MOVEMENTS AND HABITAT USE OF JUVENILE LAKE STURGEON IN THE NORTH CHANNEL OF THE ST. CLAIR RIVER

by

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A thesis submitted
in partial fulfillment of the requirements
for the degree of
Master of Science
(Natural Resources and Environment)
in the University of Michigan
April 2007

Thesis Committee:
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Abstract

Abstract: Juvenile sturgeon *Acipenser fulvescens* between the ages of 3-7 years were studied to determine movement patterns and habitat usage in the North Channel of the St. Clair River. Nine juveniles were implanted with ultrasonic transmitters and tracked in the summer seasons of 2005 and 2006. Telemetry data and Geographic Information Software were used to determine habitat preferences. All fish tracked showed a large degree of site fidelity, with an overall home range area between 0.8km^2 and 10.8km^2. Juvenile lake sturgeon habitat selection was strongly related to depth, and they were found over 95% of the time in depths that exceeded 9m. Sturgeon appeared to occupy deeper habitats compared to what was available; sturgeon were most commonly found in depths between 12 and 18m (44% of occupied locations), however the most frequently available habitat was between 9-12m (32% of all available locations). Many sturgeon had a high degree of home range overlap, and overlap was significantly higher in areas that contained gravel bottom substrate without zebra mussels. Juvenile home range was also smaller in areas that contained gravel substrate than in areas with appreciable zebra mussel coverage, indicating that more food might be available in areas that contain gravel substrate. A significant negative correlation was found between the amount of zebra mussel cover and depth, meaning greater depths had lower zebra mussel coverage. These data suggest that sturgeon chose deeper sections of the North Channel because of a lack of zebra mussels and greater amounts of other types of invertebrates that served as food.

Acknowledgements

This study was funded by the National Oceanic and Atmospheric Administration and the Michigan Department of Natural Resources. I greatly appreciate the assistance of the University of Michigan and the Mount Clemens Michigan Department of Natural Resources, Fisheries Division.

This work could not have been completed without the valuable assistance and guidance of Mike Thomas, Roy Beasley, Jeremy Maranowski, Ken Koster, Jack Hodge, and Jim Diana. They very generously contributed their extensive knowledge and time during the entire extent of this study.

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Introduction

Lake sturgeon *Acipenser fulvescens* is the only species of sturgeon endemic to the Laurentian Great Lakes. Prior to 1860, lake sturgeon were regarded as a trash fish, considered a nuisance by fisherman due to the damage they caused to nets. However, by 1860, commercial harvest of lake sturgeon increased greatly when they became valued for their meat and caviar (Caswell et al. 2004). Historically, the annual yield of lake sturgeon from the five Great Lakes and connecting waters averaged 2.87 million kilograms in 1879-1890 (Kempinger 1996). During this time, lakes Huron and St. Clair produced 1.8 million kilograms per year of lake sturgeon with a large population inhabiting the Detroit River. A caviar factory was built in 1890 along the St. Clair River at Algonac, Michigan (Manny and Kennedy 2002). Overexploitation quickly decimated the lake sturgeon population and by 1920 only 2300 kilograms were caught throughout the Great Lakes system (Benson et al. 2005). The population abundance in the Great Lakes is currently estimated at one percent of historic levels (Benson et al. 2005).

Life history traits such as longevity, large size, and late sexual maturity have made lake sturgeon especially vulnerable to ecological changes, making rehabilitation of their populations a slow process. Lake sturgeon are currently listed as threatened in twenty U.S. states, including Michigan, and seven Canadian provinces (Knights et al. 2002). Loss of spawning and rearing habitat, coupled with blockage or degradation of migratory spawning routes, may be the leading factors keeping sturgeon populations repressed. A lack of juvenile habitat knowledge has also hindered the rehabilitation of lake sturgeon populations (Auer 1996).

This study was developed to provide a more complete understanding of juvenile lake sturgeon movements and habitat usage in the North Channel of the St. Clair River. An abundant population of lake sturgeon resides in the St. Clair System, which includes the St. Clair River, Lake St. Clair, and the Detroit River. Movement patterns of adult lake sturgeon have previously been examined in this system; however, little is known about movement patterns and habitat preferences of juvenile fish (Thomas and Haas 2002; Boase 2005). Since lake sturgeon can take up to 25 years to mature, a better understanding of this critical period will help in predicting recruitment success of sturgeon prior to their attainting first maturity and in increasing and strengthening lake sturgeon populations. The main goal of this study was to identify juvenile lake sturgeon habitats and spatial requirements in the North Channel of the St. Clair River.

Telemetry techniques were used to track juvenile sturgeon in this study. A total of nine juveniles between the ages of three to seven years were implanted with ultrasonic transmitters and tracked during the summer seasons of 2005 and 2006. Ultrasonic transmitters have been commonly used in many juvenile sturgeon studies with success (Borkholder et al. 2002; Manny and Kennedy 2002; Caswell et al. 2004; Boase 2005; Smith and King 2005; Werner and Hayes 2005). Similar to the goal of this study, many of these studies have also concentrated on depth preferences. The St. Clair River has a substantial current, so to avoid problems, such as transmitter detachment or disruption of swimming behavior, internal implantation was chosen over external attachment.

While juvenile sturgeon appear to have a wide range of depth preferences depending on each system's characteristics and maximum depths, most results from previous studies showed that juveniles preferred the deepest sections of each system

(Holtgren and Auer 2004; Benson et al. 2005; Werner and Hays 2005). A high degree of site fidelity was also observed in these previous studies done on juvenile lake sturgeon behavior (Haxton 2004; Smith and King 2005). Diet analysis has also been preformed in other studies. These studies found that juvenile sturgeon appear to heavily rely upon chironomids, ephemeroptera, and annelids that live in sand and gravel substrates (Kempinger 1996; Beamish et al. 1997; Chiasson et al. 1997; Holtgren and Auer 2004; Smith and King 2005).

Objectives of this study were to examine juvenile sturgeon habitat selection by capturing juvenile sturgeon from the North Channel of the St. Clair River that were less than 80cm in length and implanting them with ultrasonic transmitters. Once transmitters were implanted, fish were consistently tracked for two summer seasons, June-August of 2005 and 2006. I used this movement data to identify commonly occupied areas; sediment samples and depth recordings were used to determine habitat characteristics of those areas. I hypothesize that juvenile sturgeon prefer habitats located in the deepest areas of the river. I believe that if there is a stable food source in these areas, there should be limited movement of implanted fish. Since the North Channel has several areas with deep habitats, I hypothesize that movements of juvenile sturgeon should be minimal in this optimal habitat. Daily tracking made it possible to observe movement patterns and habitat preferences.

Study Area

The St. Clair system is unique to the Great Lakes region in both its physical and biological characteristics. This system, including the Detroit River, forms the connecting waterway between lakes Huron and Erie. Unlike other Great Lake connecting channels, such as the St. Mary's and Niagara rivers, fish movement through the St. Clair system is unimpeded by dams or other barriers. Even when lake sturgeon abundance drastically decreased at the turn of the century, the St. Clair River, Lake St. Clair and the Detroit River supported a small but stable population that continued to grow throughout the 20th century (Thomas and Haas 2002).

The St. Clair River is 63km long flowing south along the border between the United States and Canada, splitting into a series of deltaic Channels at Lake St. Clair (Figure 1) (Thomas and Haas 2002). The river has an average discharge of 5100m^3 s^{-1} with velocities reaching 3.2km/hr at the surface (Edsall et al. 1988). The upper reaches of the river have heavy industrial development on both sides of the border. Further south, the river is dominated by urban development on the U.S. side with more than four million residents living along the banks. Wetlands and some agricultural land uses are common on the Canadian side south of the South Channel. At the delta, flow is divided into three main channels. The South Channel is used for shipping and is regularly dredged at a minimum depth of 8.3m to maintain a shipping lane (Boase 2005). The Middle and North channels have similar bottom contours and substrates present, and are characterized by regions of extensive, submerged sand bars and naturally carved holes in the bedrock. The North Channel is consistently deeper however, reaching depths that exceed 25m (Thomas and Haas 1999). An estimated 33% of the discharge passes through the North Channel into Anchor Bay, Lake St. Clair (Edsall et al. 1988). Previous studies in the North Channel have found several spawning locations frequented each year by adult and juvenile lake sturgeon (Manny and Kennedy 2002; Thomas and Haas 2002; Boase 2005).

Sediment composition and samples of benthic organisms have been collected previously in Lake St. Clair and partially in the St. Clair River (Boase 2005). The majority of benthic organisms found were Nematoda, Oligochaeta, Polychaeta, Amphipoda, Isopoda, Diptera, Ephemeroptera, Gastropoda, and Pelecypoda (Boase 2005). In the 1980s, the St. Clair system and surrounding waters were invaded by the zebra mussel *Dreissena polymorpha.* Since its introduction, *Dresissena polymorpha* has become the dominant mollusk in both Lake St. Clair and the St. Clair River, and is hypothesized to be an important contributor to diets of adult lake sturgeon (Boase 2005). The role of zebra mussels in the diet of juvenile sturgeon is unknown. In the North Channel of the St. Clair River, *Dreissena polymorpha* do not seem to inhabit the deepest holes carved in the bedrock.

Methods

Five juvenile lake sturgeon under 80cm in total length were caught in the North Channel of the St. Clair River in the first week of June 2005. Four more juveniles were implanted in June 2006. All sturgeon were captured using setlines that were left for 24 hours on the river bottom. Each setline consisted of a 94.4m main line with 25 dropper lines attached at 3m intervals. Each dropped line had a baited hook line, 0.46m of number 36 tarred nylon twine, and a net snap with swivel. Gill-net anchors (11.4kg) were attached at each end of the main line using nylon anchor lines. Hooks were baited with whole or pieces of round goby, which had been previously frozen and later thawed.

The setlines were deployed near known spawning locations across the bottom contours and currents to cover the widest possible range of depths and to maximize the scent plume.

Hooked fish were brought aboard and placed in a large aerated trough until each was ready for measurement, usually between five to twenty minutes. Total length (cm) and weight (kg) were recorded (Table 1). The leading edge ray of the left pectoral fin was removed for age determination. All sturgeon were internally tagged with a passive integrated transponders placed directly behind the neurocranium bone.

Fish were not anesthetized, but were instead restrained on a net stretcher with their eyes covered during implantation. The sturgeon were kept wet during surgery by periodically pouring water over them. A small incision approximately two to five cm long was made on the abdominal cavity, lateral to the midline and anterior to the anal fin. A Sonotronics CT-04-1 ultrasonic transmitter was placed inside the abdominal cavity. In 2005, fish were sutured with dissolvable nylon suture material using a square knot to secure each suture. In 2006, the incision was closed using five to six 316L stainless steel staples from a 3M Precise PGX disposable surgical skin stapler. Super glue was also applied to the incision in 2006 to insure complete closure. Each fish was then injected with the antibiotic oxytetracycline at 0.23 mg per kg of body weight. The ultrasonic transmitters had batteries rated to last eight months, so transmitters implanted in June 2005 were expected to stop functioning sometime in February 2006. The fish numbering system was determined by the frequency of the implanted transmitters. Two fish had overlapping frequencies. In this case an “N” was added to the end of the number to show distinction.

Fish were caught for implantation during or soon after adult spawning migrations to the North Channel. Fish were tracked immediately after the implantation. Every fish was located the day after implantation and consistently throughout the study. Individual fish were located with a success rate ranging from 82% to 100% of days tracked in 2005, and 95% to 100% of days tracked in 2006.

Ultrasonic transmitters operated at frequencies between 71-79 kHz, and possessed a unique code of pulses. The transmitters were 45mm in length and 15mm in diameter, weighing 15g. Implanted lake sturgeon were tracked using an ultrasonic receiver (Sonotronics USR-5W) with a directional hydrophone (Sonotronics DH-4). Typical detection ranges were slightly greater than half a nautical mile under optimal conditions. I advanced towards the signal until the sound had equal strength in all directions; this was identified as the fish's location. Attempts were made to locate fish on a daily basis, Monday through Friday of each week, but depended on weather conditions and boat availability. The fish were located by boat on approximately 40 dates over the summer of 2005 and 29 dates in 2006. Locations were pinpointed using a global positioning system (GPS) which was rated to have a ±12m accuracy range. These locations were entered into a geographical information system (GIS) map using ArcView® GIS software. Data were collected at different times during the day ranging from 8:00am to 1:00am. Depth data was recorded using a Garmin GPSmap 168 Sounder at each location a fish was identified to occupy. Available depths for the entire extent of the North Channel where fish were tracked were collected using maps supplied by NOAA (National Oceanic and Atmospheric Administration), which recorded depths every 130 meters.

Efforts were also made to capture and track sturgeon in other areas of the St. Clair system. In the beginning of July 2005 setlines were employed in the Middle Channel using the same technique described previously, however no juveniles were caught. In 2006, one juvenile was captured with a trawl in Lake St. Clair using standard Michigan Department of Natural Resources methodology (Thomas and Haas 2002). The juvenile was implanted with a transmitter using the same methods described previously. This fish was tracked only from 8 to 17 August 2006.

In July of 2005, dissolved oxygen and temperature profiles were taken at four locations where sturgeon were regularly found, using a Walter Quality Instrument YSI. Both water temperature and dissolved oxygen readings were recorded. The results showed that there was no D.O. stratification in the North Channel and D.O. remained between 8.55 and 9.2mg/L at depths ranging from zero to twenty meters. Temperature profiles also showed no stratification and remained the same at all depths that were sampled. Water temperatures throughout the sampling season ranged from 14-24°C with an average of 20°C in 2005 and 21°C in 2006.

Juvenile sturgeon preferred certain locations and could be regularly located in these areas. In these regions, substrate samples were taken with a petite ponar (2.4L volume) lowered until it reached the river bottom (Figure 2). Each sample was emptied into a large tub and passed through a sieve with a mesh size 1.6mm. Clay and silt passed through the sieve, leaving gravel in the sieve, enabling me to record two substrate classifications. The percentages for these two substrate categories (clay/silt and gravel) were observationally estimated as compared to the entire sample. This procedure was not possible for samples which contained exclusively zebra mussels. Each time a sample was taken in an area that contained heavy zebra mussel coverage, only zebra mussels were collected, and the underlying sediment remained unknown. In this case the zebra mussel percentage was recorded as 100%.

Once commonly occupied regions were identified, home ranges were computed for each fish by creating a polygon that encompassed all the locations a fish moved throughout the study. The boundaries of each home range polygon were designated by the outermost locations each fish was found to occupy. Because data collection was limited to only two field seasons, all of the tracked locations were included and considered one home range. The area (km^2) of each home range polygon was then calculated.

Home range overlap was calculated by determining how much overlap of home range areas existed for a pair of fish. Each fish's home range was compared to every other fish's home range to determine if other fish occupied the same home area. Each pair of fish was analyzed and an overall overlap was calculated as the percentage of the resident's home range that was overlapped by the second fish's home range. Overlap was used to determine whether or not certain areas were more preferred by juvenile sturgeon than others.

Relationships between study variables were detected using Pearson correlations. Home range areas were compared to average depth using correlations. Average depth was determined from the depths recorded for all locations of each fish. Home range overlap was compared to gravel bottom cover and to zebra mussel cover using correlations. Available depth data in the North Channel were compared to observed depth data using a χ^2 - test. All statistical tests were done using SPSS 12.0 software with alpha of 0.05.

Results

The nine transmitters had a battery life predicted to last up to eight months, but four of the five lake sturgeon tracked in 2005 were found through the conclusion of the second field season on 18 August 2006 (fourteen months later). In 2006, I was not able to locate the fifth fish implanted in 2005. The fish implanted in 2005 were tracked a total of 55 different days over the time periods from 1 June through 26 August 2005 and 6 June through 18 August 2006. Juveniles implanted in 2006 were tracked 22 days from 6 June to 28 August 2006 (Table 1).

Juvenile sturgeon moved very little and could be found in predictable locations, showing a high degree of site fidelity. Home range areas varied from $0.8km^2$ to $10.8km^2$ (Table 2). The largest home range area for each different sampling season corresponded to two of the oldest and largest fish implanted, 77 (2005) and 78 (2006). The largest displacement observed over both 2005 and 2006 was done by fish 73. Smallest home ranges were seen for fishes 71, 74, and 76, which occupied the deepest hole furthest upriver (Table 2).

Fish 79 and 73 consistently showed strong fidelity to certain locations. Fish 79 remained within two general locations, which were relatively close to one another, throughout the study (Figure 3). I became concerned that fish 79 had died or shed its transmitter, so divers were commissioned at the end of August 2005 to locate the fish. Reacting to the intrusion of the divers, the sturgeon did move slightly. The divers observed a small, smooth impression, and it appeared as though the juvenile sturgeon had been lying on the river bottom. Fish 73 was the only fish to occupy any region of the Middle Channel. Adult sturgeon have been observed in the Middle Channel, although attempts to capture a juvenile for tracking purposes were not successful. Fish 73 chose the deepest section of the Middle Channel, which is very close to the confluence with the North Channel (Figure 4). Here depths reach 13m, which is considerably deeper than the rest of the Middle Channel.

Fish 71 and 76 were first caught on the same setline in 2004 and were externally tagged and released. They were captured again at the same location, on the same setline, in 2005, when they were implanted with ultrasonic transmitters. Both of these juveniles remained relatively close together for both the 2005 and 2006 seasons. They occupied the same deep hole where they were implanted, with depths exceeding 25m (Figures 5 and 6). Both fish did not leave this large hole and traveled little during the entire study. In 2006, fish 74 was implanted and also occupied this same region (Figure 7). This section of the river was also visited by several other fish, and proved to be a highly preferred region for juvenile sturgeon. Fish 71, 74, and 76 displayed little movement throughout the study.

In 2005, fish 77 had the largest home range area, showing the least site fidelity (Figure 8). This fish displayed a clear preference for deep habitats (between 11m and 21m) and habitats commonly occupied by other implanted sturgeon. This was also the largest and oldest fish implanted with a transmitter. I was unable to relocate this fish in the summer of 2006.

The remaining three sturgeon implanted in 2006, fish 75, 77_N, and 78, showed similar movement patterns to the other fish previously mentioned. All fish were commonly found in limited areas, making home range identification simple (Figures 9, 10, 11).

Juvenile lake sturgeon habitat selection seemed to be strongly related to depth. Over 95% of the lake sturgeon locations were in depths that exceeded 9m (Table 3). Figure 12 compares the depth frequencies found throughout the North Channel with the frequencies of where sturgeon were actually located. This figure shows the two distributions were different and sturgeon displayed a preference for deep water (Figure 12). The χ^2-test produced significant results ($\chi^2 = 316.2$, DF= 8), showing sturgeon occupied deeper habitats compared to what was available. Sturgeon were most commonly found in depths between 12 and 18m (44% of occupied locations); while the most available habitat was between 9-12m (32% of all available locations) (Table 3). Three fish occasionally occupied the deepest part of the North Channel where depths approached 27m (16% of occupied locations) — only 1.6% of the available habitat. No fish were located in areas less than 6m in depth (13% of the available habitat).

Home range area was calculated and then correlated to the average of all recorded depths found for each fish. There was a statistically significant, negative correlation between home range size and depth ($r^2= 0.554$, $p= 0.021$) (Figure 13). The home range area decreased with increasing water depth, suggesting that sturgeon moved less in deeper habitats.

During the study, it became obvious that limited areas of the river were preferred by juvenile sturgeon, and in these areas, several implanted sturgeon could commonly be found. As a result of this apparent preference, most fish displayed a large degree of home range overlap (Table 4). The overall overlap in home ranges (resident's overlap with all other fish combined) averaged 67% and ranged from 9.5 to 100% for individual fish.

Substrate samples were taken in many of the home range areas and analyzed as an indicator of habitat characteristics. Each site sampled showed considerably different substrates. Some sites contained complete zebra mussel coverage; others contained partial zebra mussel coverage with the majority of substrate comprised of clay and silt (Table 5). Following sample collection and analysis, habitat overlap was compared to substrate type at the overlapping habitat locations. There was a strong negative correlation between the amount of zebra mussel coverage and overall overlap of home ranges (Figure 14), indicating that more sturgeon congregated in areas that had lower amounts of zebra mussels. There was also an equally strong positive correlation between home range overlap and the amount of gravel substrate coverage (Figure 15), showing a preference for gravel locations. These two values were inversely related, making it less clear which of the variables may be causing selection or avoidance.

Average depth of all locations for a sturgeon was significantly correlated to the amount of zebra mussel coverage; the density of zebra mussel coverage decreased with increasing depth (Figure 16). The deeper habitats had less zebra mussels than shallower habitats, and in the deepest section of the river (above 19m), no zebra mussels were present.

Discussion

Individual juvenile lake sturgeon in the North Channel of the St. Clair River varied slightly in their movements but showed a fairly consistent pattern. Sturgeon showed a high degree of site fidelity, and commonly chose overlapping sites to occupy. Juvenile sturgeon chose sites based on depth and substrate type found at those sites. The lack of movement that was observed during this study supports my hypothesis that fish in the North Channel display little movement and considerable site fidelity. This tendency towards site fidelity in juvenile sturgeon was further recognized in studies done by Werner and Hayes (2005) in the St. Lawrence River and Smith and King (2005) in Black Lake, Michigan. A tendency towards grouping of fish in ideal habitats in the St. Clair system was also identified by Thomas and Haas (2002). These three studies found that fish chose habitats that were in the deepest sections of the system, regardless of maximum depth available.

The two leading influences for habitat selection appeared to be depth and bottom substrate. My results suggest that these factors were related. The data suggested that sturgeon preferred deeper habitats with gravel substrate. The data also showed there was a decrease in zebra mussel coverage with increasing depth. Sturgeon could be selecting deeper habitats on the basis of depth, lack of zebra mussels, and the increase in gravel substrate. This tendency to avoid areas colonized by zebra mussels was also recognized in a study done by McCabe et al. (2006) in a laboratory setting. They suggested that zebra mussels change the substrate consistency, with even a 50% cover by zebra mussels resulting in almost complete elimination of chironomids. The results also showed that 90% of the time juvenile lake sturgeon avoided habitats with zebra mussels (McCabe et al. 2006). Juvenile sturgeon rely heavily upon chironomids, ephemeroptera, and annelids that live in sand and gravel substrates for most of their diet (Kempinger 1996; Beamish et al. 1997; Chiasson et al. 1997; Holtgren and Auer 2004; Smith and King 2005). Zebra mussels appear to exclude the invertebrates that juvenile sturgeon feed upon, and by this means may reduce sturgeon selection of habitats with zebra mussels.

One assumption that was important in this study was that habitat preference was not dependent on time of day. Some observations show juvenile sturgeon movements into shallower areas at night (Holtgren and Auer 2004). I collected data for diel movements for only one fish on one occasion, and it showed no movement throughout the night. My data collection was also limited because I did not perform any data collection from September to May, therefore assuming there are no seasonal effects on movement trends. This assumption is consistent with other studies that found juveniles do not appear to have seasonal movement patterns (Holtgren and Auer 2004; Smith and King 2005; Werner and Hayes 2005). Finally, substrate samples were taken at only a few locations; thus, analysis of substrates and juvenile preferences were based on a relatively small data set. Other studies have concentrated more on substrate preferences of juvenile sturgeon; in these studies sturgeon were found to also favor gravel substrate (Kempinger 1996; Beamish et al. 1997; Chiasson et al. 1997; Holtgren and Auer 2004; Smith and King 2005).

The largest fish implanted in 2005, fish 77, was not found in 2006. Potential causes include transmitter malfunction, mortality, or migration out of the area. Since fish were not tracked from September to May, this fish could have easily moved into Lake St. Clair. Adult sturgeon commonly move into the North Channel in the spring to spawn and then move to Lake St. Clair for the rest of the year (Boase 2005). Fish 77 could have followed the adult sturgeon back to the lake after the spawning migration. Efforts were made to locate fish 77 near the confluence of the lake and North Channel on three occasions with no success.

There are several qualities to juvenile rearing habitat that could be identified as limiting factors. The North Channel of the St. Clair River has many deep pools and a strong current. Sturgeon seem to prefer these deep areas and the strong current could be contributing their food supply. This type of environment might not be available in other river systems. Also a lack of habitats void of zebra mussels could limit juvenile habitat availability, since zebra mussels appear to deplete levels of invertebrates, which serve as food for juveniles (Kempinger 1996; Beamish et al. 1997; Chiasson et al. 1997; Holtgren and Auer 2004; Smith and King 2005; McCabe et al. 2006).

Knowledge of habitat utilization and movement patterns of sturgeon during this vulnerable juvenile stage is critical to the rehabilitation of this species (Boase 2005). Information gathered during this study, which observed habitat selection trends and movement patterns in the North Channel of the St. Clair River, should help to strengthen lake sturgeon populations in this system. Juvenile sturgeon chose habitats that were located in the deepest sections of the North Channel and contained gravel substrate. This habitat preference could have been due to avoidance of areas heavily colonized by zebra mussels. Further studies could be done to analyze the invertebrate populations that live in the gravel substrate to further synthesize juvenile sturgeon diet.

Figures

Figure 1: Map of Lake St. Clair and the St. Clair River

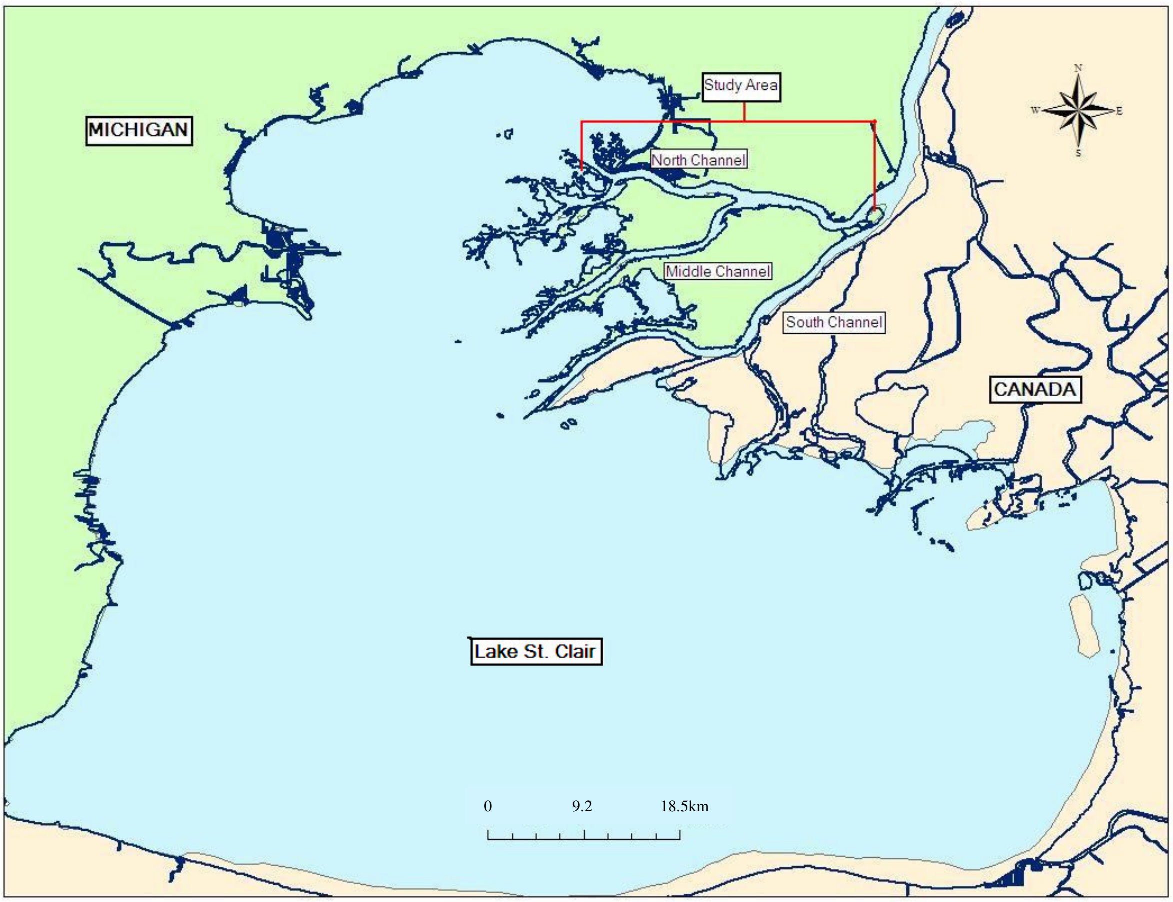


Figure 2: Map of the North and Middle Channel of the St. Clair River, with locations where sediment samples were taken.

Figure 3: Map of locations for fish 79 from 1 June 2005-20 August 2006 in the St. Clair River. Home range area is outlined in red, the star represents where the sturgeon was implanted and lighter dots are earlier in the study and progress to darker later in the season.

Figure 4: Map of locations for fish 73 from 1 June 2005-20 August 2006 in the St. Clair River. Notation as in Figure 3.

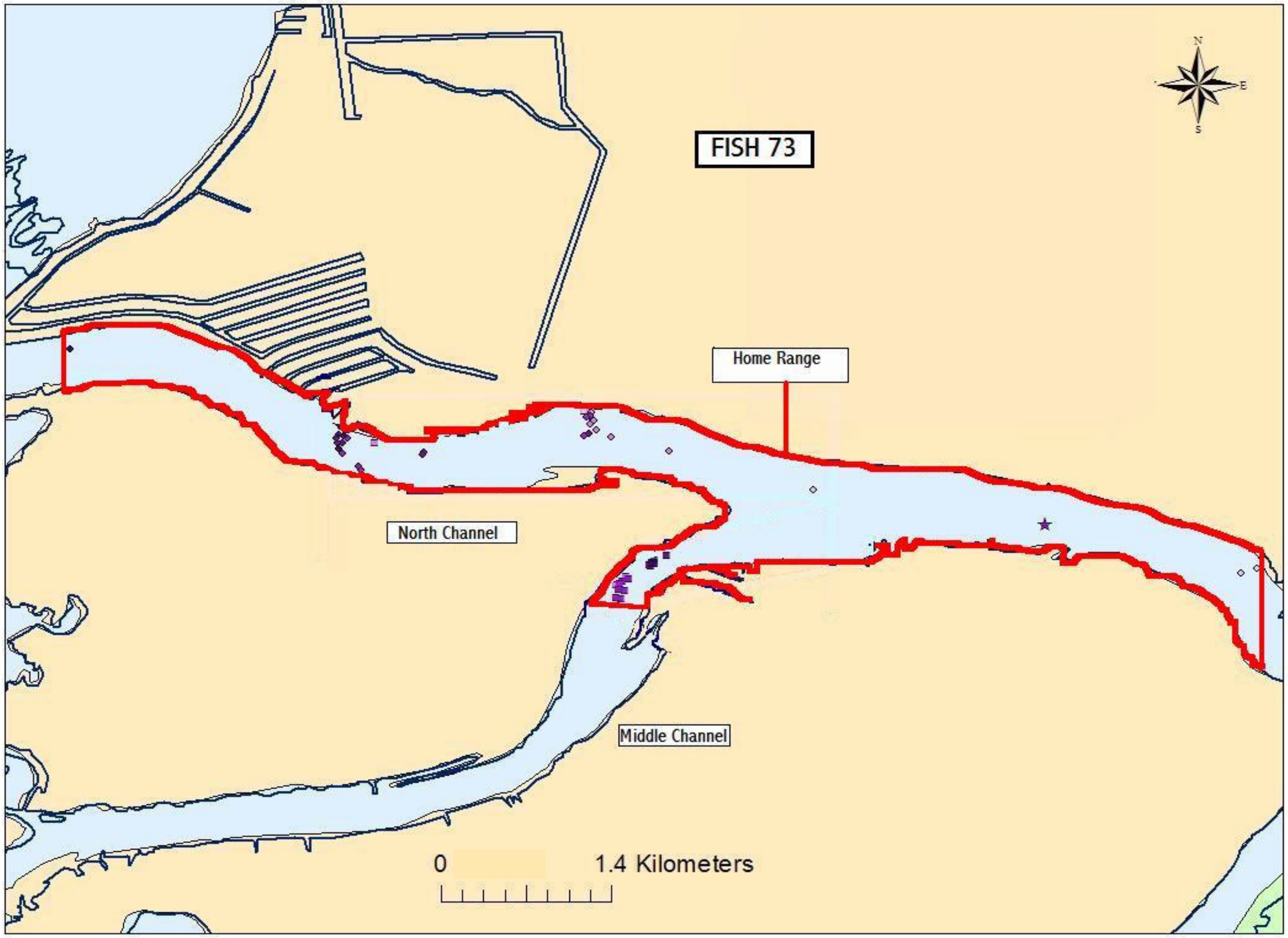


Figure 5: Map of locations for fish 71 from 1 June 2005-20 August 2006 in the St. Clair River. Notation as in Figure 3.

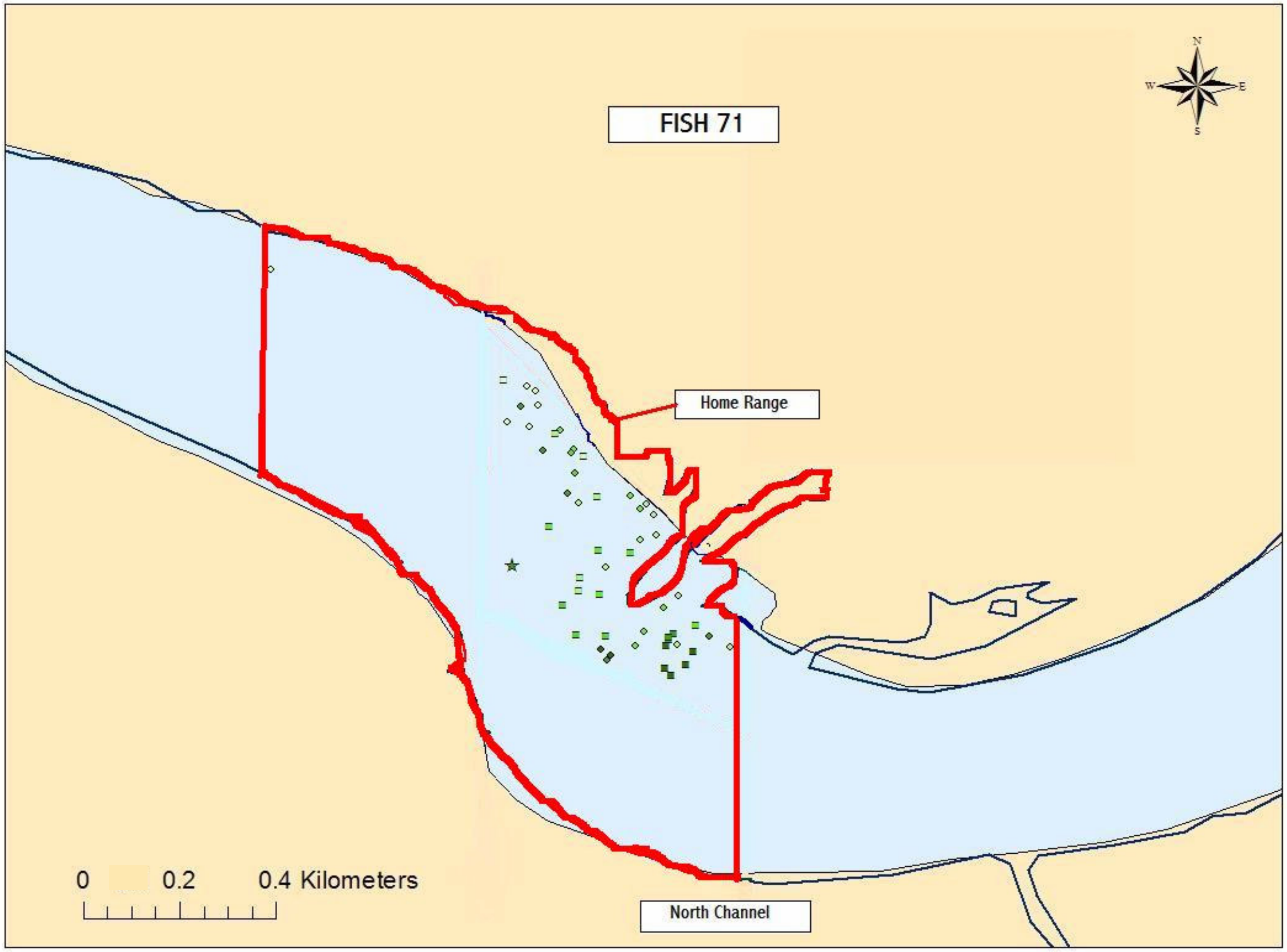


Figure 6: Map of locations for fish 76 from 1 June 2005-20 August 2006 in the St. Clair River. Notation as in Figure 3.

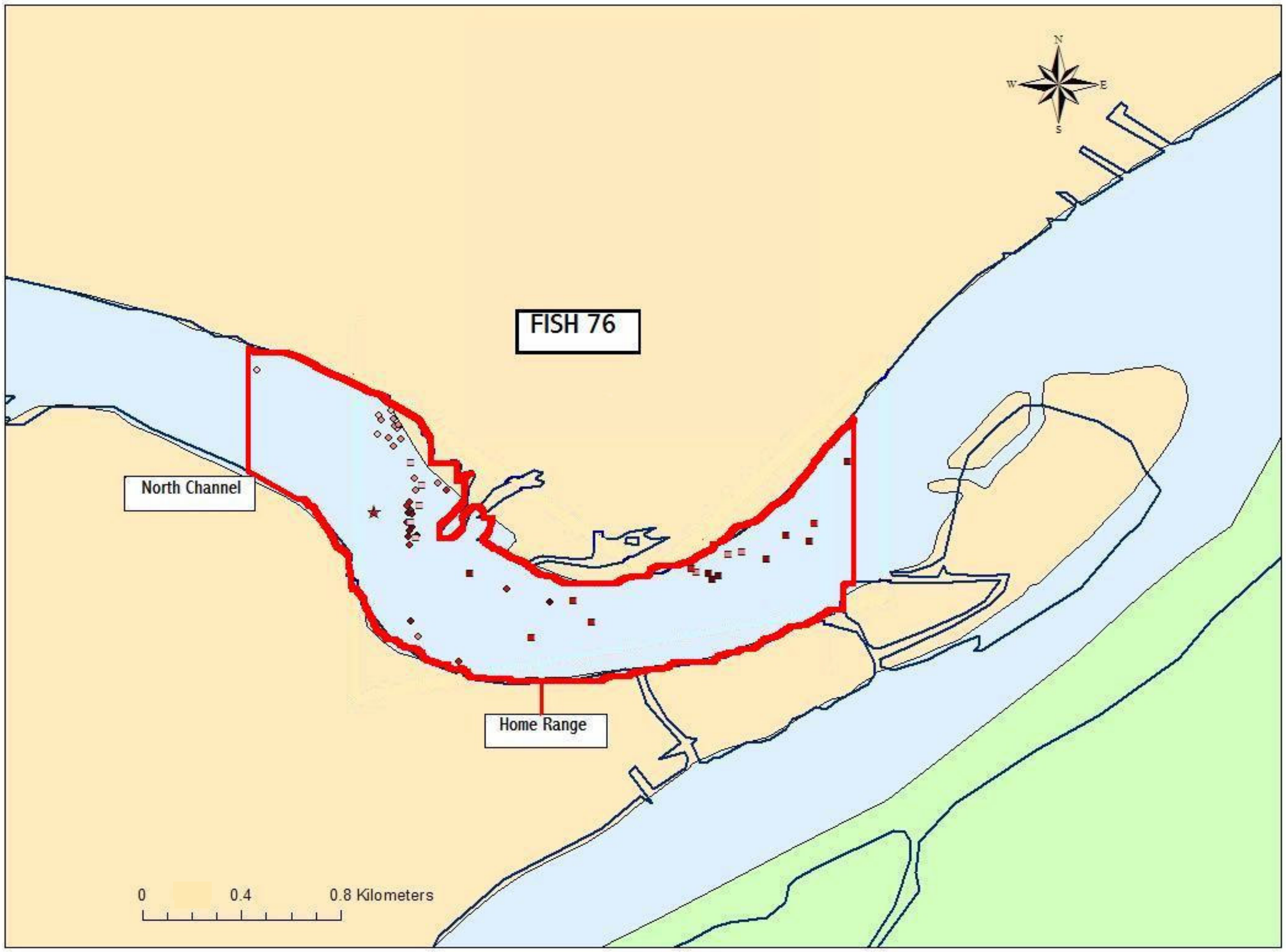


Figure 7: Map of locations for fish 74 from 20 June 2006-20 August 2006 in the St. Clair River. Notation as in Figure 3.

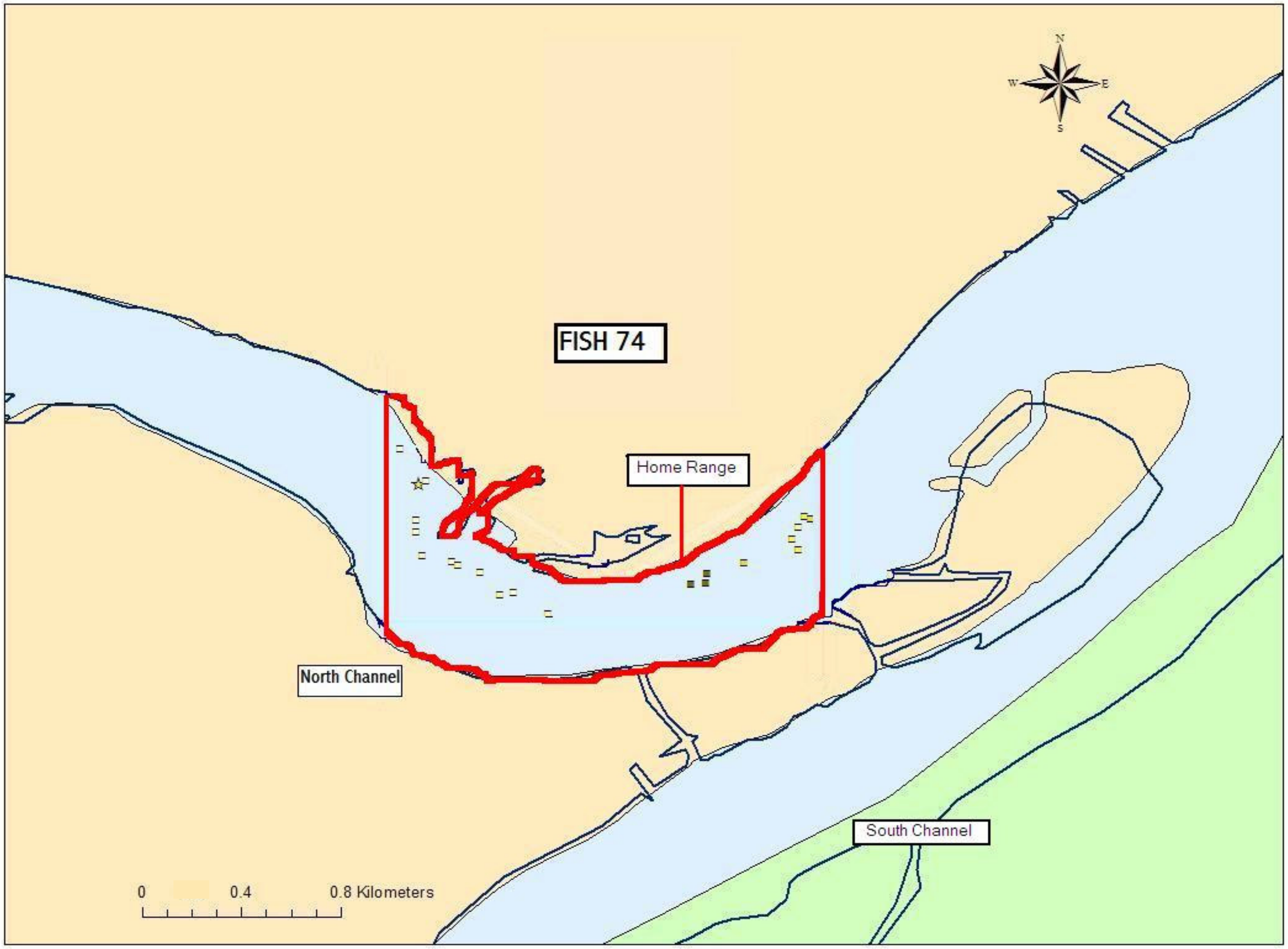


Figure 8: Map of locations for fish 77 from 1 June 2005-28 August 2005 in the St. Clair River. Notation as in Figure 3.

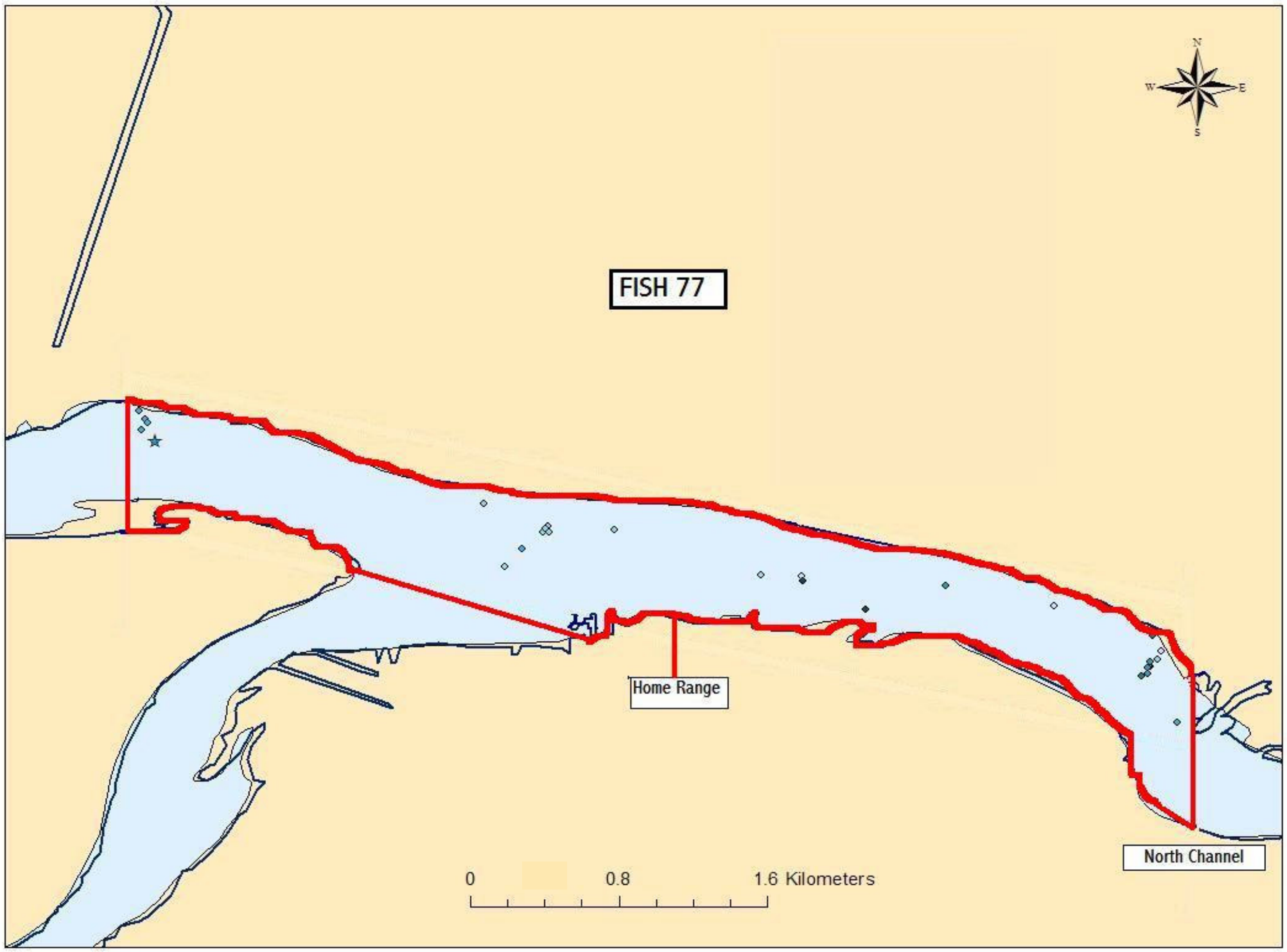


Figure 9: Map of locations for fish 75 from 20 June 2006-20 August 2006 in the St. Clair River. Notation as in Figure 3.

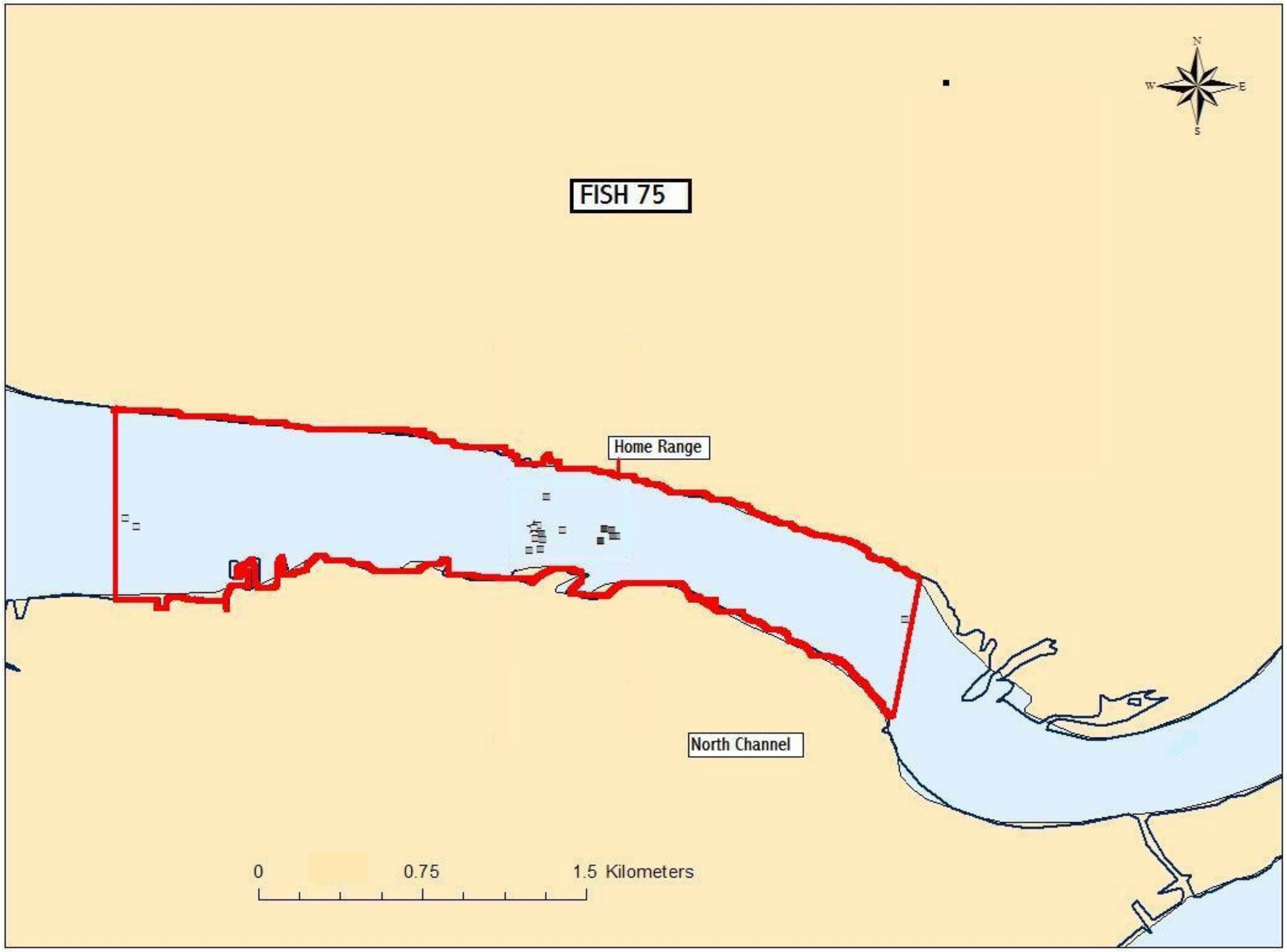


Figure 10: Map of locations for fish 77_N from 20 June 2006-20 August 2006 in the St. Clair River. Notation as in Figure 3.

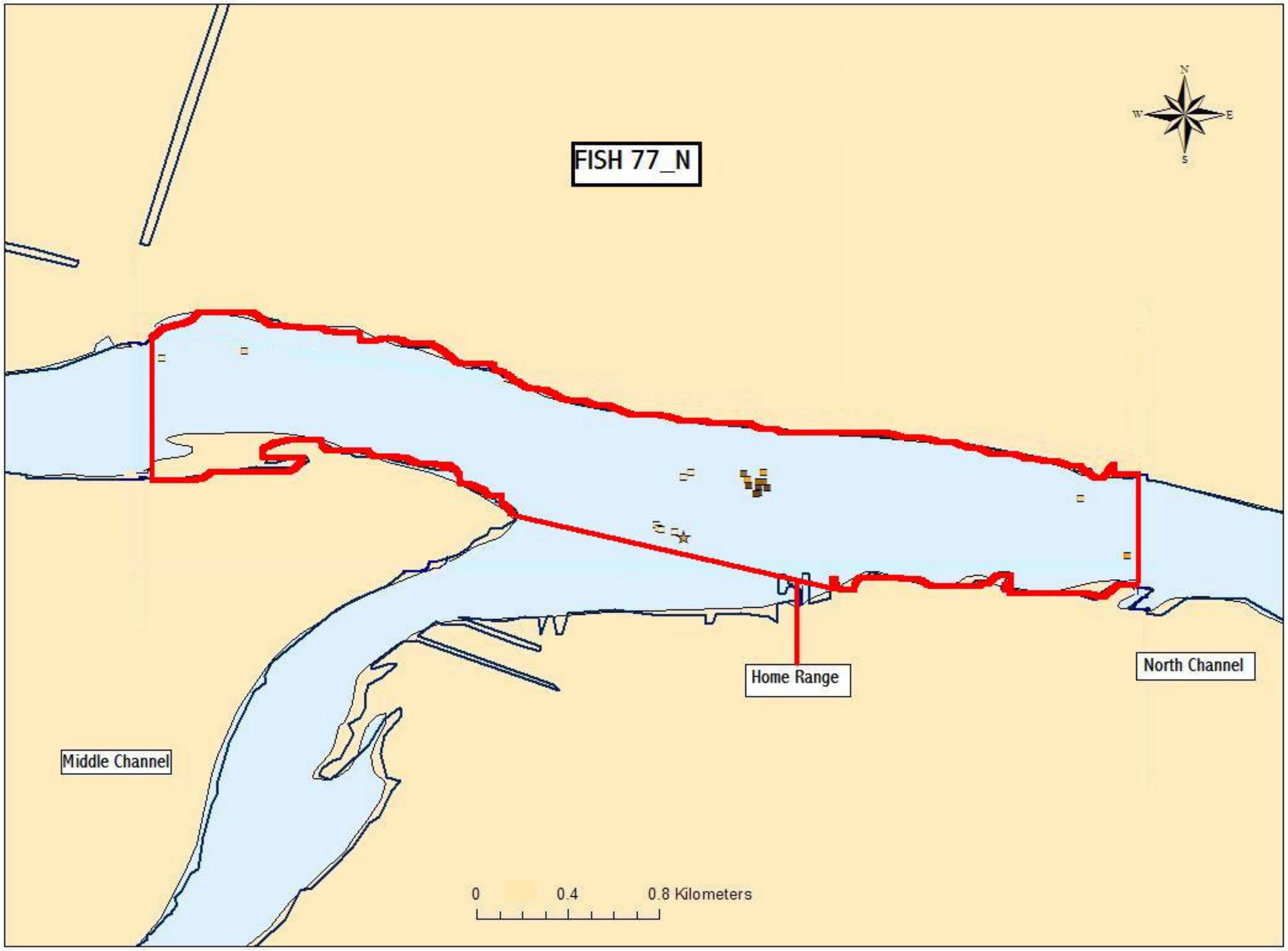


Figure 11: Map of locations for fish 78 from 20 June 2006-20 August 2006 in the St. Clair River. Notation as in Figure 3.

Figure 12: Percent occurrence of river depths in North Channel compared to depths occupied by juvenile sturgeon.

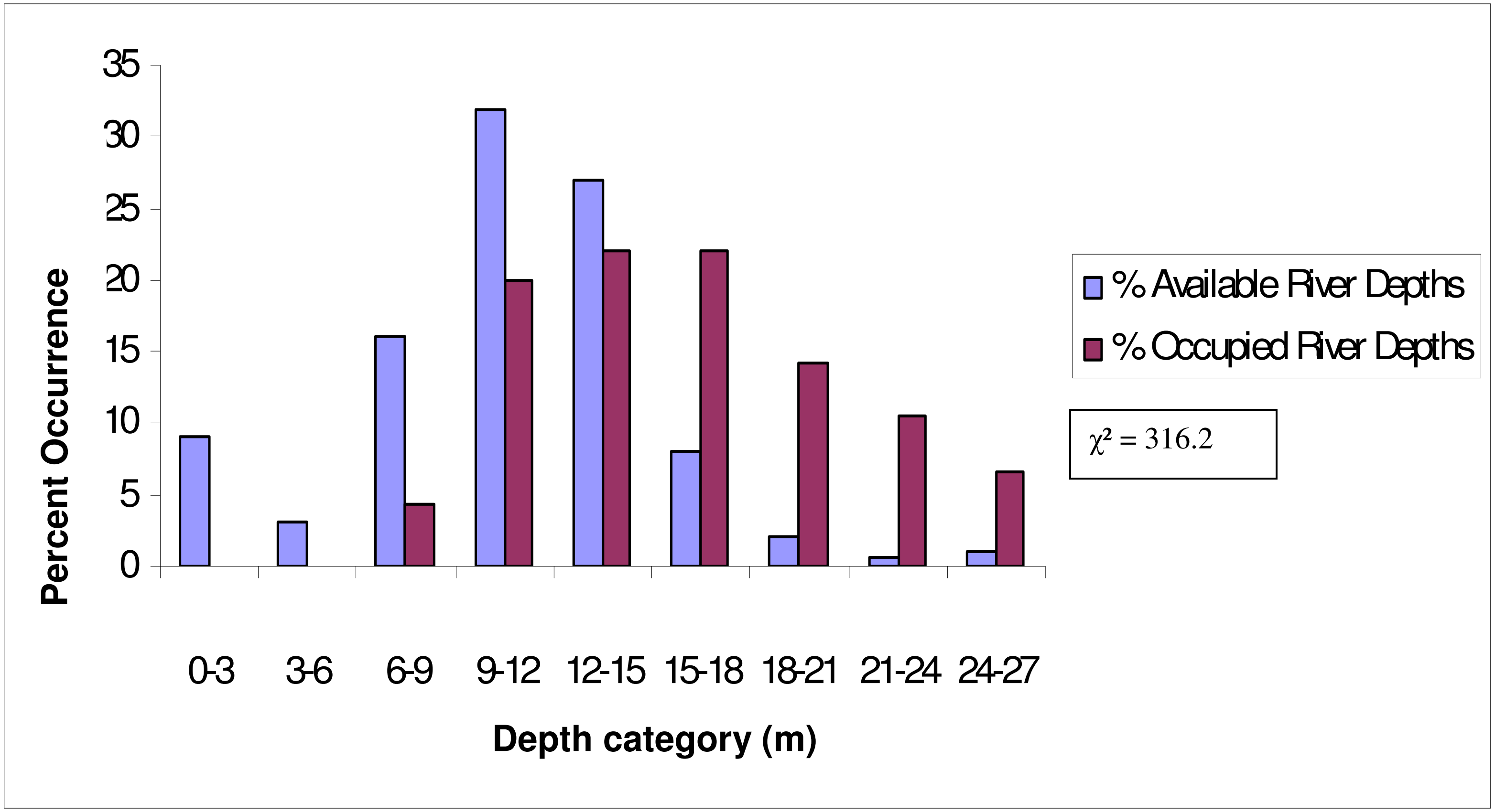


Figure 13: Correlation between home range area (km²) and the average of every recorded depth (m) for each fish.

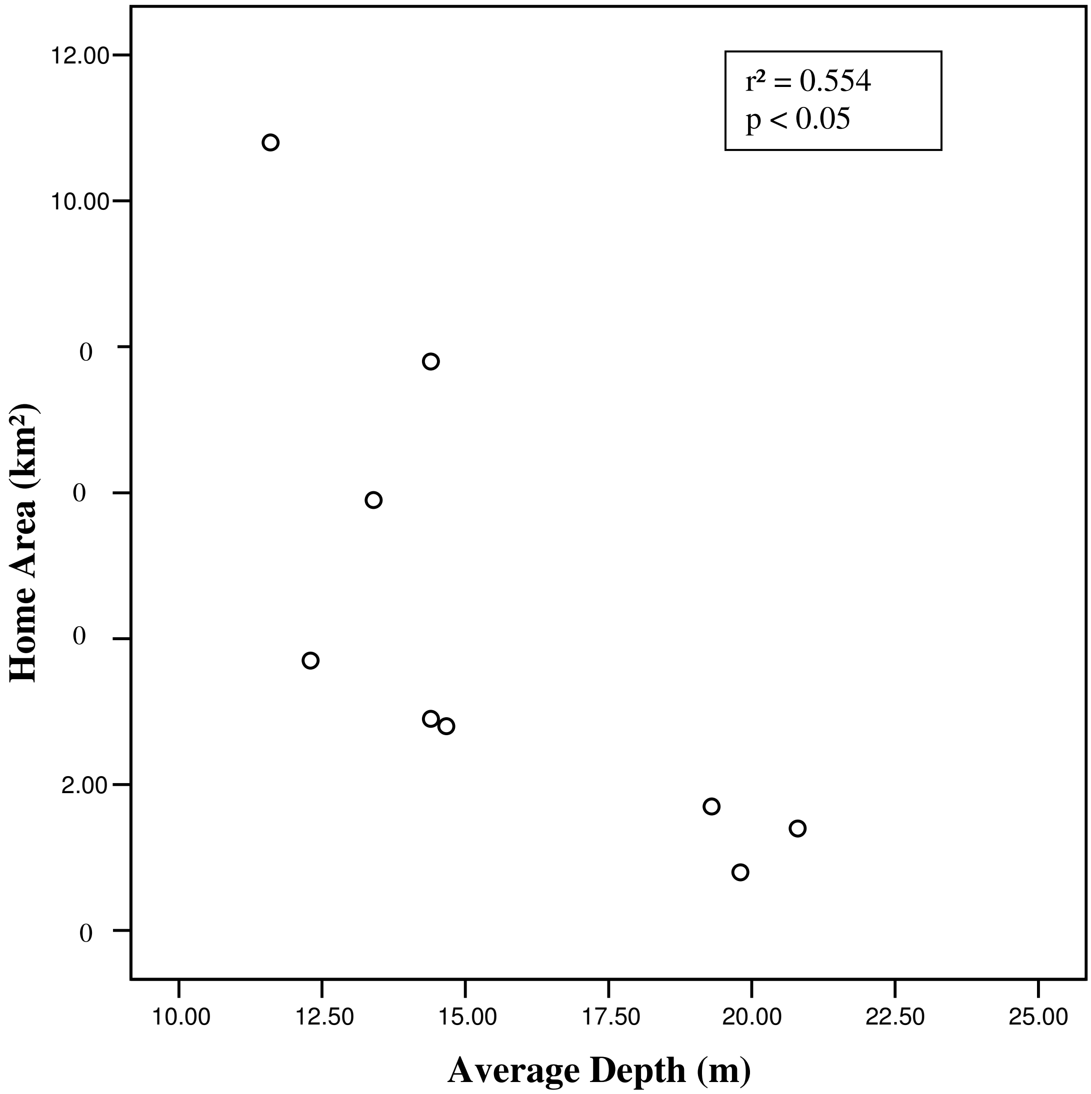


Figure 14: Correlation between amount of zebra mussel coverage for samples within the home range and amount of overall home range overlap.

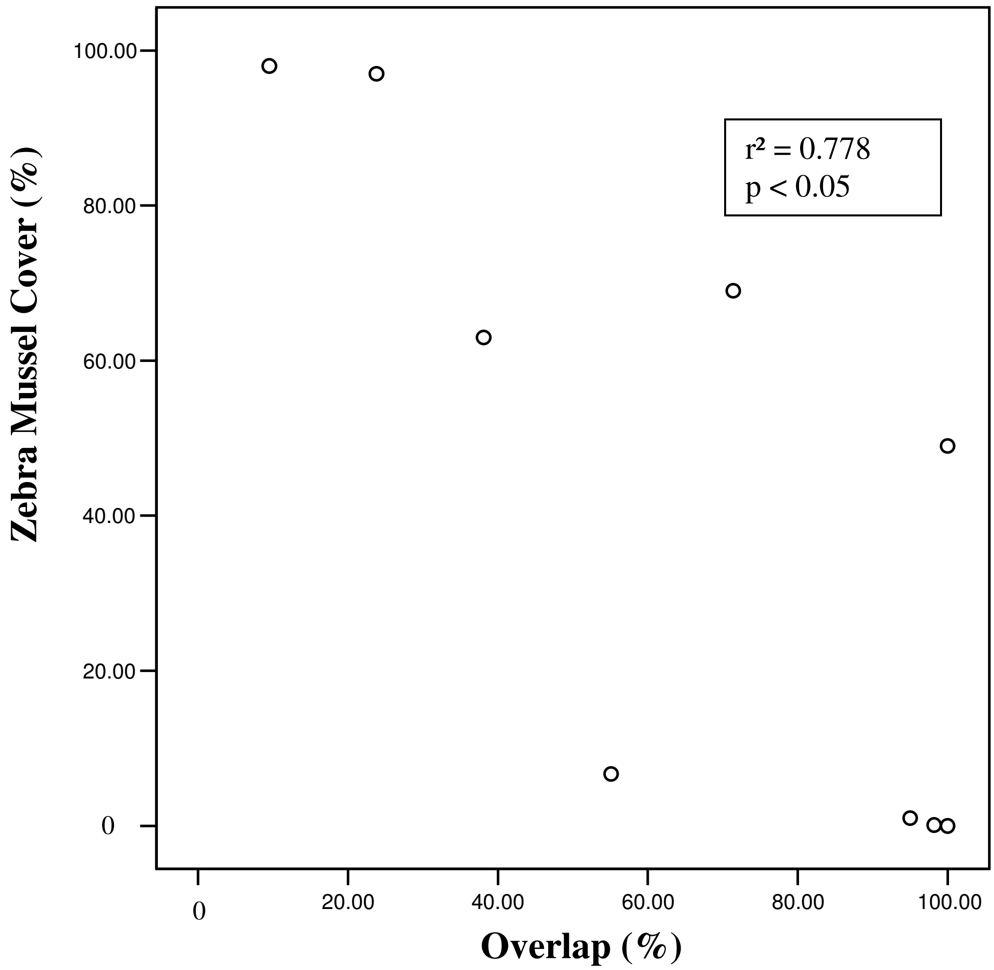


Figure 15: Correlation between percent of gravel substrate for samples in each home range and amount of overall home range overlap.

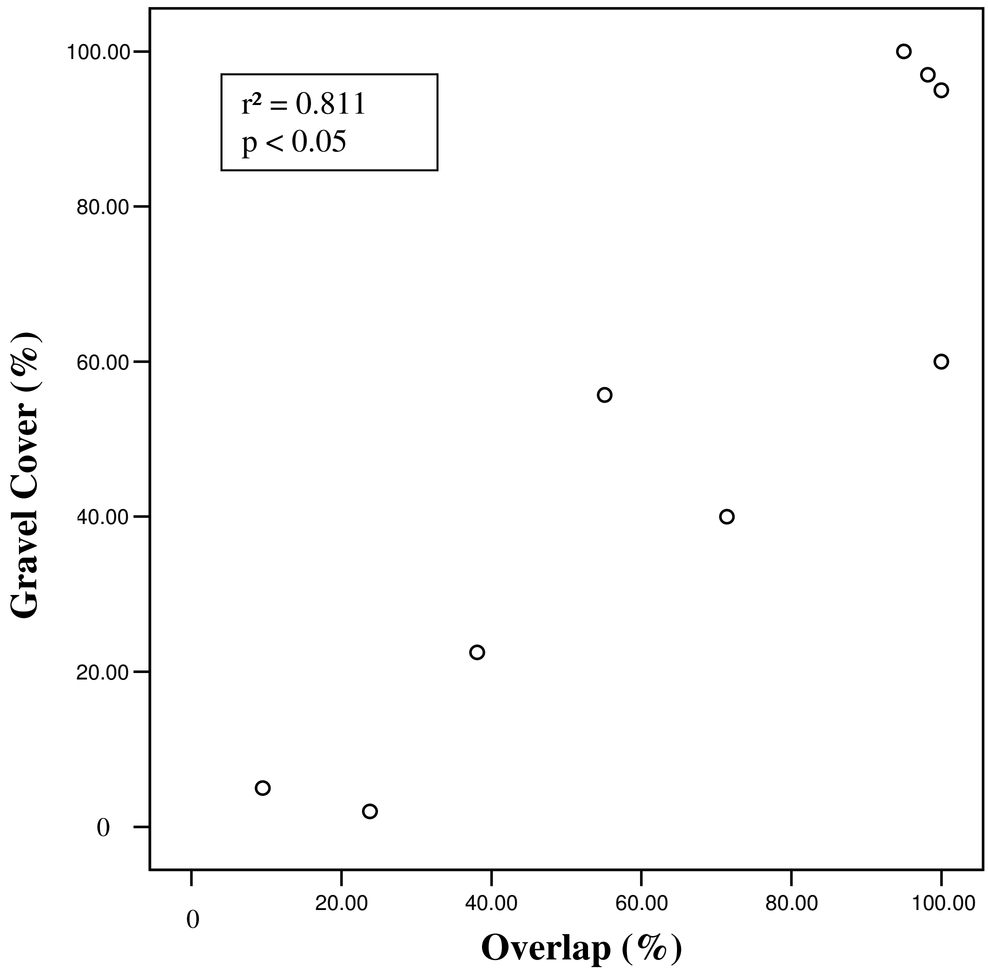
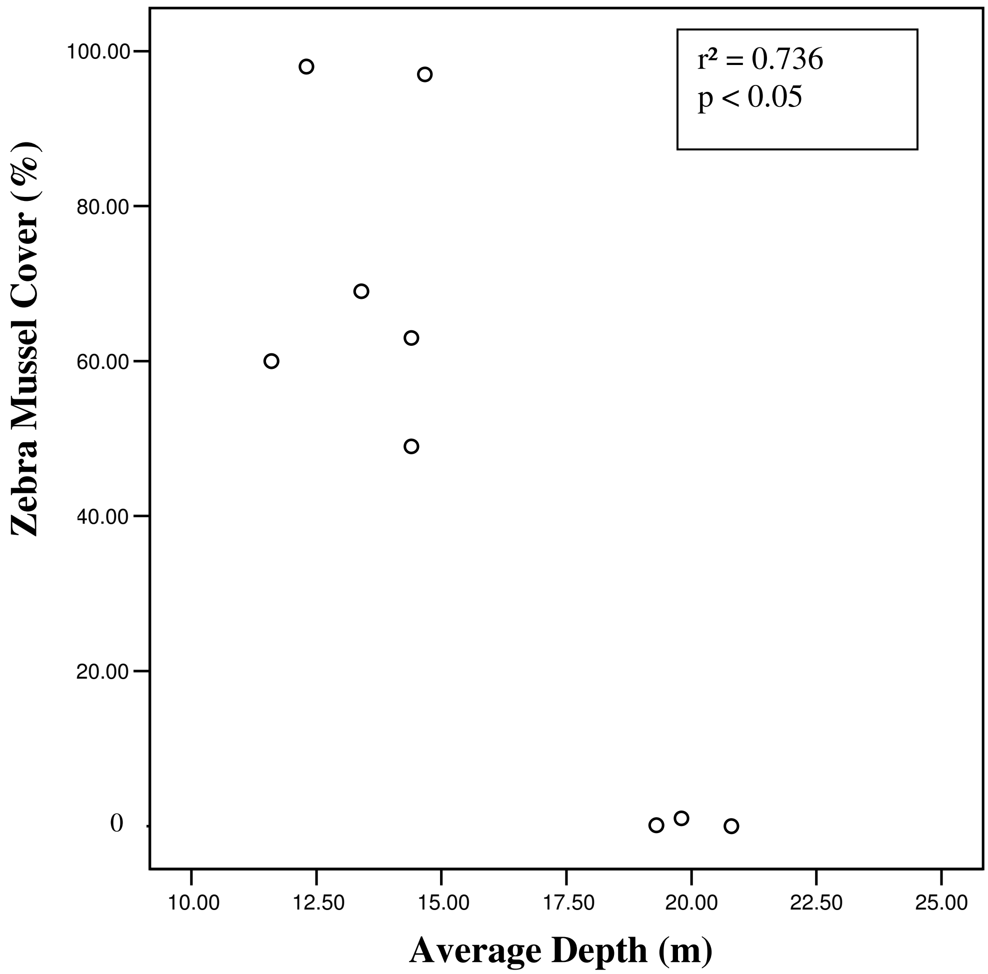


Figure 16: Correlation between average zebra mussel cover for all samples taken in a home range and average depth each fish occupied.



Tables

Table 1: Size and basic telemetry data for nine juvenile lake sturgeon implanted in the North Channel of the St. Clair River in 2005 and 2006.

Fish #	Total Length(cm)	Weight(kg)	Year Class	Times located	Date Implanted	Date Last Located
71	68.1	1.6	1999	55	1-Jun-05	20-Aug-06
73	71.1	2	2000	49	1-Jun-05	20-Aug-06
74	66	1.7	2002	21	20-Jun-06	20-Aug-06
75	58.2	0.7	2003	21	20-Jun-06	20-Aug-06
76	66	1.7	2001	54	1-Jun-05	20-Aug-06
77	79.3	2.7	1998	28	1-Jun-05	26-Aug-05
77_N	72.9	2.2	2002	21	22-Jun-06	20-Aug-06
78	77	2.2	2001	20	20-Jun-06	20-Aug-06
79	74.4	1.7	2000	48	1-Jun-06	20-Aug-06

Table 2: Home range area size as compared to weight and length of each fish.

Fish #	Weight (kg)	Total Length (cm)	Home Range (km²)
71	1.6	68.1	0.76
73	1.7	71.1	10.78
74	1.7	66	1.36
75	0.7	58.2	3.04
76	1.7	66.1	1.7
77	2.7	79.3	5.4
77-N	2.2	72.9	3.71
78	2.2	77	7.45
79	1.7	74.4	2.05

Table 3: The number of sites in each depth category for each fish location from 1 June 2005 to 20 August 2006

Depth category (m)

Fish #	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	Average	Range
71	0	0	0	0	1	17	20	9	8	19.8	12 to 26
73	0	0	9	26	7	5	0	1	1	11.6	7 to 25
74	0	0	1	0	0	4	3	8	5	20.8	7 to 26
75	0	0	0	4	13	1	0	2	1	14.67	9 to 27
76	0	0	0	3	2	14	16	13	6	19.3	11 to 27
77	0	0	0	13	6	9	0	0	0	13.4	9 to 17
77_N	0	0	2	10	8	0	1	0	0	12.3	8 to 20
78	0	0	2	5	4	5	4	0	0	14.4	8 to 19
79	0	0	0	1	30	16	1	0	0	14.4	11 to 20
% Frequency	0	0	4.4	19.6	22.4	22.4	14.2	10.4	6.6		

Table 4: Percent overlap of home ranges with horizontal grouping representing the home range resident and vertical grouping the second fish. The total overlap represents the percent of the home range for a resident fish that overlapped with any other fish.

	Home Range Resident									
Overlap Grouping	**71**	**73**	**74**	**75**	**76**	**77**	**77-N**	**78**	**79**	**Overall % Overlap**
71	100	0	50	4.8	82	29	0	0	0	98.2
73	3.6	100	0	0	0	18	10	25	96	55.1
74	98.2	4.1	100	14.2	98.2	29	0	0	0	100
75	0	1.8	0	100	0	17.8	9.5	5	0	23.8
76	98.2	3.7	100	14.3	100	29	0	0	0	98.2
77	98.2	31	76	14.3	76	100	90.4	25	71	71.4
77_N	0	1.8	0	9.5	0	29	100	15	0	9.5
78	0	0	0	0	0	0	0	100	0	38.1
79	0	44.4	0	0	0	17.8	9.5	25	100	100
Total Overlap	98.2	55.1	100	23.8	98.2	71.4	9.5	38.1	100	
Average	37.2	10.8	28.3	5.3	32	21.2	14.9	11.8	20.8	

Table 5: Characteristics of substrate samples collected with ponar grabs along the North Channel.

Area	Latitude	Longitude	Depth (m)	Clay/Silt(%)	Gravel (%)	Zebra Mussels (%)	Date
1	42.37.786	82.38.996	18.8	10	90	0	8/15/2006
1	42.37.773	82.38.890	18	70	0	30	8/15/2006
1	42.37.763	82.38.980	17.3	80	0	20	8/15/2006
2	42.37.367	82.36.434	17.4	0	0	100	7/21/2005
2	42.37.356	82.36.428	17.4	5	0	95	7/21/2005
2	42.37.367	82.36.414	17.4	2	0	98	7/21/2005
2	42.37.368	82.36.426	17.7	2	0	98	7/21/2005
3	42.37.37	82.35.72	12.8	15	85	0	7/21/2005
3	42.37.373	82.35.724	14.6	10	90	0	7/21/2005
3	42.37.389	82.35.713	14.6	15	85	0	7/21/2005
3	42.37.381	82.35.728	14.6	10	90	0	7/21/2005
4	42.36.733	82.35.816	10.3	5	95	0	8/15/2006
4	42.36.725	82.35.800	10.6	2	98	0	8/15/2006
4	42.36.715	82.35.796	10.2	10	70	20	8/15/2006
5	42.37.128	82.34.562	12.8	2	0	98	7/21/2005
5	42.37.122	82.34.523	14	5	0	95	7/21/2005
5	42.37.128	82.34.523	13.4	0	0	100	7/21/2005
5	42.37.125	82.34.520	13.4	2	0	98	7/21/2005
6	42.36.375	82.32.690	22.9	0	100	0	7/21/2005
6	42.36.37	82.32.689	23.4	0	100	0	7/21/2005
6	42.36.369	82.32.687	21.3	0	100	0	7/21/2005
6	42.36.365	82.32.691	23.4	0	100	0	7/21/2005

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