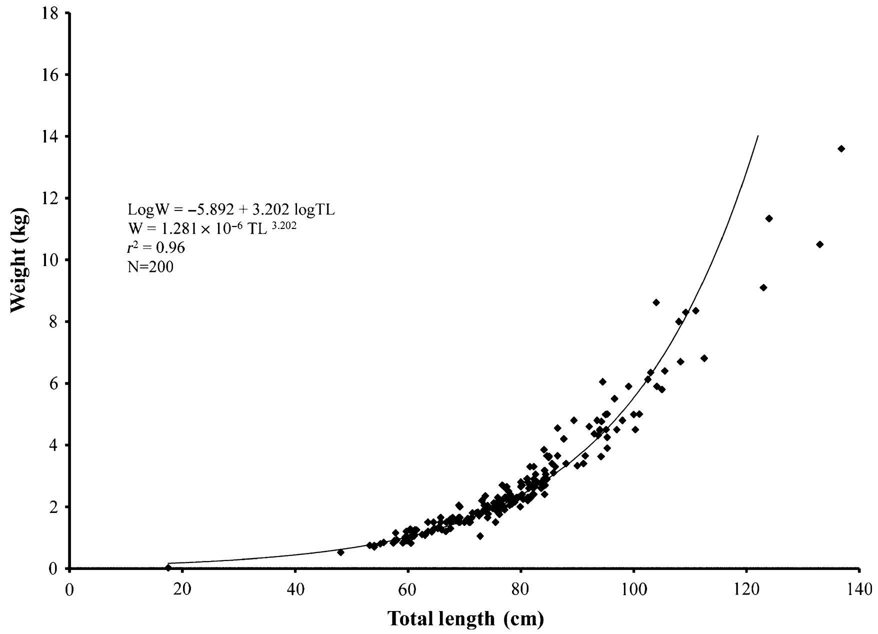

Fig. 3. Length-weight relationship of Grasse River lake sturgeon captured between 1 April 2007 and 9 October 2008

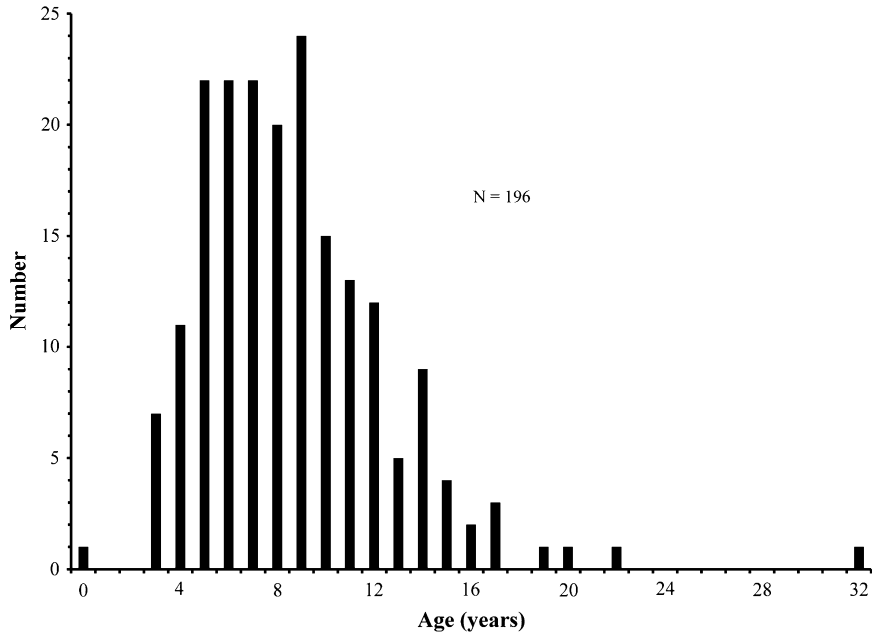

Fig. 4. Age frequency of Grasse River lake sturgeon captured between 1 April 2007 and 9 October 2008

in the Grasse River (Carlson et al., 2001). Although differences in the diel timing of sampling between these two studies do exist, our values are similar to those reported previously for the Grasse River suggesting that lake sturgeon abundance has remained relatively stable over the last 8 years. Lallaman et al. (2008) reported gill net CPUE values for the Manistee River in Michigan as ranging from 0.10 to 0.59 fish per net night. The Manistee River system supports a small but stable population of lake sturgeon with a range of year classes (Lallaman et al., 2008). Although a direct comparison between Grasse River and Manistee River abundance values may potentially be confounded by differences in mesh sizes and diel timing of sampling, the similarity between CPUE values suggest that lake sturgeon in the Grasse River are of a comparable density to a population with known continual recruitment.

Total length and weight values of lake sturgeon captured from the Grasse River are comparable to nearby populations from the St. Lawrence River (Fortin et al., 1993; Johnson et al., 1998). Commercial gill net catch from Lake St. Louis of the St. Lawrence River reported mean TL by year class ranging from 493 mm at age 5 to 1493 mm at age 33 and mean *W* ranged from 3300 to 16 500 g (Fortin et al., 1993). Gill net catch reported from two studies conducted in the tailwater of Moses-Saunders Generating Station on the St. Lawrence River ranged from approximately 743–1486 mm TL during 1969–1970 sampling (Jolliff and Eckert, 1971) and from approximately 660–1560 mm TL during 1993–1994 sampling (Johnson et al., 1998). Differences in mesh sizes used in our study may have contributed to the abundance of the smaller length fish we observed in the Grasse River. The wide range of sizes observed in gill net catch, supported by the presence of a

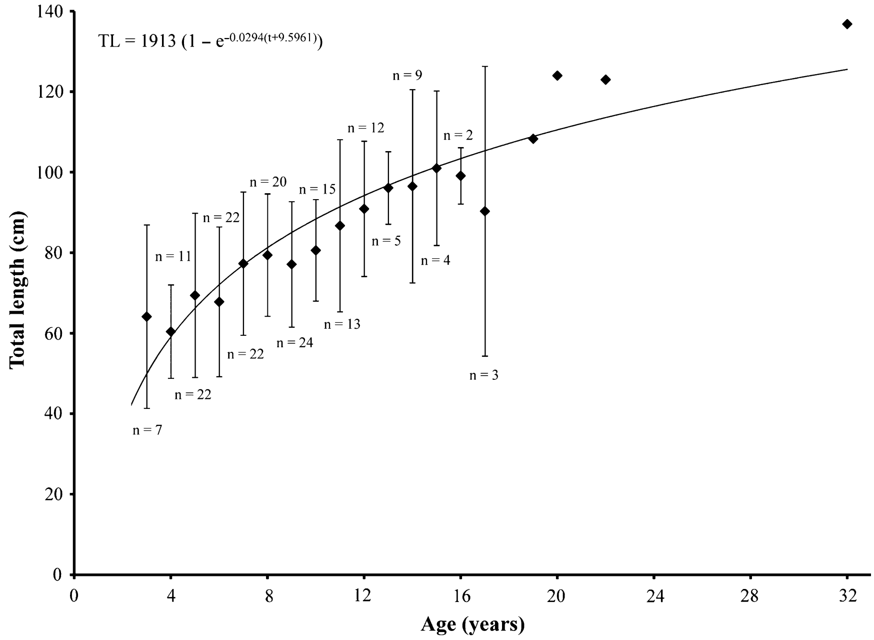

Fig. 5. Mean total length at age (±95% confidence intervals) of Grasse River lake sturgeon captured between 1 April 2007 and 9 October 2008. Line depicts von Bertalanffy growth curve. Age classes without confidence intervals reflect data collected from a single individual

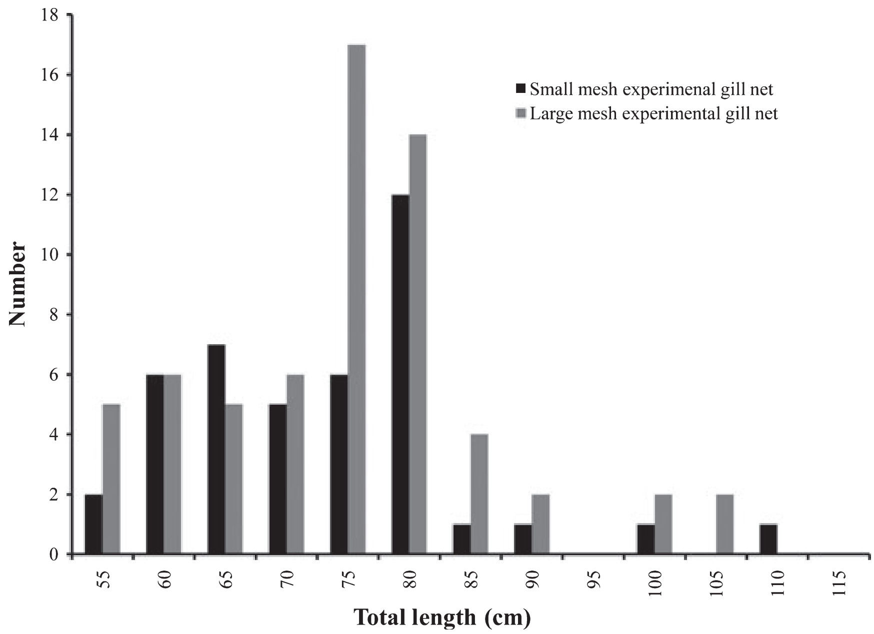

Fig. 6. Length frequency distributions for catch from small mesh experimental gill nets and large mesh experimental gill nets for lake sturgeon, June to November 2007

175 mm TL individual and sturgeon eggs (Normandeau Associates, unpubl. data) suggests some recruitment is occurring.

Variations in growth in length and body weight of lake sturgeon have been studied for populations throughout the range (e.g. Fortin et al., 1996; Power and McKinley, 1997) and the comparison of weights at a given reference length is necessary as the length-weight relationship for lake sturgeon is generally not isometric (Fortin et al., 1993). Fortin et al. (1996) described an inverse relationship between latitude and growth rate for lake sturgeon within their range. Based on the length-weight relationships for St. Lawrence River populations, a calculated weight for an individual of 1000 mm TL was estimated at 6461 g for Lake St. Louis, 6763 g for the Upper St. Lawrence River, and 5872 g for Lake St. Francis. For the Grasse River population, the calculated weight for an individual at 1000 mm TL was 5174 g. Our study value is lower than those previously reported for lake sturgeon from nearby systems. Differences in weight may be related to selection for large adult fish and gravid females in other systems and not actual length-weight differences. The collection of length-weight data from the Grasse River was conducted using non-commercial gear. Alternatively, observed differences in weight could also be attributed to differences in feeding behaviors, quality of available habitat characteristics, or competition. Power and McKinley (1997) suggested that quantity and quality of food sources may be important in explaining differences in the variation of growth rates among lake sturgeon populations.

Our age estimates from pectoral spines of lake sturgeon are within the younger portion of the ranges observed for nearby St. Lawrence River populations. Ages estimated from commercial catch of lake sturgeon from Lake St. Louis of the St. Lawrence River ranged from 5 to 97 years (Fortin et al.,

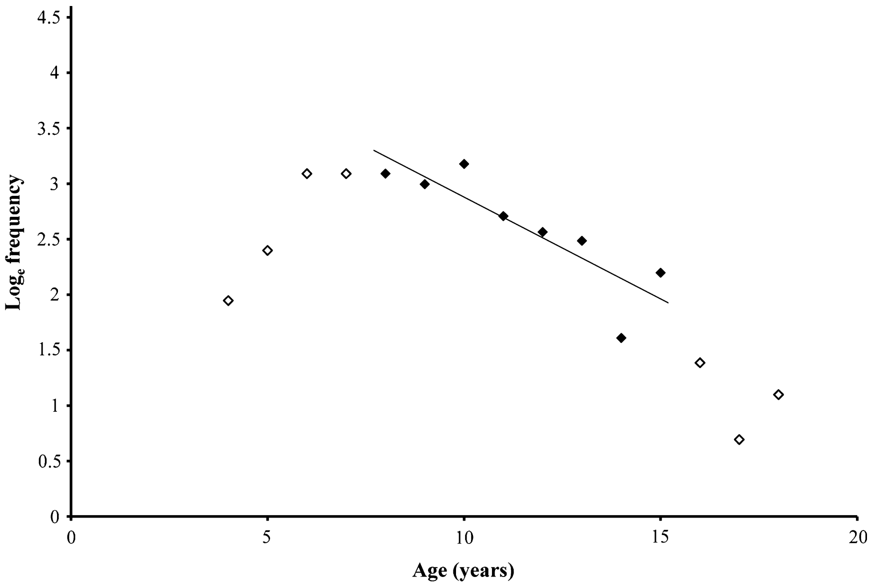

Fig. 7. Catch curve for Grasse River lake sturgeon. Open diamonds = age classes prior to full recruitment to sampling gear and not included in estimate of Z; closed diamonds = age classes included in estimate of Z

1993). Values reported for catch from the tailwater of the Robert Moses Generating Station on the St. Lawrence during sampling conducted during 1969 and 1970 ranged from 7 to 38 years (Jolliff and Eckert, 1971) and sampling conducted from 1993 to 1994 ranged from approximately 4–51 years (Johnson et al., 1998). Nearly 80% of the total catch (N = 139) reported from the 1969–1970 sampling was between the ages of 9 and 13 years (Jolliff and Eckert, 1971). Recent work conducted by Bruch et al. (2009) assessed the accuracy of lake sturgeon pectoral spines for age determination and stated that pectoral spine sections underestimated the true age of fish older than 14 years, with error increasing with age. Bruch et al. (2009) stated that ages estimated from otoliths were valid up to 52 years of age. In addition, Bruch et al. (2009) provided a power function to provide a means of correcting existing age estimates obtained from lake sturgeon pectoral spines. Due to the threatened status of lake sturgeon in New York State and the lack of population-specific knowledge for the Grasse River, the use of otoliths for age determination was not feasible. While a strong relationship exists for the true age-estimated age function developed by Bruch et al. (2009) for Lake Winnebago sturgeon, uncertainty over the transferability of that relationship out of the system prevented us from incorporating it into this study. Previous age determination studies for nearby St. Lawrence River populations of lake sturgeon (Fortin et al., 1993; Johnson et al., 1998) were conducted using the same aging methodologies as this study; their results, although potentially underestimating true ages, were comparable in our judgment. In addition to potential biases in age determination related to individuals older than age 14, the lack of abundance of lake sturgeon older than 32 years in the Grasse River can potentially be attributed to sampling bias associated with smaller mesh gill nets than those used in commercial sampling. It is also possible that the Grasse River is used primarily by juvenile sturgeon.

Studies have fitted a von Bertalanffy growth equation to length and age (Johnson et al., 1998; Smith and Baker, 2005) and several literature reviews are available (Fortin et al., 1996; Power and McKinley, 1997). Based on available length data from commercial fisheries from nearby portions of the St. Lawrence River (Fortin et al., 1993), we feel our estimate of L_∞ is biologically reasonable. Our growth coefficient (k) estimate of 0.029 is similar to that reported for lake sturgeon captured in the tailwater of the nearby Robert Moses Dam (0.042; Johnson et al., 1998). Mean length of St. Lawrence River populations of lake sturgeon between the ages of 23–27 years were reported as 1241 mm for Lake St. Louis, 1262 mm for the Upper St. Lawrence River, and 1138 mm for Lake St. Francis (Fortin et al., 1996). For the Grasse River population, the mean length of individuals within this age range was calculated as 1220 mm (range = 1179–1260 mm). The calculated value using our von Bertalanffy parameters for mean TL for fish ages 23–27 was similar to previously reported parameters for similar latitudes within the St. Lawrence River watershed.

Catch curve estimates of total instantaneous mortality (Z) obtained for lake sturgeon from the Grasse River (Z = 0.184, ages 7–14) were lower than those reported by Fortin et al. (1996) for Lake St. Louis of the St. Lawrence River for the 1981–1985 time period. Similarly, total annual mortality (A = 16.8%) estimates for the Grasse River were lower than estimates for the Lake St. Louis population calculated during 1981 (A = 20.0), 1982 (A = 23.0) and 1983 (A = 23.0) for sturgeon ages 16–31 (Fortin et al., 1993). Previously reported values from the St. Lawrence River were estimated during a period of both natural and significant fishing mortality. Incidental catch and release by recreational anglers and an unquantified commercial harvest on the nearby Akwesasne Reservation does occur. However, the lower mortality, when compared to a commercially harvested population, coupled with the collection of young of year fish as well as documentation of spawning through the collection of two eggs during 2008 and 2009, each at different spawning sites (Normandeau Associates, unpubl. data), indicates some level of recruitment to this population and provides a positive indicator.

This study was intended to provide needed information related to the age, growth, abundance, and mortality of *A. fulvescens* in the Grasse River, whereby age was similar to previous reports from nearby St. Lawrence River populations. Length at age as predicted by our von Bertalanffy growth model was similar to previously predicted values for St. Lawrence River populations of lake sturgeon. We provide the first estimates of abundance and mortality in the Grasse

River, which will contribute to the enhancement of future management of lake sturgeon in the Grasse River.

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Authors' addresses: Drew G. Trested, Normandeau Associates Inc., 25 Nashua Road, Bedford, NH 03110, USA.
E-mail: dtrested@normandeau.com
and
J. Jeffery Isely, South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, South Carolina 29631 USA.
E-mail: jisely@clemson.edu