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Movement of Juvenile Lake Sturgeon (Acipenser fulvescens) in the Lower Genesee River, New York

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Movement of juvenile lake sturgeon (*Acipenser fulvescens*)

in the lower Genesee River, New York

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ABSTRACT

As an important step in a long-term stocking program, this project investigated the movement and habitat use of juvenile lake sturgeon after they were stocked in the lower Genesee River, New York. Nine young animals were selected to represent the population, ranging from two to three years of age and from 0.180 kg to 0.910 kg in weight. The young animals were implanted with internal radio transmitters; six of the nine radio-tagged animals provided useful tracking data. Their movements were monitored during the summer and fall of 2006. These fish aggregated often, with fish gathering occurring in 21% of all observations. The young fish traveled a total of 5.57 km to 22.03 km throughout the study period between tracking periods of 28 to 103 days. Based on a 24-hour survey, the fish traveled an average of 0.806 km/day. The juvenile fish occupied the southern sections of the lower Genesee River more frequently than other sections, with 57% of all locations occurring between rkm 7 and 9. River use was not randomly distributed (χ^2 = 66.85, dF = 6, p-value = 0.001). The fish occupied all depths, but most locations (49.1%) were within water 3.0 m to 5.0 m deep. A pronounced downstream movement to river kilometer 2.8 and 2.9 was recorded in mid-fall, when the water temperature dropped from 9°C to 5°C. Overall, the behavior of the stocked population in the lower Genesee River was comparable to other juvenile lake sturgeon naturally occurring in other systems. The findings from this study indicate that the stocked lake sturgeon move throughout the river and the stocking program is successful to the first years.

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INTRODUCTION

One of 28 living species of the family Acipenseridae, the lake sturgeon *Acipenser fulvescens* lives in the freshwaters of North America from Hudson Bay through the Mississippi River drainage basin (Dewey and Sturgeon 2007). Native to the Great Lakes, the lake sturgeon was once abundant throughout its range, including the Genesee River, a major tributary of Lake Ontario. However, the species declined dramatically as a result of over-exploitation caused by high demand for sturgeon eggs and smoked sturgeon (Baldwin *et al.* 1979); construction of dams, which eliminated spawning and nursery areas; and the by-products of urban and rural development, such as habitat pollution and channelization. By the early 1900s, many populations of lake sturgeon, including that of the Genesee River, Monroe County, New York, USA, had been severely reduced or extirpated. Regier and Hartman (1973) reported that "when sturgeon would become entangled in the gill nets set for other species, the scutes tore the fishermen's nets. Fishermen retaliated by setting heavier nets with large mesh to capture sturgeon and kill them, often piling them like wood on the beaches, dousing them with oil, and burning them."

Currently, the lake sturgeon is not federally protected in the United States. However, the species receives various levels of protection at the state level, and is listed as either threatened or endangered in several states. Populations in New York and Michigan are designated as threatened (Peterson *et al.* 2007). The species was listed in 1975 under Appendix II of the Convention on International Trade of

Endangered Species. Although this listing was temporarily suspended in 1983, it was reinstated in 1998 (Peterson *et al.* 2007). The International Union for the Conservation of Nature down-listed the lake sturgeon from "Vulnerable" in 1996 to "Species of Least Concern" in 2004. Major conservation and restoration efforts have contributed to the recovery of the species (IUCN, 2006).

The New York State Department of Environmental Conservation (NYSDEC) has set a goal "to reestablish a viable population of lake sturgeon and a self-sustaining component of the fish community in New York State to the point that the species is no longer classified as threatened" (Carlson 2000; Carlson 2005). Since 1995 the NYSDEC has artificially propagated this species to reestablish populations in various areas such as the St. Lawrence River, the St. Regis River, the Oswegatchie River, Black Lake, Oneida Lake and Cayuga Lake (Carlson 2005). In 1999, the NYSDEC decided to launch a similar restoration of the lake sturgeon population in the Genesee River.

Between 1999 and 2002, the United States Geological Survey (USGS) conducted a lake sturgeon habitat assessment in the lower portion of Genesee River (Dittman and Zollweg 2006). Their objective was to determine if the Genesee River, a historical part of the range of the lake sturgeon, currently constituted habitat suitable for restoring these fish. Analysis with a Habitat Suitability Index model rated this area in 1999 and 2000 as good or optimal spawning habitat and a good candidate for a lake sturgeon stocking project (Dittman and Zollweg 2006). Nineteen hundred lake sturgeon were stocked in the Genesee River in 2003 and 2004. Efforts to restore lake sturgeon populations to the first few years have proven effective as demonstrated by capture rate and fish growth (Dittman and Zollweg 2006). Out of 900 fish released in 2003, 167 juvenile sturgeon (18.5%) were captured during the first year of habitat use assessment. Between 2003 and 2004, the average length of the stocked fish increased by 146 mm, and the average weight increased by 151g. For the 2004 year class fish, the average length increased by 268 mm, and the average weight increased by 317g (Dittman and Zollweg 2006). Such improvements demonstrate the positive effects of conservation efforts.

In 2003, the Great Lakes Lake Sturgeon Coordination Meeting suggested "individual system and habitat requirements studies" for different life stages, including juveniles, as a Priority Research and Assessment need (Zollweg et al., 2003). In fact, information regarding the movements of stocked lake sturgeon in the Genesee River and their selection and use of habitats was meager or unknown. Questions remained about how long these stocked sturgeon would reside in the Genesee River system and when they would migrate to Lake Ontario (Dittman and Zollweg 2006).

My study was designed to determine movement patterns of juvenile lake sturgeon within the lower Genesee River in the summer and fall, to determine if movement to Lake Ontario occurred, and to investigate any relationships between individuals and how they use the lower Genesee River. Further, I intended to provide additional information useful for the long-term restocking program and the study of lake sturgeon in the Genesee River led by USGS Tunison Laboratory and the New

York State DEC. Lake sturgeon have been extensively studied, as demonstrated by the 1,317 literature references on lake sturgeon covering the period 1817 to 2005 (Dick *et al.* 2006). Therefore, I expected that the results from this study would supplement other research on lake sturgeon, and contribute to a successful restoration of the species in the lower Genesee River system. Two primary sets of research questions were developed, one dealing with movements, and one with habitat use:

1. Do juvenile lake sturgeon move throughout the lower Genesee River? If so, are there any seasonal or temporal variations in the movement? Do the juvenile fish visit Lake Ontario? *Hypothesis*: The stocked juvenile lake sturgeon move throughout the lower Genesee River.
2. How do stocked juveniles use the river? Do they use one or more parts of the river compared to others? Do they use the water depths of the Genesee River equally? If so, what might determine this usage? *Hypothesis*: The stocked juvenile lake sturgeon use all the regions and all depths of the Genesee River equally.

Definitions

The following terms were applied during this study, primarily based on definitions by Jones (2001). Abundance: the quantity of a component in the environment, as defined independently of the consumer. Availability: accessibility of a component to the consumer. Usage: the quantity of a component utilized by the consumer in a fixed period of time. Selection: a process in which an animal actually chooses a component. Usage is said to be selective if components are used disproportionately to their availability. Preference: a reflection of the likelihood of that component being chosen if offered on an equal basis with others. Habitat selection and habitat use patterns were beyond the scope of the current study. On the other hand, the study was designed to provide some insights on how the juvenile lake sturgeon use the lower Genesee River and its habitats during a set period of time.

Biology of the species

The lake sturgeon was first described as a "distinct species" in the early twentieth century (Rafinesque 1817). *Acipenser fulvescens* refers to its dark fulvus color (Hubbs 1917), as the back and sides of large adults are olive-brown to dull gray in color, while the juveniles are light brown with dark blotches. Lake sturgeon are long-lived and slow maturing. These fish inhabit the bottom of lakes and large rivers over mud, sand and gravel to depths of 5 to 9 m, and migrate seasonally between shallow and deeper waters, occasionally entering brackish water (Scott and Crossman 1973). Adult lake sturgeon generally range between 0.9–1.5 m in length and between 4.5–36.3 kg in weight. Females reach sexual maturity between 14 to 23 years and may live up to 80 years. Males reach sexual maturity between eight to 19 years and may live up to 55 years of age (Scott and Crossman 1973).

Lake sturgeon are omnivorous and feed on virtually anything edible that can be sucked from the substrate by the mouth. However, they primarily consume insects and other benthic invertebrates, such as snails, clams and crayfishes. These fish occasionally feed on fish eggs, algae and small fishes (Scott and Crossman 1973).

In the Genesee River, juvenile lake sturgeon primarily feed on chironomids, while Oligochaeta and Amphipoda constitute only a minor part of the diet (Dittman and Zollweg 2006).

Study Area

The Genesee River is a major tributary of Lake Ontario; the lower part of the river is located in the City of Rochester, Monroe County, New York. The surface area is approximately 256 ha. The sediment of the lower Genesee River is composed of coarse, medium and fine sand; silt and clay are common near the docks (Dittman and Zollweg 2006). The macroinvertebrate community is mostly dominated by Chironomidae and Oligochaeta. The invasive mussel species *Dreissena polymorpha* is also present (Dittman and Zollweg 2006). The lower portion of the river is mostly bordered by dense commercial, industrial and residential development. A navigation channel has been dredged upstream approximately 4 km. Except during the winter, the lower Genesee River is home to water activities such as recreational and commercial boating, as well as fishing. The lake sturgeon restoration project took place in the lower part of the river, between the mouth at Lake Ontario and the Lower Falls, a total distance of approximately 10 km (Figure 1). The Lower Falls, a 33.5-m waterfall, prevents fish from moving farther upstream.

METHODS

A preliminary sampling trip was conducted in the spring of 2006 to determine the weight range of the sturgeon present in the river. Gillnetting of sturgeon was conducted from 24 to 27 July 2006 at sites where sturgeon had been previously caught. The monofilament gillnets were the same used by USGS, and were 38 m long and 2.4 m deep, with stretch meshes varying from 5 to 15 cm (Dittman and Zollweg 2006). Internal radio transmitters were used to tag the lake sturgeon. Silver oxide or lithium batteries powered the radio transmitters, which were cylindrical in shape, allowing easy insertion into the body cavity of the fish.

Immediately after capture, selected lake sturgeon were kept in an aerated holding tank on board the electroshocker boat, a SUNY Brockport research vessel. Radio transmitters were internally implanted through a small incision along the abdomen of the animal. The incision was closed with five to six simple interrupted sutures (Summerfelt and Smith 1990). A catheter was used to pass a trailing antenna through a separate 1 to 2 mm exit hole about 3 cm posterior to the incision. Sutures and incisions were treated with an antiseptic. No anesthesia was administered, to optimize fish recovery. No postoperative antibiotic was injected (Rusak and Mosindy 1997). After the surgery, the fish were placed in a recovery-holding tank and released into the river when active swimming behavior was observed. A total of nine juvenile lake sturgeon were selected for the study. This number was determined based on the funds, logistics and human resources available for the study. Each animal was implanted with a radio transmitter with a unique frequency. The size of the transmitter relative to body weight was minimized to reduce its effect on animal movement. I established a target weight range of fish so that transmitter weight would fall within the 2% body ratio suggested in the literature (Mech and Barber 2002). The fish were then implanted with the radio tag that was closest to the 2% body weight.

A conventional VHF radio-tracking system, consisting of the radio transmitters, a receiver unit and a loop antenna, was used for monitoring fish. Typically, VHF transmitters have a range of 5 to 10km on the ground; in the water, transmission is reduced and radio transmitter function decreases with increasing depth. Rusak and Mosindy (1997) considered a maximum depth of 11m as being within the reception range of the telemetry equipment. A hand-held bi-directional diamond-shaped loop antenna was employed. Two R2000 Scientific Receivers (receiving frequency between 053.000 and 054.000MHz) manufactured in 1982 by Advanced Telemetry Systems, Minnesota, were refurbished and recalibrated in 2005 by the manufacturer. Headphones were employed to reduce external noise (Mech 1983; Samuel and Fuller 1996).

Sturgeon tracking was conducted with the SUNY Brockport electroshocker boat and "bass-boat" during the day, typically between 0800 and 1800 hours. Fish tracking was conducted in the upstream direction starting at the dock. When one or more fish was not found in the first transect, additional trips were conducted down to the river mouth. Fish tracking was conducted every day during the first week of tagging, two days during the second week, and once a week for the next thirteen weeks. Additional tracking was conducted in March and June of 2007 to verify if the transmitters were still operational. One 24-hour tracking trip was conducted in the beginning of the study period to record fish behavior and/or habitat use on a round-the-clock basis. A night tracking was conducted at the end of the fall 2006 season, from 2000 hours on 4 November 2006 to 0600 hours on 5 November 2006, to record nocturnal movements. However, the radio tagged animals could not be located that night. Thus only data from the 24-hour survey could be used to determine nocturnal movements.

The animals were tracked using the "homing in technique," which consisted of following a signal toward its greatest strength. As the boat came closer, the signal increased and the receiver gain was reduced to further discriminate the signal's direction. The process of proceeding forward and continually decreasing the gain was repeated until the animal was judged sufficiently near due to a strong signal, usually directly below the boat (Mech 1983). Signal strengths were recorded on a scale of 0 to 5. I arbitrary assigned these values based on the different levels of incoming signals. A value of zero referred to when the fish was captured, therefore yielding no transmission, but the geographic coordinates were still recorded; a value of one referred to a very weak signal, and a value of five referred to a very strong signal. The geographic coordinates of the location were recorded using a hand-held Magellan Gold Global Positioning System (GPS) unit.

Water quality was recorded using a Hydrolab Quanta G. Three sets of data were collected at fish location. Measurements were taken at the surface (0-0.5 m) and, whenever possible, at the bottom of the river. However, on several occasions, bottom readings could not be taken due to very strong water currents. Some velocity readings were taken sporadically with a Pygmy current-meter, depending on water current conditions. However, when the current was too strong, the water pushed away the equipment to an angle; therefore, the readings were biased or the wings would stop working. Depth, temperature, pH, conductivity, dissolved oxygen and percent saturation of oxygen in the water were measured. Differences of each analyte between the surface and the bottom were compared using paired *t*-test. All water quality data were normally distributed. A description of the location, the strength and the clarity of the signal from the radio transmitter, air temperature and cloud cover were recorded at the time of readings.

The movement of each radio-tagged animal was described from the time of release to the last day it was tracked. The geographic coordinates in decimal degrees of each location for each animal were plotted on a map, which were created in ESRI ArcGIS 9.2 using the ecological extension "Hawth's Analysis Tools." To look for a relationship between water quality and fish location, I used scatter plot graphs between water quality (temperature, dissolved oxygen, pH, conductivity) and the location of the fish, expressed in river kilometers (rkm) starting from the river mouth.

The minimum distance traveled by each animal throughout the study period was calculated by computing distances between successive locations. It was not adequate to compare the minimum distance traveled by each individual, since the lifetime of each radio transmitter was different. However, the results were intended to indicate whether the fish were moving, and to what extent. The average daily distance traveled by the animals was calculated. I analyzed data recorded during the 24-hour survey, when each individual was located four times. The total distance moved during that 24-hour period was taken as an index of the daily rate of movement of the juvenile lake sturgeon.

Habitat use was analyzed in terms of the location of the fish along the river, the water depth at which they occurred, and substrate composition. River use was determined by dividing the lower Genesee River into 1 km sections and calculating the number of times an animal was located in each section (hereafter referred to as rkm). The frequency of use of all sections of the river was then analyzed using a χ^2 test, with the null hypothesis that fish locations on the river followed a Poisson distribution. The physical characteristics of each section were described based on substrate data collected by USGS in 2004. Use of the river in the summer and in the fall was compared using the Kolmogorov-Smirnov test for two samples. The water depths at which the fish were located were recorded. The frequency of use of water depth use was analyzed using a χ^2 test, with the null hypothesis that water depths used by the fish followed a Poisson distribution. Water depth uses in the summer and in the fall were compared using the Kolmogorov-Smirnov test for two-samples. Since lake sturgeon are primarily bottom-dwellers (Peake 1999), a major assumption of the depth analysis was that the fish were located on the bottom of the river at the time of recording, and not in the water column.

For seasonal analyses, the start of each season followed the dates of the official calendar. During the study period, the first day of summer was 21 June 2006; the first day of fall was 23 September 2006; the first day of winter was 22 December 2006; and the first day of spring was 21 March 2007.

I attempted to determine home ranges of the radio-tagged juvenile fish. Burt's (1946) widely used definition of home range is: "the area traversed by the individual in its normal activities of food gathering, mating and caring for young". Therefore, the definition was not entirely applicable to the animals of this study since juveniles do not mate or care for young. Further, a stability analysis showed that more data points were needed to fully determine the home range of the animals, since the asymptotic curve still increased after the last tracking point was plotted (Kenward, 1987). Therefore, I did not pursue any further analyses of home ranges and I adopted a simpler approach in terms of the surface area covered by each individual throughout the study period. These surface areas were formed by four outlier points, independent of the shape, location and size of the river. Using functions in ArcView 3.2, the surface obtained was then clipped to the river so that only the parts containing the river became pertinent, visible and computed.

All statistical analyses were performed in Minitab 15 and were considered statistically significant at $p < 0.05$ (Raymond and Havel 2006).

RESULTS

Water Quality

Except for percent saturation in dissolved oxygen (p-value = 0.000) and for dissolved oxygen (p-value = 0.002), all other habitat variables were homogenous throughout the water column. Paired t-tests indicated no significant difference between the surface and bottom values of water temperature, pH and conductivity, with p-values > 0.05 (Table 1). However p-value for water temperature was very close to the significance level (p-value = 0.056). Therefore summer and fall water temperatures were separately analyzed. The results indicated a statistical difference between the surface and bottom temperatures in the summer (p-value = 0.006); but no statistical difference in the fall (p-value = 0.102). Water temperature at the surface and on the bottom was also statistically different in July (p-value = 0.006). Dissolved oxygen and temperature values reflected the expected seasonal changes (Figure 2). Surface and bottom water temperature, as well as air temperature, increased to late July and decreased thereafter. Dissolved oxygen was lowest in the beginning of the tracking season with a surface value of 6.65mg/l: 86.2% saturation. It was highest on the last day of the tracking season with a surface value of 18.62mg/l; 148.2% saturation. Conductivity varied throughout the study period (Figure 3). The values ranged between 0.262 mS/cm to 0.597mS/cm; the average conductivity was 0.379 (±0.01 SE) mS/cm. The average pH was 8.10 (±0.02 SE) throughout the study period. On some occasions, when bottom temperatures were not available, analyses were conducted using surface data.

Results From Gillnetting And Radio Tracking

During preliminary sampling in May 2006, 73 juvenile lake sturgeon were captured. Fish weight ranged between 100 and 1000 g (mean weight = 264g); most individuals weighed between 250-400 g (n=48). During sampling in July 2006, 58 fish were caught. Fish weight range increased to 250-1000 g (mean weight = 391 g) between May 2006 and July 2006. In July 2006 more individuals weighed between 400-550 g (n=26) (Figure 4). A two-sample t-test showed that the mean weight of fish in July was significantly greater than the mean weight of fish in May (t = 4.24; p-value = 0.001). Nine fish were radio tagged in the July 2006 sampling. The selected individuals represented the weight range of fish present in the river (Table 2). The nine fish were also selected based on the target or closest weight range needed for transmitter implant (Table 3).

Three individuals were radio tagged and released on 25 July 2006 (Fish 053.429, 053.448, and 053.469); five others (Fish 053.332, 053.376, 053.392, 053.409, and 053.489) were tagged and released the next day; and one (Fish 053.359) was tagged and released on 27 July 2006 (Appendix 1). Three radio transmitters did not yield proper data. The radio signals from these transmitters were found farther and farther downstream, with no movement observed after 16 days (Fish 053.359), 18 days (Fish 053.429), and 19 days (Fish 053.489). I assumed that the three individuals carrying these transmitters were dead, or that the transmitters had been expulsed from their bodies. Data from these transmitters were not analyzed. Therefore, six out of the nine radio-tagged animals were followed during the study period. On average each tagged animal was located 16 times over the study period.

The strength of the radio signal from the six fish was often low. Forty-two percent of signals were of strength 1 or 2 on a scale of 1 to 5 (Table 4). Water conductivity did not seem to affect the transmission; the regression of conductivity against signal strength was not significant and indicated no relationship between the two variables ($r^2 = 0.02$; p-value = 0.184). Success in locating fish also differed among tracking dates. On 3 October 2006 for example, only 20% of the fish were found, while on 5 October 2006, 100% of tagged animals were found.

Fish Movement

Fish 053.376 (Appendix 2) was captured 5.6 km from the river mouth and released downstream at river km 3.7. On the first day of tracking, the fish was recorded farther upstream of where it was released, demonstrating a capacity to swim against the current. The fish then gradually moved downstream. During the 24-hour monitoring, this fish was located near the walk bridge in the middle of the river (rkm 7.5). Fish 053.376 was last recorded near the 104 bridge at river km 8.2. Its transmitter worked for 28 days.

Fish 053.392 (Appendix 3) was captured and released at the same locations as Fish 053.376. The fish was also found farther downstream from its point of release on the first day of tracking (rkm 3). It gradually moved upstream, except on tracking day 53, when it was found downstream again (rkm 4; transmitter signal level of 5).

During the round-the-clock survey, Fish 053.392 was located by the walk bridge. It remained in the area during the survey and was recorded nearby for another 24 days (rkm 7.6). On 16 September 2006 the fish traveled a long distance downstream to rkm 3.5. It gradually made its way upstream to rkm 6.5, 8.2 and 9.3. It was last recorded near Seth Green Island on 23 August 2006 at rkm 8.2. The transmitter worked for 83 days.

Fish 053.409 (Appendix 4) was captured in the same gillnet as Fish 053.376 and Fish 053.392. Unlike the other two fish, Fish 053.409 moved directly upstream after release. A few days later, it was found near its point of capture at rkm 5.5. It remained in this upper part of the river for the next 50 days. On 16 September 2006 it was located far downstream (rkm 3.7; signal level 5), along with Fish 053.392. It then returned in the upper part of the river near rkm 8.9. During the round-the-clock monitoring, Fish 053.409 was located near the walk bridge and did not travel far from it. Fish 053.409 was last recorded on 17 October 2006. Its transmitter worked for 82 days.

Fish 053.448 (Appendix 5) was caught near Route 104 bridge (rkm 7.9) and released downstream at rkm 4.3. This fish also moved upstream the day after release. It remained around rkm 6.1-6.5 for a few days. It then moved and stayed in the upper part of the river not far from its point of capture (rkm 7.3 to 8.3), including during the round-the-clock monitoring. On 16 September 2006 it was recorded downstream at rkm 3.7, along with Fish 053.409 and Fish 053.392. It gradually returned upstream, and on 10 October 2006 it was located at rkm 8.8. It started to migrate downstream again and was last recorded at rkm 3.2 at the end of the fall study, on 5 November 2006.

Fish 053.469 (Appendix 6) was also caught below Route 104 bridge and released farther downstream at rkm 6.5. The day after its release, the fish was found in the lowest part of the river covered by this study (rkm 2.7), 3.8 km from the point of release. The fish stayed in the same area for several days. This stationary position likely corresponded to a recovery period. It then made its way upstream between the walk bridge and the route 104 bridge (rkm 7.1 to 8.4), where it remained for the majority of the season, including during the 24-hour monitoring. On 16 September 2006 it was located downstream at rkm 3.8 along with Fish 053.392, Fish 053.409 and Fish 053.448. On the last day of tracking, the fish was once again found in the lowest part of the river at rkm 2.8.

Fish 053.332 (Appendix 7), the largest of the fish at 0.910kg, was captured in a much lower part of the river compared to the other fish (rkm 4.5). It was released downstream but not far from its point of capture (rkm 3.8). After release, the fish was found even farther downstream (rkm 2.3) in the northern part of the study area. Afterwards, this individual was always located upstream between its point of capture (rkm 4.5) and south of Route 104 bridge. During the round-the-clock monitoring, it was found by the walk bridge (rkm 7.5), near which the other animals were also stationed. It remained in the same area for the next 22 hours. Overall, this fish stayed in the upper part of the river during the two study seasons (rkm 7.3 to 9.3). On the last day of the fall tracking period, this juvenile fish was recorded downstream at rkm 2.9.

In early spring of 2007, I tracked the three remaining transmitters (053.448, 053.469, 053.332) to verify if they were still operational. The transmitter from Fish 053.448 was working and the animal was located almost at the same location as in November, around rkm 2.8 (signal level 5). The distance between the two successive locations was very small (0.3 km) suggesting that this juvenile fish probably remained in that area all winter long. Fish 053.469 was also located near Fish 053.448 (rkm 2.7). It was very likely that this juvenile also remained in that part of the river during winter. On 2 June 2007 the transmitter from Fish 053.469 was no longer heard (last expected day of transmission, 9 June 2007). However, it was recaptured in a USGS gillnet on 26 July 2007 at 1632 hours at rkm 2.4. The tagged fish was healthy, its transmitter was still attached and the antenna was still trailing (Personal Communication, Dawn Dittman, USGS 2007). Finally Fish 053.332 was also located at the same location, together with Fish 053.448 and Fish 053.469, in that early spring 2007.

Overall the six radio-tagged fish traveled the length of the Genesee River. Locations were recorded between rkm 2.3 and rkm 9.3. In early fall the young fish were located close to the Lower Falls. On the other hand, the juvenile fish did not approach the marinas or the river mouth (Figure 5) at any time and none of the six animals was found in Lake Ontario.

During the first two weeks of monitoring, I found that radio-tagged animals displayed a certain "recovery period," which could be defined as the lapse of time during which the animal probably "recovered" from the procedures and showed no movement, or a pronounced downstream movement, before making their way upstream again. Fish 053.469 had the longest recovery phase, which lasted 18 days, followed by Fish 053.376 and 053.392, which both recuperated for seven days. The other juveniles took two days or less to regain strength as demonstrated by their upstream movement. On average, this recovery period was of six days.

Fish Aggregations

Fish aggregations, hereafter defined as two or more fish found together, (Table 5; Figure 6) were observed in five out of the 24 days of monitoring (21% of observations). Fish 053.448 and 053.469 were found together on 12 August 2006 at night; Fish 053.332, 053.448 and 053.469 on 16 September 2006 at 1705 hours; Fish 053.392, Fish 053.448, Fish 053.409 and Fish 053.469 on 7 October 2006 at 1709 hours. Finally, Fish 053.332, Fish 053.448 and Fish 053.469 were found together on the last day of tracking on 5 November 2006 around 1000 hours. These last three fish were again located together at the same place in early spring, on 31 March 2007 at 1245 hours. Interestingly, Fish 053.448 and Fish 053.469 were associated in five out of the five occasions when fish gatherings were recorded (Table 5). Gatherings occurred during all seasons (summer, fall, winter) and at different times of the day, including during winter and at night. Qualitative observations indicated that schooling occurred when the weather was rather calm (no strong wind, no heavy rain) and the sky was clear.

Relationship Between Fish Location and Water Quality

Scatter plots of fish location – as expressed in rkm – against water quality variables revealed no significant relationship. During warmer months, the fish moved independently of the changes in water temperature. On the other hand, fish location was related to a drop in water temperature in the fall (Figure 7 to 9). The juvenile lake sturgeon moved downstream when the bottom water temperatures dropped from 10°C to about 5°C based on the locations of the three fish bearing long-term transmitters. A pronounced movement downstream between rkm 2 – 3 is demonstrated by the locations of Fish 053.332 (Figure 7), Fish 053.448 (Figure 8) and Fish 053.469 (Figure 9). Fish 053.332 moved from rkm 9.3 to 2.9 when water temperature dropped from 9.4°C to 5.6°C. Fish 053.448 moved from rkm 8.8 to rkm 3 when water temperature dropped from 9.5°C to 4.9°C. Finally, Fish 053.469 also moved from rkm 8.8 to rkm 2.8 when temperature dropped from 9.5°C to 4.9°C. The fish were stationary and likely remained in the same area throughout the winter, as suggested by their location in early spring of the following year.

Minimum distance traveled

The minimum distance traveled by lake sturgeon throughout the study period varied among individuals (Table 6). The fish traveled on average 18.3 (±2.9 SE) km within an average period of 83 days. The range of minimum distance traveled was between 5.57km in 28 days to 26.64km in 103 days.

Fish of similar weight traveled different distances. For instance, Fish 053.392 at 0.280kg traveled 22.03 km over a period of 83 days while Fish 053.409 at 0.260kg travelled 15.35km over a period of 82 days. The minimum distances traveled by the fish were not comparable because of the differences in the lifetime of the transmitters. However, these results clearly demonstrated that the juvenile lake sturgeon were mobile and moved relatively long distances throughout the lower Genesee River.

Daily Distance Traveled

Based on the 24-hour monitoring, during which the location of each animal was recorded four times, the juvenile lake sturgeon traveled an average of 0.806 (±0.15 SE) km/day. Fish 053.376 traveled the shortest distance (0.364 km), followed by Fish 053.332 (0.395 km), Fish 053.469 (0.801 km), Fish 053.409 (0.885 km) and Fish 053.448 (0.988 km). Fish 053.392 traveled the longest distance with 1.404 km over the 24-hour period (Table 7). No relationship was found between the weight of the fish and the distance traveled per day ($r^2 = 0.160$, p-value = 0.433).

River Use

The juvenile fish were located throughout the lower Genesee River between rkm 2.3 – 9.3 (Figure 5). However, the use of some regions of the river was clearly heavier compared to others. The sections between rkm 7 and rkm 9 were the most frequented, with the fish located in that section more than 57% of the time (37% in rkm 7 – 8; 20.6% in rkm 8 – 9). The other parts of the river were much less frequented: 11.34% in rkm 5 to 6, and less than 10% for the other sections of the river (Table 8). An analysis of frequencies showed that the observed distribution of the fish did not follow a Poisson distribution ($\chi^2 = 66.85$, dF = 6, p-value = 0.001) (Table 9). Thus, the fish were not randomly located throughout each section of the river.

The young fish occupied all regions of the river during the summer with most locations detected in rkm 7 – 8 (38.5%). During the fall, the young fish were mostly located upstream between rkm 8 – 9 (55% of locations). Sections lower than rkm 7 were much less frequented, with no records at sections 4 to 5 and 5 to 6 (Table 10). A Kolmogorov-Smirnov test indicated a significant difference in river use between the two seasons, with $D = 0.562$ and p-value = 0.001. However, the reduced number of samples during the fall might have biased the results. During winter, the juvenile lake sturgeon may not have moved or moved only a small distance, as suggested by the successive locations at the beginning and end of winter. Three radio-tagged juveniles with working transmitters were found at the same location (rkm 2) at the beginning of the winter season as well as at the end of it. The juvenile fish may have been sedentary during the winter months. However, additional tracking would be necessary to confirm fish location and movement in winter.

Substrate Composition of the Genesee River

The substrate analysis by USGS in November 2004 (Dittman and Zollweg 2006) determined the sediment composition at various sites. The substrate of the study area is mostly composed of silt and clay, constituting more than 62% of the substrate. The upstream sections (rkm 6 – 9) have a higher percentage of fine sand

(45% of substrate) whereas the downstream sections are mostly composed of silt and clay (61% to 97% of substrate). The lower Genesee River has a low composition of gravel (0.02%), coarse sand (0.03%) and medium sand (0.06%). The heavily used section between rkm 7 and rkm 8 is 3 to 5 m deep, and is composed of 45% fine sand and 36% silt and clay. The winter spot at rkm 2 is 4.9 m deep and is mostly composed of silt and clay (82%) (Table 11). The frequent location of the fish in the upstream sections (57% of all locations) and the substrate composition at these locations may suggest that the juvenile fish were inclined to fine sand substrate.

Water Depth Use

The juvenile fish were found in all water depths of the study area, from shallow waters less than 1 m deep to 9.6 m, the maximum depth of the lower Genesee River. More locations were recorded in 3.0 – 4.0 m of water, with 27.8% of all observations, followed by locations in 4.0 – 5.0 m (21.4%). Locations at extreme depths above 1m and below 9 m were few. Analysis of frequency distribution indicated that the water depths used followed a Poisson distribution ($\chi^2 = 5.77$; dF = 5, p-value = 0.329) (Table 12). Therefore, water depths used by juvenile lake sturgeon were randomly distributed. A one-way ANOVA also showed no statistical difference in water depth used by the six juvenile lake sturgeon (p-value = 0.781) (Table 13).

Seasonally, the fish were most frequently detected in 3.0 to 4.0 m of water during both the summer (51.5% locations) and fall (45% locations) (Table 14). A Kolmogorov-Smirnov test further indicated no difference in water depth use between the two seasons (*D* = 0.188; *p*-value = 0.385). The range of depths used in the fall (0.9 to 9.61 m) was slightly greater than the range of depths used in the summer (1.3 to 7 m). Again, the smaller number of samples during the fall might have biased the results. Based on the 24-hour survey, the water depths used during the day (0600 – 1759 hours) were similar to those used at night (1800 – 0559 hours). A paired *t*-test indicated no statistical difference between the average depth used during the day and at night ($t = -0.70$; *p*-value = 0.499). Most locations during the 24-hour period were also recorded in 3.0 – 4.0 m water depth, representing 36.4% of total locations (Table 15).

Surface Area Covered

The surface areas covered by the young fish varied between 21.8 ha to 46.8 ha, with an average occupation of 35.8 ha. These surfaces covered represented 8.5% to 18.3% of the 256 ha of study area. Interestingly, the smallest of the six fish occupied the smallest surface areas, while the largest of the fish occupied the largest surface areas (Table 16). The coefficient of determination ($r^2 = 0.663$; *p*-value = 0.048) indicated a small but positive relationship between the size of the animal and the surface area occupied (Figure 10). Surface overlaps between all six animals often occurred. Surface occupation was greater in the upstream portion of the river.

DISCUSSION

The findings from the current study clearly indicate that juvenile lake sturgeon moved throughout the lower Genesee River, but favored the southern region of the river. The juvenile fish did not travel near the river mouth or in Lake Ontario. Information collected during this study was limited because it was gathered during only two study seasons. However, the findings indicate that the behaviors of the juvenile lake sturgeons stocked in the Genesee River were comparable to the behavior of other natural or artificial populations in other regions. In addition these findings suggest that the artificial population of the Genesee River is healthy and the stocking program is successful.

In the current study, I tagged nine juvenile lake sturgeon, six of which provided useful movement data. The number of tagged animals and the tagging success were comparable to several other studies. In the North Channel of the St. Clair River, Lord (2007) radio tagged and tracked nine juvenile lake sturgeon. In Black Lake, Michigan, eight individual lake sturgeon were captured and tagged; one animal died while seven out of the eight tagged animals yielded data (Smith and King 2005). In the Portage Lake/Sturgeon River system in Michigan, four sub-adult and one juvenile lake sturgeon were fitted with radio transmitters, and all yielded data (Holtgren and Auer 2004). With an average of 16 data points per animal, the number of observations in this study was comparable to the average number collected in other research. In the Niagara River and nearby Lake Ontario, each fish was located approximately 15 times during an average tracking period of 147 days (Hughes 2002). In the Black Lake, Michigan, each fish was located on between 14 to 23 occasions over a period of 83 days (Smith and King 2005).

Three of nine radio-tagged fish in this study did not provide useful tracking data. Within seven days after the procedure, the three fish may have perished and/or their transmitters may have been expulsed from their body. Complications from surgery, as well as tag weight, may have caused the early loss of the radio tags and/or possibly the death of some fish. A high tag weight relative to fish body weight may detrimentally affect the survivability of fish (Jepsen *et al.* 2002). The weight of fish caught during sampling did not all fall within the ideal weight for transmitter implants. Five out of nine fish were implanted with a radio tag slightly exceeding their 2% body weight (2.02% to 2.67%). In one fish that perished the excess of tag weight (2.67%) might have played a role in tag loss and/or fish mortality. However, in the other two fish that perished, the radio tags were within the suggested weight ratio of the animals, and the cause of early loss remains uncertain. Therefore the cause of early tag loss and/or fish mortality may not have been primarily from tag weight, but rather from loose sutures or other complications. Smith and King (2005) reported that out of 20 hatchery-reared lake sturgeon yearlings (age-1), only 12 were able to hold the transmitters without rejecting them after insertion.

Of the six remaining radio-tagged fish, four traveled downstream after the surgery, and two individuals immediately made their way upstream, indicating a capacity to swim against the current. Similar behavior was observed in adult green sturgeon *Acipenser medirostris* from the Rogue River system, Oregon. Two adult green sturgeon traveled downstream, and one exhibited extensive upstream movement immediately after tagging (Erickson *et al.* 2002). The downstream movements could correspond to a recovery period immediately following the surgery, during which fish were not able to swim against the current. After this initial period, juvenile fish traveled both downstream and upstream throughout the Genesee River.

The juvenile lake sturgeon stocked in the lower Genesee River were quite mobile, although they did not travel near the river mouth or into Lake Ontario during the study period. The six radio-tagged juvenile fish moved an average of 0.806 km/day. This daily rate was comparable to data from several other studies. In the Portage Lake/Sturgeon River system, Michigan, juvenile lake sturgeon traveled 0.3 – 1.6 km/day (Holtgren and Auer 2004). Age-0 lake sturgeon of the Lower Pesthigo River, Wisconsin, traveled between 0 - 0.512 km/day (Benson and Trent 2005). The mobility of the fish was further confirmed by the considerable size of surface areas occupied by the young animals throughout the river. Surface covered also indicated that the juvenile young sturgeon did not travel near the river mouth or into Lake Ontario. Overlaps of occupied surface area often occurred in the Genesee River fish. In the North Channel, St-Clair River, many juvenile lake sturgeon also had a high degree of home range overlap (Lord 2007).

A relationship between water quality and lake sturgeon movement was not found. Lake sturgeon appeared to move independently of changes in water pH or conductivity, despite the variability of the values of these parameters. Variability was likely the result of runoff of the lower Genesee River. Movement was not related to the amount of dissolved oxygen in the water, which followed the expected values for the seasons. During the summer, movement did not appear to be related to water temperature. On the other hand, when the water temperature dropped from around 9°C to around 5°C, the Genesee River juvenile lake sturgeon displayed a pronounced downstream movement towards rkm 2.8. Comparable movements of lake sturgeon were observed in other rivers. In the lower Peshtigo River, Wisconsin, seasonal downstream movements of age-0 lake sturgeon were related to drops in water temperature from 16°C to less than 13°C (Benson and Trent 2005). The authors suggested that declining water temperatures during fall months may cue fish to move downstream in search of warmer waters.

Lack of movement suggested that the juveniles were sedentary during the winter. The fish were once again active in the spring and early summer of the following year. This finding was consistent with several other studies. In the lower Niagara River, New York, lake sturgeon movements decreased dramatically as the water temperatures dropped below 10°C. The fish entered an over-wintering period for about four to five months. Movements resumed with increasing temperatures in the spring (Hughes 2002). Priegel and Wirth (1974) also observed over-wintering periods in young lake sturgeon.

Aggregation was a striking behavior of the Genesee River juvenile lake sturgeon. Various studies on juvenile lake sturgeons mention successful capture sites implying that several individuals were present at a site at a given time. Hayes and

Werner (1997) reported clustering behavior of the juvenile lake sturgeon in the St.Lawrence River. Distinct concentrations of juvenile lake sturgeon were also observed in different regions of the lower Niagara River and its confluence with Lake Ontario (Hughes 2002). Juvenile fish aggregations were mentioned by Benson and Trent (2005), and Smith & King (2005). In the lower Genesee River, Dittman and Zollweg (2006) reported on juvenile fish aggregation at capture points; further, they indicated that the number of fish caught was higher than that of the studies mentioned earlier. Juvenile fish gathering at the end of the fall season, as observed in the Genesee River fish, has also been reported in other studies. Yearlings gathered in large schools in shallow river mouths or adjacent bays during late summer and fall in Lake Winnebago, Wisconsin (Priegel and Wirth, 1971). No study, however, directly investigates why or under what conditions do juvenile lake sturgeon aggregate.

In terms of habitat use, the juvenile fish heavily used the southern region of the Genesee River between rkm 7 and 9, in comparison to other parts of the river. Preliminary studies in the Genesee River conducted by the USGS had identified that portion of the river as a good or optimal foraging habitat for juvenile lake sturgeon. Juvenile foraging variables in the Genesee River include substrates of sand, silt, silty clay and sandy gravel at depths of 2 to 7 m (Dittman and Zollweg 2006). Haxton (2003) reported that lake sturgeon display high fidelity in areas of primarily sand and clay. In the lower Niagara River and nearby Lake Ontario, sand was also the dominant substrate in high use areas (Hughes 2002). These types of substrates may be productive for benthic invertebrates, which constitute the main prey of sturgeon.

Peake (1999) however found out that substrate preference may have a genetic basis and that juvenile lake sturgeon may be inherently attracted to sand regardless of food distribution or availability. The substrate composition at the south section of the Genesee River was not particularly different from the substrate type of the rest of the river, which was also primarily composed of silt, clay and fine sand. Therefore other factors such as water velocity and boat traffic might also influence the presence of the young fish at these sections.

The upstream section of the river is characterized by a low flow rate varying between 0.01m/s to 0.2m/s in the summer and fall (Dittman and Zollweg 2006). Water flow rate in the upstream section of the river is largely influenced by the Lower Falls and Seth Green Island. Water flows faster at the bottom of the falls but considerably slows at it reaches Seth Green Island. Water current velocity then remains low in the other sections of the Genesee River. During summer and fall, water flow in the sections closer to Lake Ontario is null (Dittman and Zollweg 2006). In the South Saskatchewan River, Alberta, lake sturgeon were captured in water with a flow rate less than 0.8m/s (Haugen 1969). Benson and Trent (2005) also reported that age-0 lake sturgeon were captured and relocated at sites current velocities less than 0.6m/s. Avoidance of boat traffic by sturgeon has also been reported in other studies, such as Harkness and Dymond (1961) and Engel (1990). In the lower Genesee River, boat traffic was more intense downstream and near Lake Ontario. That part of river was close to marinas, docks and the river mouth. Conversely, boat traffic was less intense upstream which might explain the recurrent presence of the young fish in that area. Overall water velocity and avoidance of boat traffic remain speculative factors in this study. Further investigation in the upstream section of the river is clearly needed to provide additional information on the habitat preference of the Genesee River fish.

The radio-tagged juvenile lake sturgeon used all of the available water depths of the lower Genesee River from above 1m to 9.6m deep. This behavior was similar to other groups of juvenile lake sturgeon in different water systems. In shallow lakes such as Lake Winnebago, Wisconsin, where water depths are less than 7 m, lake sturgeon also occupied all depths (Priegel and Wirth 1971). However, in our study, areas with water depths between 3.0 – 5.0 m were much more frequented. In natural reaches of the Ottawa River, Canada, lake sturgeon were also generally found in shallow water with a mean depth of 3.5 m, and were occasionally found in water up to 12 m deep (Haxton 2003). Interestingly, only the largest of the six fish (58.5 cm; 910 g) frequented the deepest region recorded for the river (9.6 m).

Over the course of the 24-hour monitoring, the juvenile lake sturgeon were found upstream between rkm 7 and 8. The fish were found at similar depths during the day and night, and at water depths of 3.0 – 5.0 m water. Since the round-the-clock monitoring was only conducted once, no conclusions could be drawn about the diel vertical movements of the Genesee River fish.

Further Research and Management Recommendations

The findings from the current study may contribute to a better knowledge of the lake sturgeon movement along the lower Genesee River. However, some

additional information is still needed to obtain a complete picture of the movement patterns and the activity of the lake sturgeon stocked in the Genesee River. For instance, it would be beneficial to monitor the population over a longer period of time to determine whether the stocked individuals migrate towards Lake Ontario, and if so, when. It would be also beneficial to investigate the habitats (water depth, substrate, velocity) used by these stocked lake sturgeon throughout the year, particularly in the upstream section of the river. A few management recommendations may be derived from the findings of this study. Such management recommendations may include educating the public on the presence of the threatened fish species in river. Interpretive signs may be installed on the side of the Genesee River walkways to inform the public about the stocking program and the ongoing monitoring program. Coupled with the results from the USGS monitoring program, heavily used areas along the Genesee River such as the southern section between rkm 7 and 9 may be temporarily protected. The temporary protection may be needed until more information is available on why stocked fish favor that section of the river.
A periodic monitoring of the lake sturgeon until they reach maturity would assist with full recovery of the species in the lower Genesee River.

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TABLES

Table 1: Daily averages of river characteristics. Temperature, pH, Dissolved Oxygen (DO mg/l), Percent Saturation (DO%) and Conductivity (mS/cm).

Date	Air Temperature (°C)	Surface Temperature (°C)	Bottom Temperature (°C)	Surface pH	Bottom pH
25-Jul-06	25.35	28.80	24.26	7.91	7.96
26-Jul-06	34.05	34.19	24.90	8.27	8.33
27-Jul-06	32.06	32.02	27.22	8.12	8.17
28-Jul-06	30.49	25.90	25.61	7.91	7.89
2-Aug-2006	29.03	28.22	27.34	8.12	7.92
3-Aug-2006	26.00	27.28	27.60	7.98	8.00
12-Aug-2006	20.93	24.05	23.95	8.01	8.08
13-Aug-2006	19.18	23.65	22.46	8.10	8.07
23-Aug-2006	21.13	23.25	22.97	8.11	7.85
31-Aug-2006	19.77	18.63	18.61	8.18	8.11
6-Sep-06	17.40	15.89	17.03	8.17	8.16
14-Sep-06	18.78	17.39	17.33	8.22	8.61
16-Sep-06	18.59	17.56	17.55	8.12	8.12
20-Sep-06	17.52	18.98	18.97	8.10	8.11
29-Sep-06	11.53	15.73	15.77	8.10	8.12
3-Oct-06	15.59	14.58	14.53	8.10	7.96
7-Oct-06	16.55	13.17	13.00	8.04	8.03
16-Oct-06	13.17	9.61	*	8.07	*
17-Oct-06	10.00	9.43	9.44	8.15	8.13
24-Oct-06	6.03	8.5	6.81	8.06	8.12
1-Nov-06	7.59	11.88	*	8.31	*
5-Nov-06	4.70	5.60	5.31	8.15	8.03
Paired *t*-test (*p*-value)		0.056		0.798	

(Table 1: continued)

Date	Surface DO (mg/l)	Bottom DO (mg/l)	Surface DO%	Bottom DO%	Surface Conductivity (mS/cm)	Bottom Conductivity (mS/cm)
25-Jul-06	8.45	8.85	97.20	97.40	0.31	*
26-Jul-06	7.76	7.65	103.85	99.33	0.29	0.37
27-Jul-06	7.29	6.70	100.30	84.65	0.32	0.40
28-Jul-06	7.96	8.01	99.60	96.40	0.37	0.38
2-Aug-2006	8.41	7.11	107.77	89.53	0.43	0.44
3-Aug-2006	7.10	6.65	88.20	87.55	0.45	0.45
12-Aug-2006	9.72	8.61	114.51	101.17	0.39	0.39
13-Aug-2006	8.85	8.38	107.81	98.31	0.40	0.39
23-Aug-2006	8.53	8.16	98.90	93.03	0.60	0.60
31-Aug-2006	10.19	9.67	108.06	102.78	0.26	0.26
6-Sep-06	10.87	10.68	109.58	108.03	0.30	0.30
14-Sep-06	10.15	9.48	105.20	102.53	0.40	0.40
16-Sep-06	9.65	9.51	99.98	98.23	0.43	0.43
20-Sep-06	9.33	9.07	100.80	98.40	0.50	0.50
29-Sep-06	10.83	10.12	110.10	106.75	0.56	0.55
3-Oct-06	10.55	10.76	106.90	106.70	0.46	0.44
7-Oct-06	12.01	11.76	113.10	109.70	0.36	0.36
16-Oct-06	13.62	*	116.20		0.41	*
17-Oct-06	11.50	11.28	102.25	98.75	0.43	0.44
24-Oct-06	12.54	12.48	119.65	106.40	0.41	0.40
1-Nov-06	13.29	*	113.90		0.35	*
5-Nov-06	16.00	13.85	124.40	105.72	0.32	0.32
Paired *t*-test (*p*-value)	0.002		0.000		0.243	

Table 2: Characteristics of the nine juvenile lake sturgeon selected for the study, sorted by weight (g).

Fish	Frequency (MHz)	USGS tag	Fish weight (g)	Fish length (mm)	Girth (mm)	Year Class
1	053.376	593	180	355	142	2004
2	053.409	316	260	395	152	2004
3	053.392	589	280	391	150	2004
4	053.429	586	347	407	165	2004
5	053.448	457	464	444	182	2004
6	053.469	585	590	512	180	2003
7	053.489	208	600	526	189	2003
8	053.359	672	670	518	188	2003
9	053.332	236	910	585	205	2003

Table 3: Characteristics of the radio transmitters implanted in the nine juvenile lake sturgeon.

Fish	Frequency (MHz)	Model	Targeted fish weight (g)	Fish weight (g)	Transmitter weight (g)	Percent of body weight
1	053.376	F1805	[150 – 200]	180	3.20	1.78%
2	053.409	F1810	[250 – 300]	260	6.00	2.31%
3	053.392	F1815	[250 – 300]	280	6.00	2.14%
4	053.448	F1815	[300 – 350]	347	7.00	2.02%
5	053.429	F1815	[300 – 350]	464	7.00	1.51%
6	053.469	F1820	[450 - 600]	590	8.75	1.48%
7	053.489	F1835	[650 – 850]	600	13.00	2.17%
8	053.359	F1840	[900 – 1100]	670	17.90	2.67%
9	053.332	F1840	[900 – 1100]	910	17.90	1.97%

(Table 3: continued)

Fish	Frequency (MHz)	Lifetime (days/month)	Last day expected	Last day tracked
1	053.376	35 (1month)	30-Aug-06	23-Aug-06
2	053.409	87 (3 months)	21-Oct-06	16-Oct-06
3	053.392	87 (3 months)	21-Oct-06	17-Oct-06
4	053.448	250 (8.3 months)	2-Apr-07	31-March-07
5	053.429	250 (8.3 months)	2-Apr-07	N/A [1]
6	053.469	318 (10.6 months)	09-Jun-07	31-March-07 [2]
7	053.489	788 (2.2 years)	21-Sept-08	N/A [1]
8	053.359	1045 (2.9 years)	05-July-09	N/A [1]
9	053.332	1045 (2.9 years)	05-July-09	31-March-07 [1]

1. Three animals did not yield proper tacking data. Lack of movement in more than 15 days suggested the fish was dead.
2. Fish 053.469 was caught by a gillnet in July 2007 during the USGS lake sturgeon monitoring. The fish was healthy; its transmitter was still attached

Table 4: Strength of incoming radio signals from the transmitters, recorded on an arbitrary scale from 1 to 5

Signal strength	Number of observations	Percent observation (%)
1	16	17.58
2	22	24.18
3	21	23.08
4	11	12.09
5	20	22.09
TOTAL (*)	91	100,00

(*) Radio signals were at the time of capture and at the time of release were not applicable.

Table 5: Fish aggregation data. (-) indicates that the transmitters were no longer working.

			Fish Frequency/Aggregation				
Date	Time (hours)	Weather conditions	053. 392	053. 409	053. 332	053. 448	053. 469
12 Aug 2006	2005	Light breeze, sky cover 0%				✓	✓
16 Sept 2006	1705	Warm, sky cover <40%			✓	✓	✓
7 Oct 2006	1709	Warm, Sunny, sky cover 0%	✓	✓		✓	✓
5 Nov 2006	1000	Cold, sunny Sky cover < 30%	-	-	✓	✓	✓
31 Mar 2007	1245	Sunny, sky cover < 20%	-	-	✓	✓	✓

Table 6: Minimum distance travelled by each fish over the tracking period and/or while the transmitters was operational.

Fish	Weight (g)	Period (days)	Minimum distance traveled (km)
053.376	180	28	5.57
053.409	260	82	15.35
053.392	280	83	22.03
053.332	910	102	19.93
053.448	347	103	20.33
053.469	590	103	26.64

Table 7: Distance traveled by the fish during a 24-hour survey on 12 – 13 August 2006, with four locations per fish.

Fish	Fish weight (g)	Time start (hours)	Time end (hours)	Distance traveled (km)
053.376	180	1301	1018	0.364
053.409	260	1323	1049	0.885
053.392	280	1222	1105	1.404
053.448	347	1414	0948	0.988
053.469	590	1339	1004	0.801
053.332	910	1229	1009	0.395

Table 8: Frequency of use of each section of the river (rkm)

Location on the river (rkm)	Frequency of use	Percent use (%)
2 – 3	6	6.2
3 – 4	9	9.3
4 – 5	3	3.1
5 – 6	11	11.3
6 – 7	9	9.3
7 – 8	36	37.1
8 – 9	20	20.6
9 – 10	3	3.1
TOTAL (*)	97	100.0

(*) Locations at the point of release were not computed for this analysis.

Table 9: Chi-Squared (χ^2) analysis of the locations of the fish along the river, with the null hypothesis that the locations follow a Poisson distribution.

Location (rkm)	Observed frequency	Poisson Probability	Expected Frequency	Contribution to χ^2	*p*-value
≤ 2	6	0.055	5.30	0.094	0.001
3	9	0.082	7.92	0.147	
4	3	0.126	12.23	6.963	
5	11	0.156	15.10	1.113	
6	9	0.160	15.54	2.753	
7	36	0.141	13.71	36.238	
8	20	0.109	10.58	8.379	
≥ 9	3	0.171	16.62	11.165	
TOTAL	97	1.000	97.00	66.853	

Table 10: Frequency of use of each river section in summer (26 July – 22 Sept 2006) and fall (23 Sept 2006 – 06 Nov 2006).

	Summer[1]		Fall	
Location on the river (rkm)	Observed Frequency	Percent (%)	Observed Frequency	Percent (%)
2	4	6.90	2	10.0
3	7	12.07	1	5.0
4	1	1.72	0	0.0
5	10	17.24	0	0.0
6	8	13.79	1	5.0
7	20	34.48	2	10.0
8	8	13.79	11	55.0
9	0	0.0	3	15.0
TOTAL[2]	58	100	20	100

Kolmogorov-Smirnov test: $D = 0.562$, p-value = 0.001

Note: Transmitter from Fish 053.376 was operational during the summer only. Therefore, data from that fish were not considered in the comparison to avoid bias.
([1]) Only the first and last data points from the summer 24-hour period survey, recorded on two different days, were computed for this analysis to avoid bias.
([2]) Locations where the fish were released after tagging were not computed for this analysis.

Table 11: Substrate composition at each river section based on USGS Data 2004. Bold types indicate the overwintering section (rkm 2 – 3) and the heavy use areas (rkm 7 – 8).

			Substrate composition				
Section (rkm)	# ponar samples	Depth (m)	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt and Clay
1 – 2	3	3.4	0.00	0.02	0.07	0.14	0.77
2 – 3[1]	**2**	**4.9**	**0.00**	**0.01**	**0.01**	**0.17**	**0.82**
3 - 4	1	1.0	0.00	0.00	0.01	0.02	0.97
4 - 5	1	6.0	0.00	0.08	0.06	0.07	0.79
5 - 6	4	2.2	0.00	0.01	0.02	0.37	0.61
6 - 7	3	2.6	0.01	0.02	0.16	0.45	0.36
7 - 8[2]	**3**	**4.0**	**0.03**	**0.08**	**0.08**	**0.45**	**0.36**
8 - 9	4	2.9	0.12	0.04	0.09	0.49	0.27
TOTAL			0.02	0.03	0.06	0.27	0.62

[1] Section incorporating the over-wintering spot of three fish.
[2] Most frequented section of the river.

Table 12: Chi-Squared (χ^2) analysis of the water depths used by the fish, with the null hypothesis that the water depths used follow a Poisson distribution.

Depth (m)	Observed frequency	Poisson Probability	Expected Frequency	Contribution to χ^2	*p*-value
≤1	7	0.098	8.13	0.157	0.329
2	7	0.153	12.68	2.544	
3	23	0.199	16.55	2.514	
4	18	0.195	16.20	0.200	
5	12	0.153	12.69	0.037	
6	9	0.100	8.28	0.063	
≥7	7	0.102	8.47	0.256	
TOTAL[(1,2)]	83	1.000	83.00	5.770	

[(1)] Data from 14 locations, including at the point of capture, were not available.
[(2)] Water depth at the point of release was not computed for this analysis.

Table 13: One-way ANOVA on the average depth at which the six animals were located.

Source	DF	SS	MS	F	P
Fish	5	8.17	1.63	0.49	0.781
Error	77	255.17	3.32		
Total	82	263.44			

Table 14: Depth at which the radio-tagged animals were located in the summer (26 July – 22 Sept 2006) and fall (23 Sept 2006 – 06 Nov 2006).

	Summer[(1)]		Fall	
Water depth (m)	Observed frequency	Percent (%)	Observed frequency	Percent (%)
0	0	0.0	2	11.8
1	3	6.0	2	11.8
2	5	10.0	0	0.0
3	12	24.0	6	35.3
4	15	30.0	2	11.8
5	8	16.0	1	5.9
6	3	6.0	1	5.9
7	4	8.0	2	11.8
8	0	0.0	0	0.0
9	0	0.0	1	5.9
TOTAL[(2)]	66	100.0	17	100.0

Kolmogorov-Smironov test: *D* = 0.188, *p*-value = 0.385

Note: Transmitter from Fish 053.376 was operational during the summer only. Therefore, data from that fish were not considered in this comparison either.
([1]) Only the first and last data points from the summer 24-hour period survey were computed for this analysis to avoid bias.
([2]) Locations where the fish were released after tagging were not computed for this analysis.

Table 15: Depth at which the six fish were located during the day (0600 – 1759 hours) and at night (1800 – 0559 hours) during the 24-hour survey.

Depth (m)	Day Frequency	% Total	Night Frequency	% Total
< 3	2	18.2	0	0.0
3 – 4	4	36.4	4	36.4
4 – 5	1	9.1	3	27.3
5 – 6	3	27.3	2	18.2
6 – 7	1	9.1	2	18.2
≥ 7	0	0.0	0	0.0
TOTAL	11	100.0	11	100.0

Paired *t*-test, $t = -0.70$; *p*-value = 0.499

Table 16: Surface area occupied by each radio-tagged fish.

Fish	Fish size (mm)	Fish weight (g)	Surface area (ha)
053.376	355	180	21.8
053.409	395	260	27.3
053.469	512	590	38.0
053.392	391	280	38.6
053.448	444	464	41.9
053.332	585	910	46.8

FIGURES

Figure 1: Overview of the lower Genesee River, Monroe County, New York, between the river mouth at Lake Ontario and the first falls in the City of Rochester.

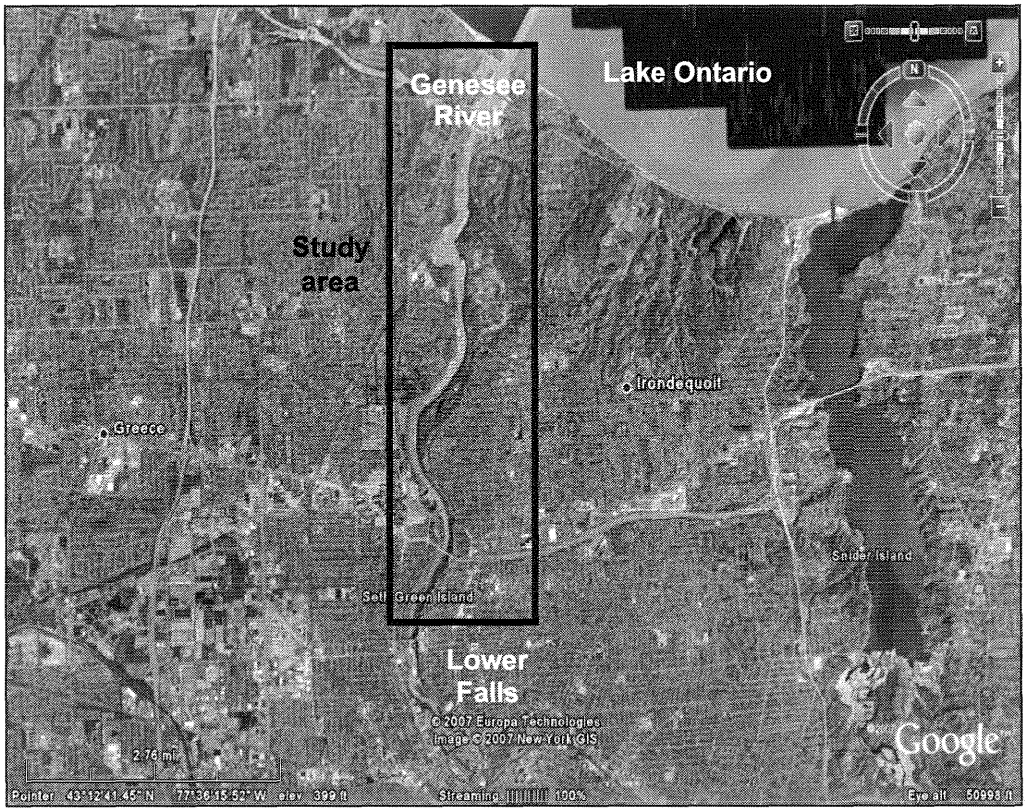


Figure 2: Variation in temperature and oxygen saturation at the surface and on the bottom of the river, 25 July 2006 – 5 November 2006.

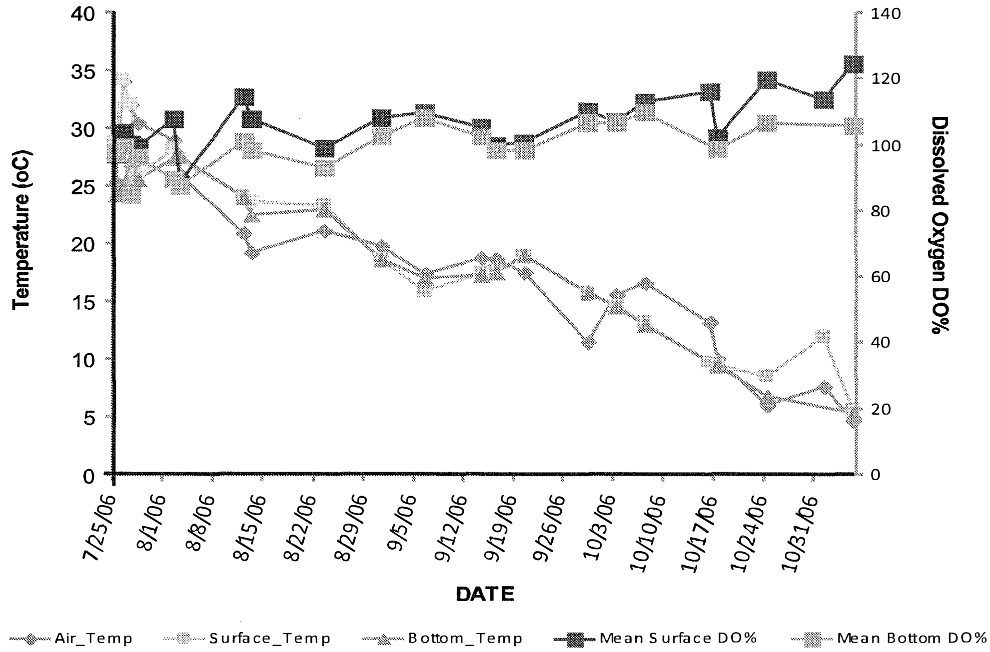


Figure 3: Variations in conductivity at the surface and at the bottom of the river, 25 July 2006 to 5 November 2006.

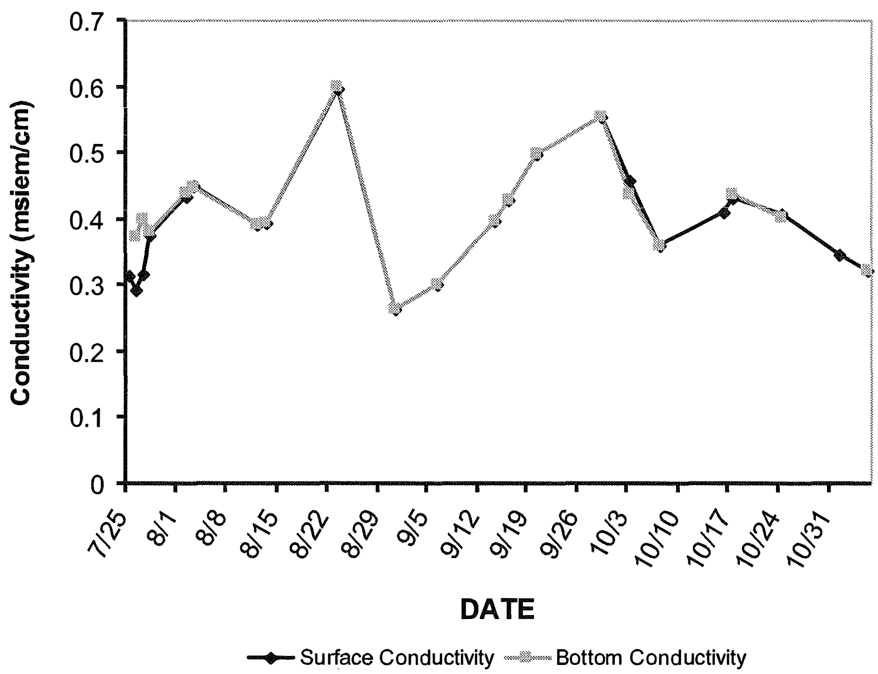


Figure 4: Weight distribution of juvenile lake sturgeon in the lower Genesee River in May 2006 (n = 73) and July 2006 (n = 56).

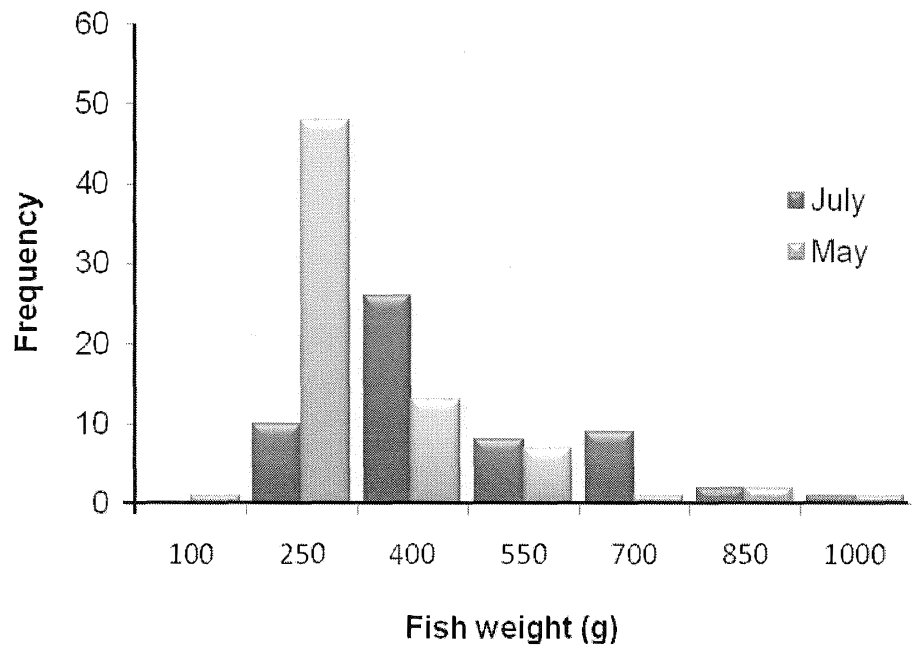


Figure 5: Locations of six radio-tagged juvenile lake sturgeon throughout the lower Genesee River, 25 July 2006 to 5 November 2006 and March 2007. Figure includes initial capture locations. The cluster between rkm 7 – 8 is highlighted.

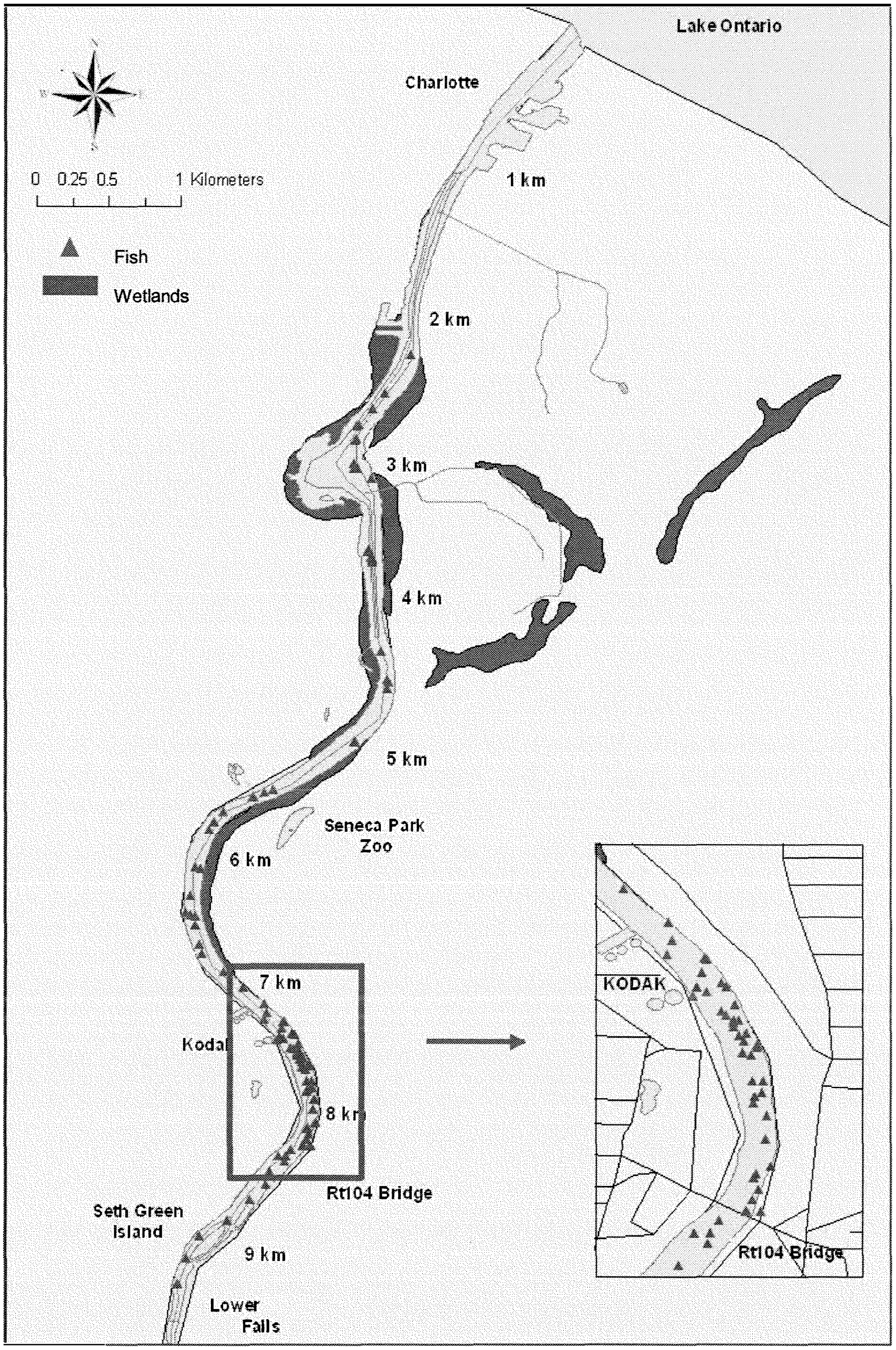


Figure 6: Locations of the six radio-tagged juvenile lake sturgeon throughout the lower Genesee River, indicating fish associations at various dates.

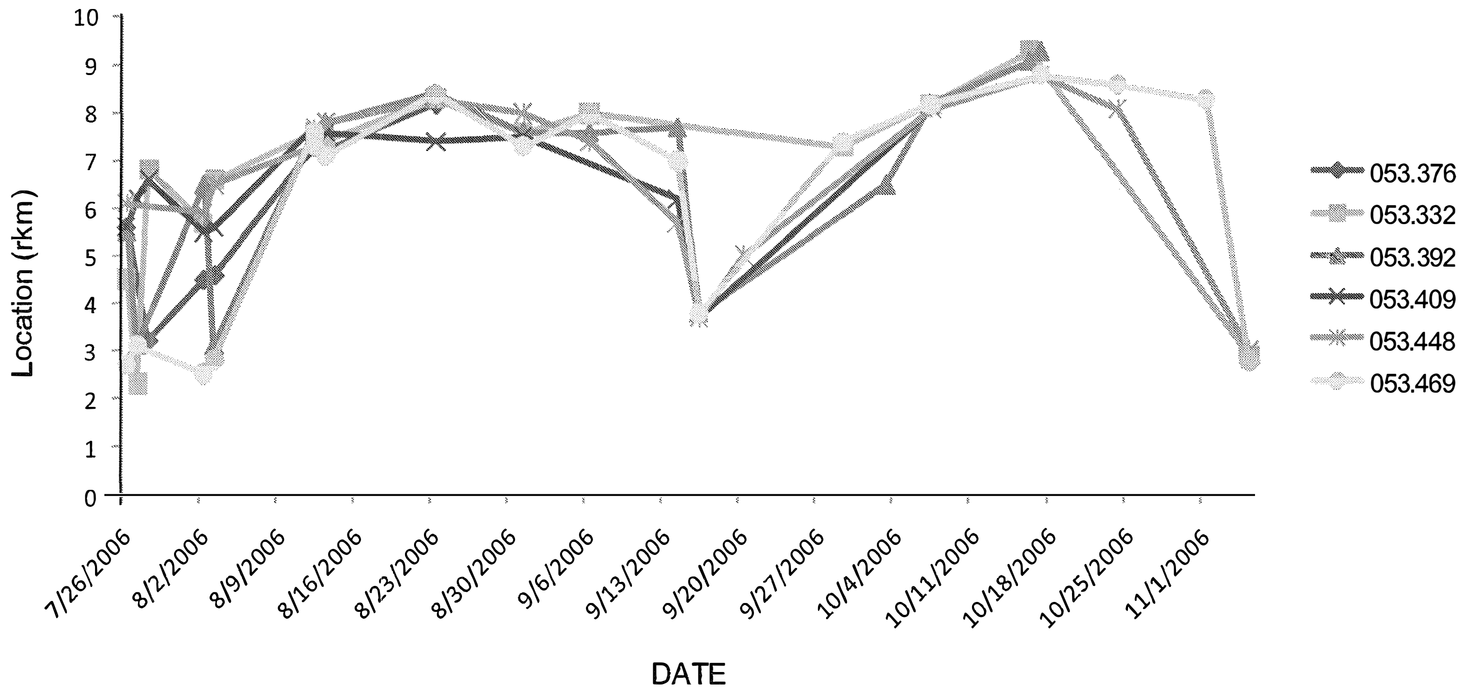


Figure 7: Location of Fish 053.332 in relation to water temperature, 26 July 2006 to 31 March 2007.

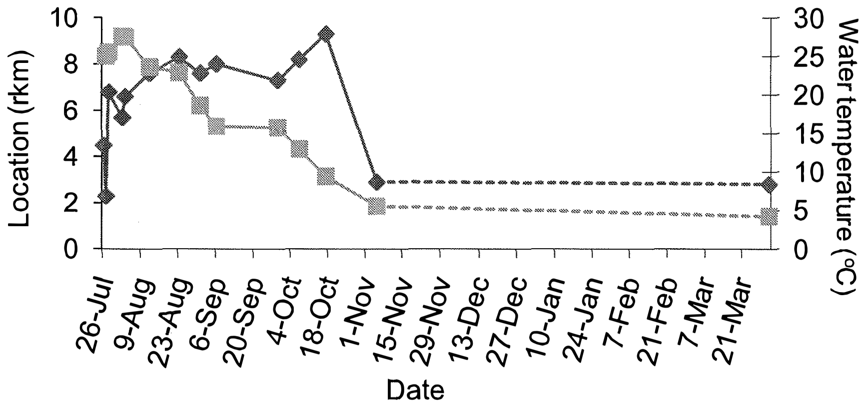


Figure 8: Location of Fish 053.448 in relation to water temperature, 26 July 2006 to 31 March 2007

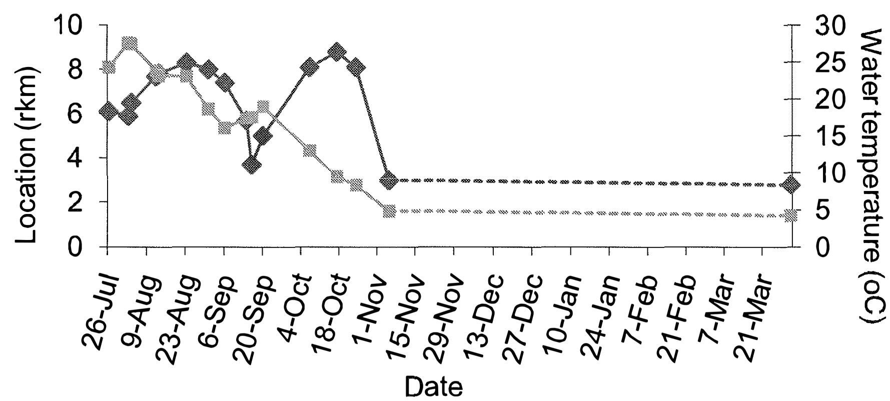


Figure 9: Location of Fish 053.469 in relation to water temperature, 26 July 2006 to 31 March 2007.

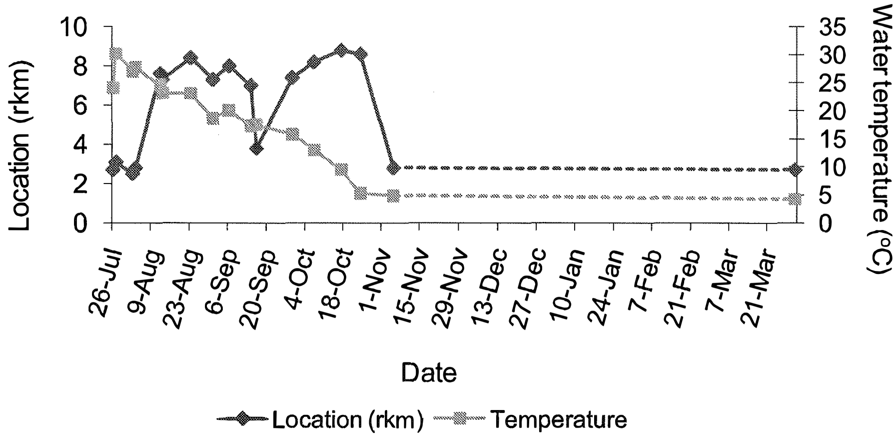
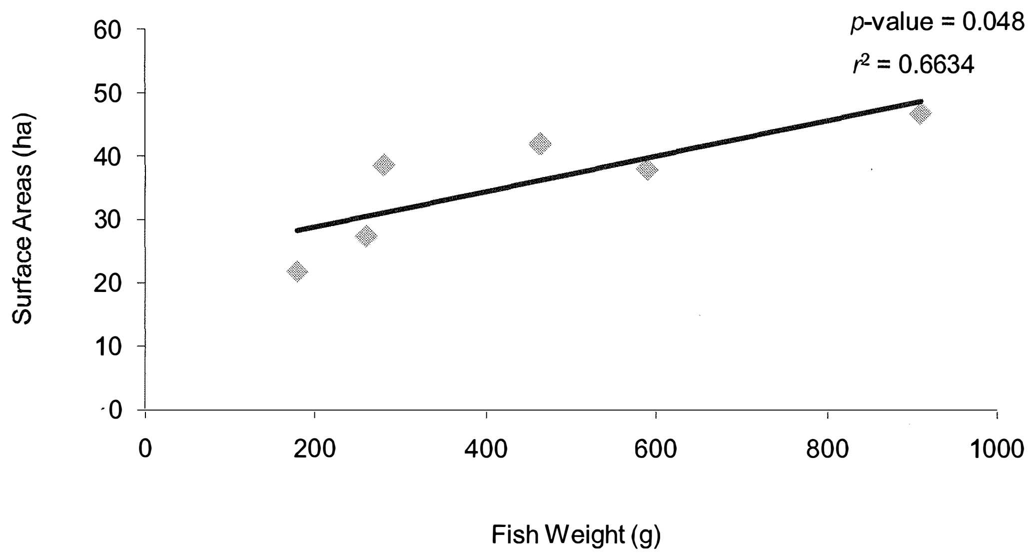


Figure 10: Correlation between fish size and surface area occupied on the Genesee River.



APPENDICES

Appendix 1: Tracking data from the six radio-tagged juvenile lake sturgeon in the lower Genesee River.

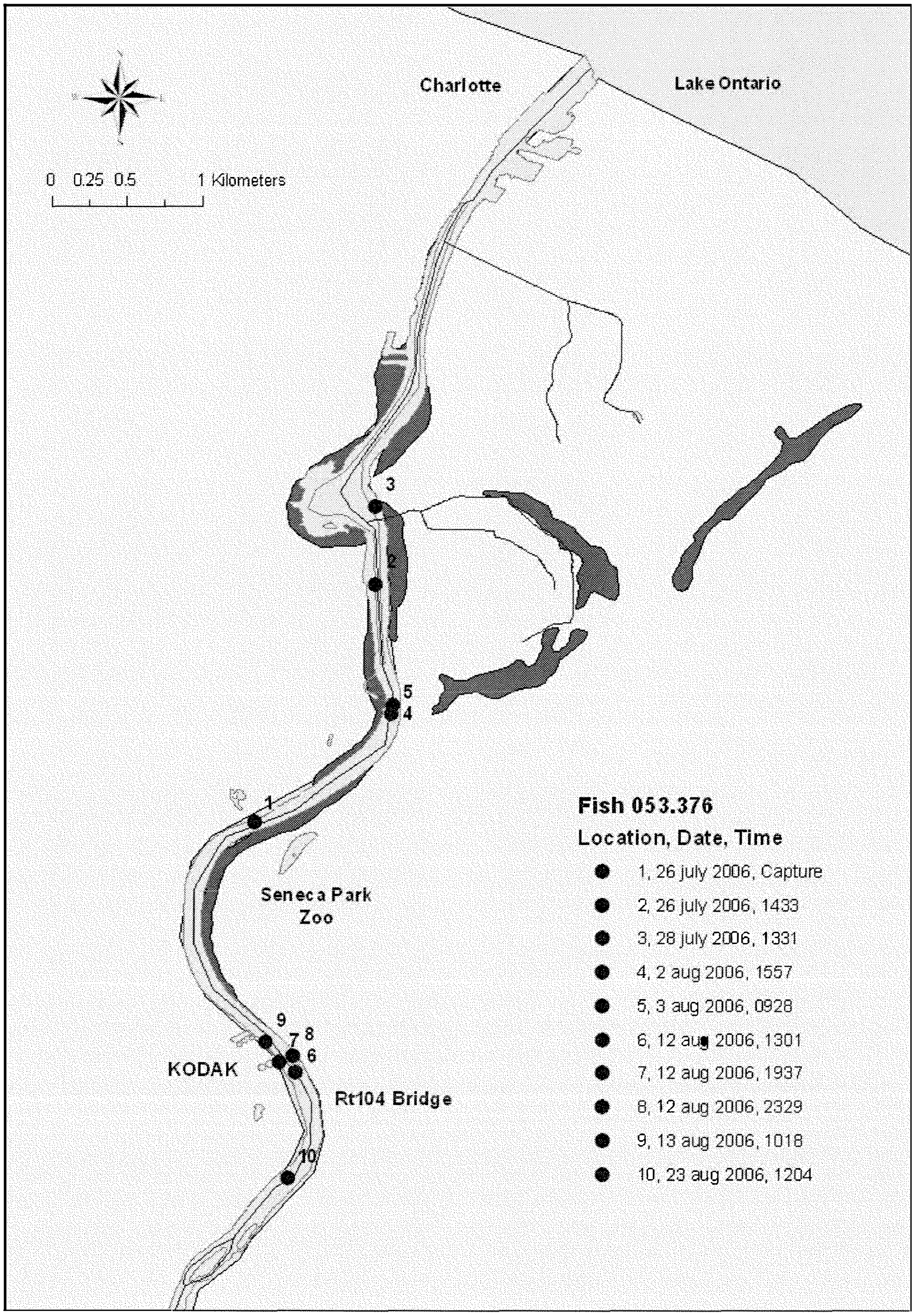
Fish	Date	Time (hours)	Action	# days elapsed	Strength of signal (1-5)[1]	Location (rkm)	Distance traveled (m)
053.376	26-Jul-06	*	Capture	0	0	5.6	-
053.376	26-Jul-06	1433	Release	0	5	3.7	-
053.376	28-Jul-06	1331	Location	2	1	3.2	509.80
053.376	2-Aug-06	1557	Location	7	1	4.5	1312.69
053.376	3-Aug-06	928	Location	8	2	4.6	71.73
053.376	12-Aug-06	1301	Location	17	2	7.5	2405.04
053.376	12-Aug-06	1937	Location	17	2	7.3	104.40
053.376	12-Aug-06	2329	Location	17	4	7.3	93.16
053.376	13-Aug-06	1018	Location	18	2	7.2	166.73
053.376	23-Aug-06	1204	Location	28	3	8.2	909.25
053.392	26-Jul-06	*	Capture	0	0	5.5	-
053.392	26-Jul-06	1433	Release	0	5	3.8	-
053.392	27-Jul-06	1349	Location	1	1	3.1	589.33
053.392	2-Aug-06	1317	Location	7	2	6.5	3096.26
053.392	3-Aug-06	1248	Location	8	1	3.1	3102.48
053.392	12-Aug-06	1222	Location	17	4	7.5	3842.51
053.392	12-Aug-06	1845	Location	17	3	7.6	45.27
053.392	12-Aug-06	2308	Location	17	3	7.6	1109.35
053.392	13-Aug-06	1105	Location	18	2	7.8	249.15
053.392	23-Aug-06	1102	Location	28	4	8.4	530.70
053.392	31-Aug-06	1415	Location	36	4	7.6	800.62
053.392	6-Sep-06	1123	Location	42	2	7.6	10.55
053.392	14-Sep-06	1441	Location	50	3	7.7	100.82
053.392	16-Sep-06	1705	Location	52	5	3.8	3323.59
053.392	3-Oct-06	1620	Location	69	4	6.5	2501.52
053.392	7-Oct-06	1709	Location	73	5	8.2	1608.34
053.392	16-Oct-06	1108	Location	82	1	9.1	944.47
053.392	17-Oct-06	1319	Location	83	1	9.3	176.87
053.409	26-Jul-06	*	Capture	0	0	5.6	-
053.409	26-Jul-06	1628	Release	0	5	3.8	-
053.409	27-Jul-06	*	Location	1	4	6.2	2116.56
053.409	28-Jul-06	*	Location	2	4	6.6	514.13
053.409	2-Aug-06	1625	Location	7	2	5.5	1065.66
053.409	3-Aug-06	1040	Location	8	2	5.6	49.74

053.409	12-Aug-06	1323	Location	17	5	7.7	1978.48
053.409	12-Aug-06	1927	Location	17	2	7.5	151.49
053.409	13-Aug-06	0	Location	18	3	7.2	310.99
053.409	13-Aug-06	1049	Location	18	1	7.6	422.86
053.409	23-Aug-06	1148	Location	28	2	7.4	255.98
053.409	31-Aug-06	1558	Location	36	1	7.5	168.02
053.409	14-Sep-06	1530	Location	50	2	6.2	1293.48
053.409	16-Sep-06	1715	Location	52	5	3.7	2371.50
053.409	7-Oct-06	1709	Location	73	5	8.1	3847.03
053.409	16-Oct-06	*	Location	82	1	8.9	804.66
053.448	25-Jul-06	*	Capture	0	0	7.9	-
053.448	25-Jul-06	1331	Release	0	5	4.3	-
053.448	26-Jul-06	922	Location	1	5	6.1	1688.28
053.448	27-Jul-06	*	Location	2	1	5.6	546.18
053.448	2-Aug-06	1647	Location	8	3	5.9	310.13
053.448	3-Aug-06	1015	Location	9	2	6.5	569.82
053.448	12-Aug-06	1414	Location	18	1	7.7	1263.66
053.448	12-Aug-06	2005	Location	18	3	7.6	166.41
053.448	12-Aug-06	2339	Location	18	3	7.3	265.69
053.448	13-Aug-06	948	Location	19	3	7.8	555.46
053.448	23-Aug-06	1119	Location	29	5	8.3	461.44
053.448	31-Aug-06	1527	Location	37	4	8	350.69
053.448	6-Sep-06	1105	Location	43	1	7.4	551.04
053.448	14-Sep-06	1547	Location	51	4	5.7	1566.96
053.448	16-Sep-06	1705	Location	53	5	3.7	1804.14
053.448	20-Sep-06	1504	Location	57	2	5	1192.05
053.448	7-Oct-06	1709	Location	74	5	8.1	2662.14
053.448	17-Oct-06	1246	Location	84	2	8.8	624.66
053.448	24-Oct-06	1017	Location	91	3	8.1	654.09
053.448	5-Nov-06	1016	Location	103	5	3	4877.22
053.448	31-Mar-07	1345	Location	249	5	2.8	4877.52
053.469	25-Jul-06	*	Capture	0	0	8	-
053.469	25-Jul-06	1140	Release	0	5	6.5	-
053.469	26-Jul-06	1413	Location	1	5	2.7	3427.05
053.469	27-Jul-06	1338	Location	2	5	3.1	376.38
053.469	2-Aug-06	1515	Location	8	1	2.5	492.41
053.469	3-Aug-06	1308	Location	9	3	2.8	244.62
053.469	12-Aug-06	1339	Location	18	3	7.6	4312.42
053.469	12-Aug-06	2006	Location	18	3	7.5	114.23
053.469	13-Aug-06	109	Location	19	3	7.1	448.75
053.469	13-Aug-06	1004	Location	19	3	7.3	237.88
053.469	23-Aug-06	1215	Location	29	3	8.4	964.99
053.469	31-Aug-06	1544	Location	37	1	7.3	928.05
053.469	6-Sep-06	1008	Location	43	2	8	673.72
053.469	14-Sep-06	1457	Location	51	3	7	1053.39

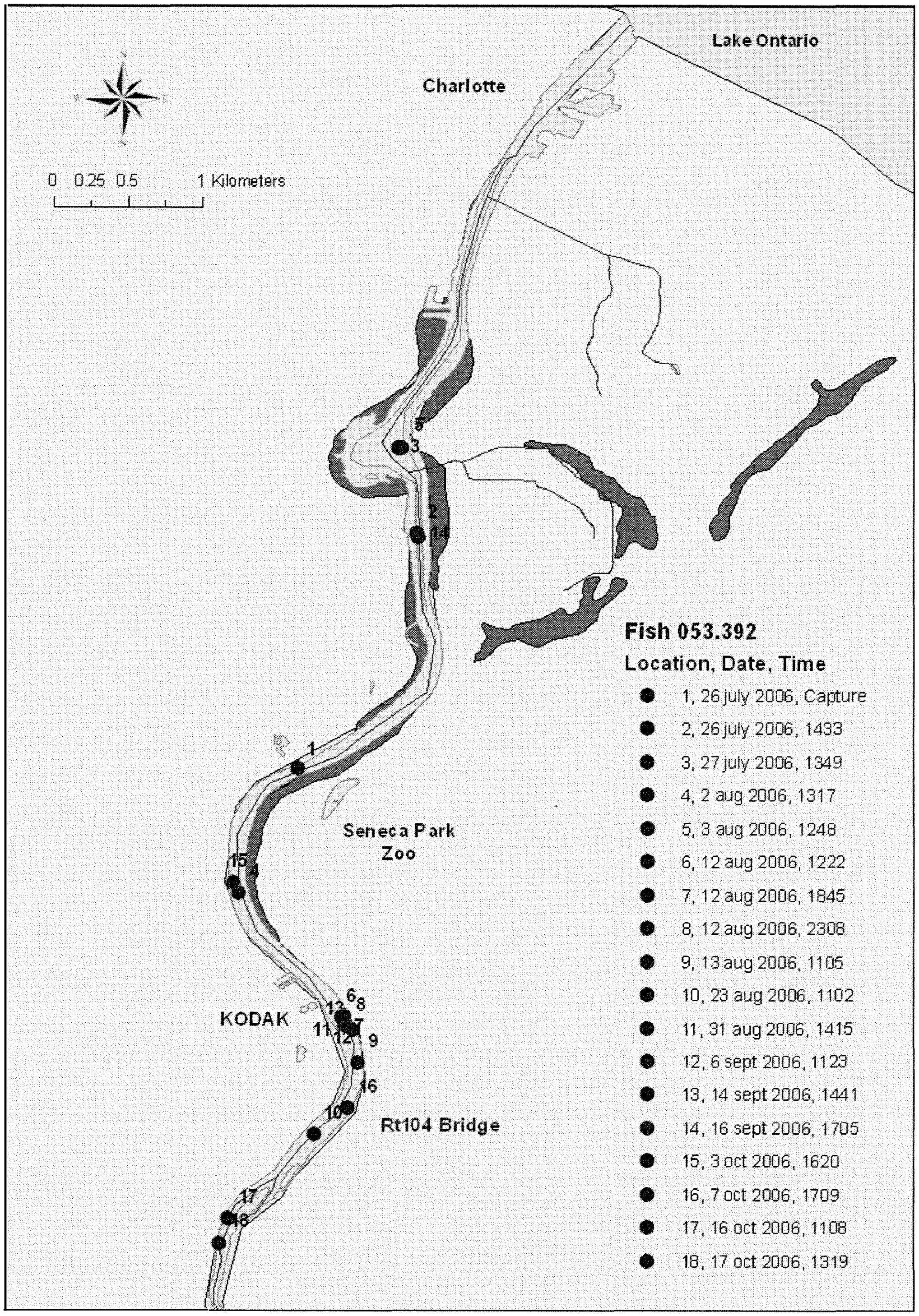
053.469	16-Sep-06	1705	Location	53	5	3.8	2875.38
053.469	20-Sep-06	1426	Location	57	3	5	1204.17
053.469	29-Sep-06	1720	Location	66	3	7.4	1864.70
053.469	7-Oct-06	1709	Location	74	5	8.2	814.35
053.469	17-Oct-06	1249	Location	84	2	8.8	619.50
053.469	24-Oct-06	1004	Location	91	2	8.6	173.76
053.469	1-Nov-06	1430	Location	99	3	8.3	320.06
053.469	5-Nov-06	956	Location	103	5	2.8	4818.39
053.469	31-Mar-07	1215	Location	249	5	2.7	4818.49
053.332	26-Jul-06	*	Capture	0	0	4.5	-
053.332	26-Jul-06	1628	Release	0	5	3.8	-
053.332	27-Jul-06	1056	Location	1	2	2.3	1457.13
053.332	28-Jul-06	1318	Location	2	4	6.8	4166.26
053.332	2 Aug 2006	1639	Location	7	3	5.7	989.27
053.332	3 Aug 2006	1132	Location	8	2	6.6	874.09
053.332	12 Aug 2006	1229	Location	17	5	7.6	860.84
053.332	12 Aug 2006	1914	Location	17	1	7.5	163.49
053.332	12 Aug 2006	2319	Location	17	4	7.6	97.60
053.332	13 Aug 2006	1009	Location	18	2	7.4	133.51
053.332	23 Aug 2006	1050	Location	28	5	8.3	826.56
053.332	31 Aug 2006	1420	Location	36	5	7.6	700.85
053.332	6-Sep-06	1013	Location	42	5	8	563.12
053.332	29-Sep-06	1720	Location	65	2	7.3	783.56
053.332	7-Oct-06	1709	Location	73	5	8.2	813.91
053.332	17-Oct-06	1319	Location	83	1	9.3	1106.47
053.332	5-Nov-06	938	Location	102	5	2.9	5755.10
053.332	31-Mar-07	1245	Location	248	5	2.8	5722.20

([1]) Signal strength = 0 was in reference to the time of release.

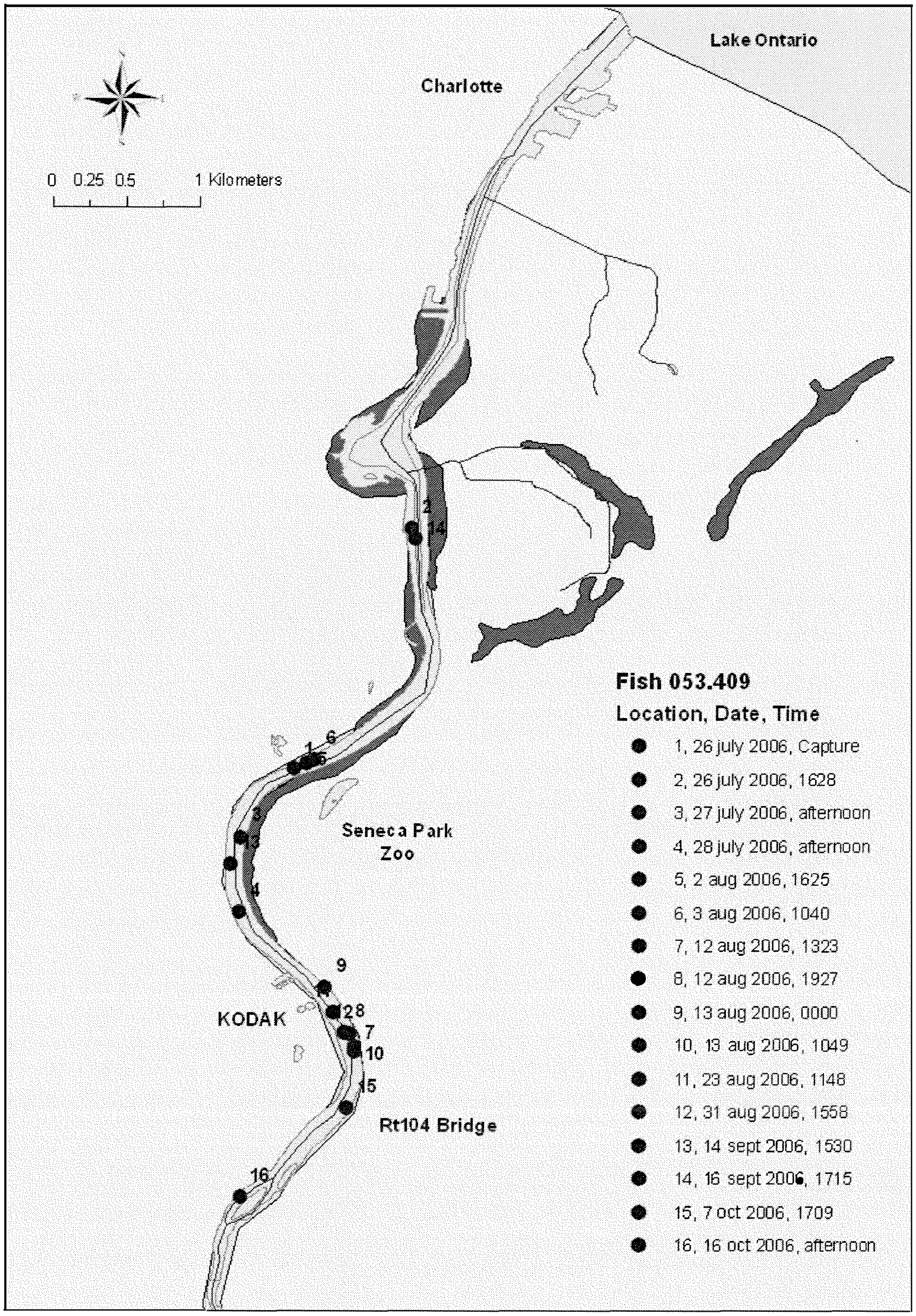
Appendix 2: Locations of Fish 053.376 from 26 July 2006 to 23 August 2006.



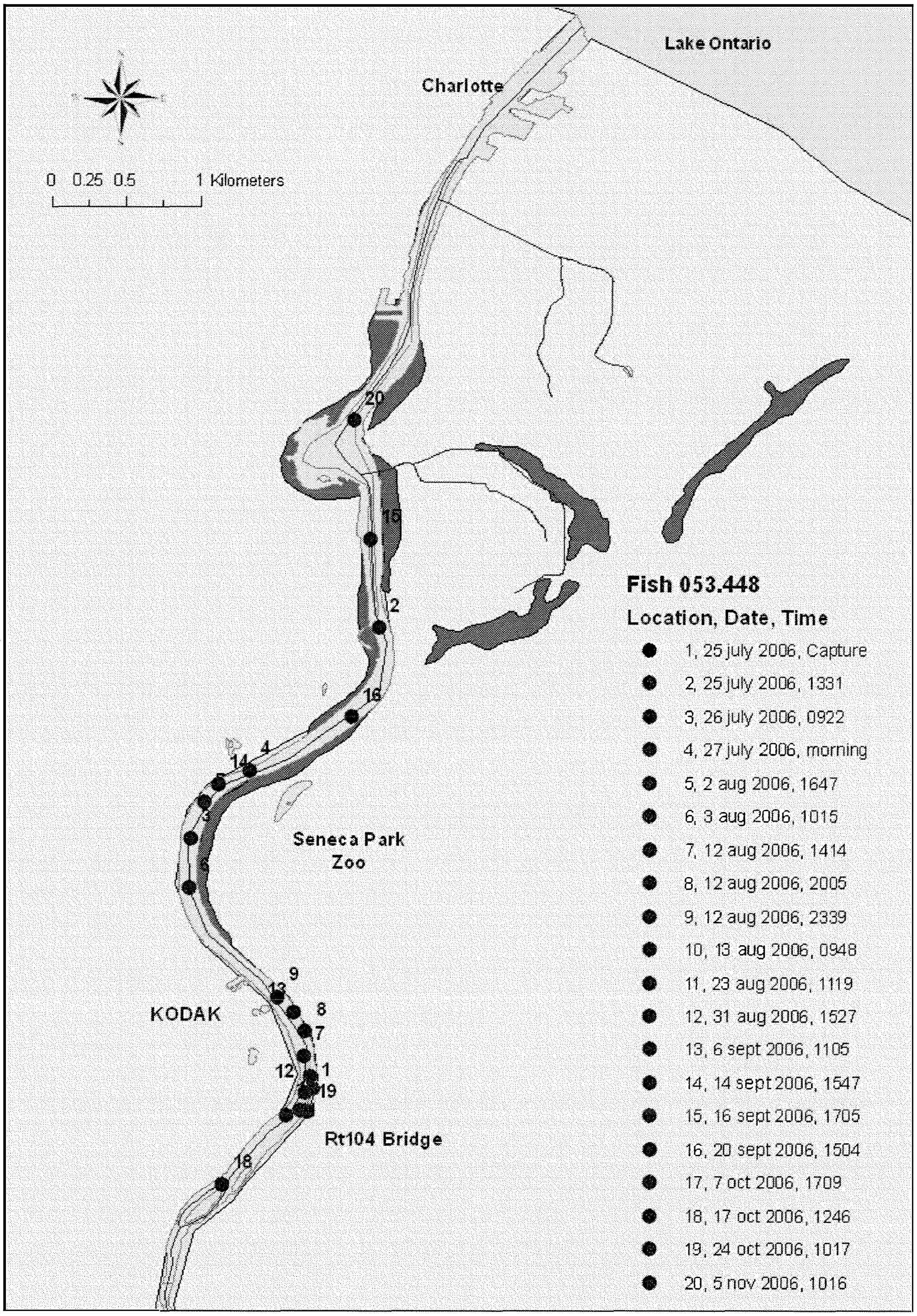
Appendix 3: Locations of Fish 053.392 from 26 July 2006 to 17 October 2006.



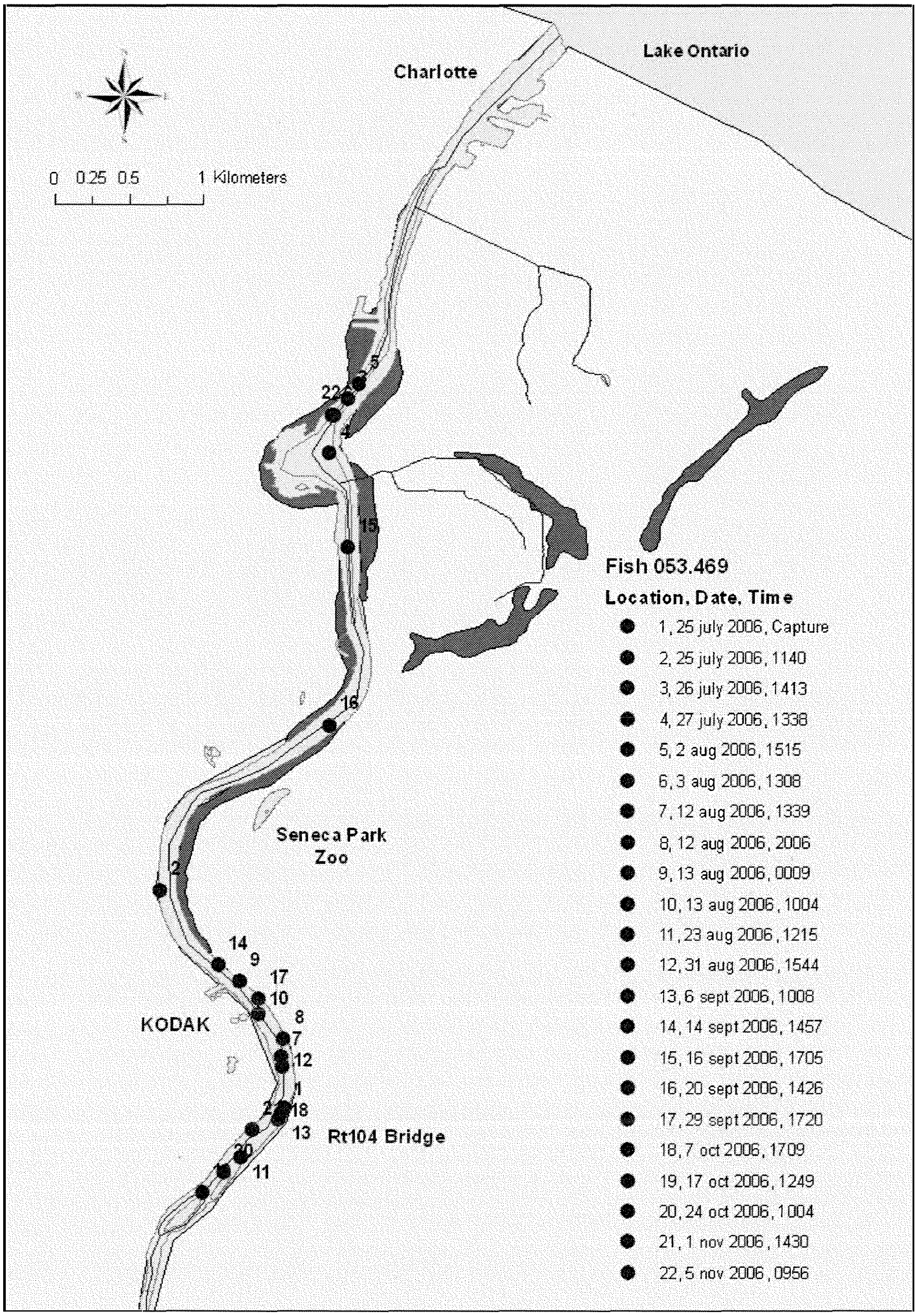
Appendix 4: Locations of Fish 053.409 from 26 July 2006 to 16 October 2006.



Appendix 5: Locations of Fish 053.448 from 25 July 2006 to 5 November 2006.



Appendix 6: Locations of Fish 053.469 from 25 July 2006 to 5 November 2006.



Appendix 7: Locations of Fish 053.332 from 26 July 2006 to 5 November 2006.