2008 Final Report: Evaluation of Lake Sturgeon Spawning in the Saginaw River Watershed (2005 - 2008)

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Introduction

Lake sturgeon *Acipenser fulvescens* were once widely distributed in rivers and lakes throughout North America. Their historic range included drainage basins of the Mississippi, Hudson Bay, and the Great Lakes (MacKay 1963; Scott and Crossman 1973). Within the last century, lake sturgeon populations were dramatically reduced or extirpated from much of their native range (Harkness and Dymond 1961; Brousseau 1987). Habitat destruction, excessive harvesting, and over fishing were determined to be the primary causes for their decline (Harkness and Dymond 1961; Tody 1974; Brousseau and Goodrich 1989). To slow the decline of lake sturgeon, state governments in the United States and provincial governments in Canada have listed them as a protected species (Brousseau 1987; Johnson 1987). Lake sturgeon are protected from harvest in seven of the eight Great Lakes border states, and have recently been listed (July 2008) as threatened under the Species at Risk Act (SARA) in the Canadian jurisdictional waters of the Great Lakes (Thomas Pratt personal communication). They are also listed as a state threatened species in Michigan (Auer 1999).

From historical records on Lake Huron, lake sturgeon spawned on at least 40 tributaries in the United States and Canada, of those 24 were located in Ontario waters with the remaining 16 located in Michigan waters (Hay-Chmielewski and Whelan 1997; Holey et al. 2000). Of those 16 tributaries in Michigan the Au Sable, Carp, Cheboygan, Saginaw, St. Mary's, and Thunder Bay rivers were identified by the Michigan Department of Natural Resources (MDNR) as rivers with a high suitability for rehabilitation or enhancement (Hay-Chmielewski and Whelan 1997). The overall goal of this project was to determine if lake sturgeon are using the Saginaw River watershed for spawning. The Saginaw River watershed is the first tributary of Lake Huron in Michigan to have been intensively surveyed for the presence of spawning lake sturgeon. The specific objectives of this study are: (1) determine if lake sturgeon are using the Saginaw River watershed for spawning and if so collect habitat information about those locations, (2) collect genetic information from lake sturgeon spawning in the system to determine their relatedness to other Great Lakes populations, (3) determine if other early life history requirements (egg development, fry development, and first year juvenile development) are adequate within the Saginaw Watershed. The conservation need for this project is consistent with the rehabilitation efforts as described in the Michigan Department of Natural Resources (MDNR) Lake Sturgeon Rehabilitation Strategy, Saginaw River Area of Concern and its Remedial Action Plan, and the Lake Huron Fish Community Objectives (DesJerdine et al. 1995; Hay-Chmielewski and Whelan 1997; PSC 2002).

In 2005 and 2006 we examined the Tittabawassee, and Cass rivers and in 2006 we added the Shiawassee River to our study areas. Our primary goal was to determine if lake sturgeon were utilizing those rivers for spawning, all are tributaries of the Saginaw River. Anecdotal reports by anglers indicate that adult lake sturgeon are occasionally captured or spotted during the spring walleye fishery below the Dow Dam on the Tittabawassee River near the town of Midland, below the Frankenmuth Dam on the Cass River in the town of Frankenmuth, and below the Chesaning Dam on the Shiawassee River in the town of Chesaning (J. Baker, MDNR, personal communication). The origin, distribution and spawning success of those lake sturgeon stocks are unknown. Information gathered form this research will provide essential data required to guide future habitat protection, enhancement, and restoration activities, as well as increase our knowledge for improved fish passage in the Saginaw River watershed. This project will be a crucial first step in determining the present and potential contribution of lake sturgeon from the Saginaw River Watershed to adjacent populations in Saginaw Bay and Lake Huron. Additionally, this effort will assist in the recovery of sturgeon from state "Threatened" status in Michigan. Information gathered from this project will allow the U.S. Fish and Wildlife Service (Service) to participate in and expedite the Lake Huron Bi-National Partnership process including on-the-ground restoration actions and support an International Joint Commission (IJC) initiative for delisting the Saginaw River as an Areas of Concern (AOC).

Methods

Setlines

In the spring of 2005 attempts were made to collect lake sturgeon using setlines, fishing either two or three lines during each set. Setlines were fished in a relatively deep section of the Saginaw River at the confluence of the Tittabawassee and Shiawassee rivers, and at a second location where the Cass and Shiawassee rivers converge (Figure 1). We used similar setline methods as those described by Thomas and Haas (1999). Setlines were deployed from an open hull, flat bottom boat from April 11, 2005 through May 26, 2005. Setlines were deployed at locations identified as potential staging areas which were essentially the deepest sections of the Saginaw River. Twenty-five baited hooks were used on each setline using a combination of dead round goby (*Neogobius melanostomus*) and frozen squid. Setlines were deployed between 0800 and 1700 hours and generally retrieved the following day before 1500 hours. Fresh bait was used for the first set at the beginning of the week and for the remainder of the week only empty hooks or hooks with tattered bait were rebaited with fresh bait. Data was collected on the number of empty hooks, water temperature, water depth, along with GPS coordinates for each setline location.

Egg-mats

In both 2005, 2006 and 2007 attempts were made to collect lake sturgeon eggs with egg-mats at locations where adult lake sturgeon have been captured or sighted in the past by anglers. Specific locations in each of the rivers where the egg mats were to be deployed was decided during October 2004 when water flows in each of the rivers was low and rock substrates could be clearly identified and geo-referenced. Egg-mats were constructed using a concrete block measuring 40 cm long X 20 cm wide X 10 cm deep wrapped with furnace filter material. The filter material was composed of latex coated hog hair measuring 2.5 cm thick X 37.5 cm wide X 50 cm long and covered three sides of the concrete block. Filter pads were secured to the concrete block with two rubber bungee straps wrapped around the block. A single orange bullet float with a unique number was tied to each block to identify its location in the river. Egg-mats were placed in the river and retrieved weekly from an open boat.

In 2005, 2006 and 2007 egg-mats were deployed at two locations below Dow Dam on the Tittabawassee River (Figure 2) below the Frankenmuth Dam on the Cass River (Figure 3), and were deployed below the Chesaning Dam only in 2006 (Figure 4). On the Tittabawassee River egg-mats (n = 48) were deployed from April 11- 29, 2005. The egg-mats were removed on April 30, 2005 to avoid interference with recreational anglers for the opening of walleye season. Egg-mats were then redeployed on May 11 and lifted for the season on May 26, 2005. In 2006 egg-mats were again deployed at two locations (n = 24 at each location) on the Tittabawassee River beginning on April 10. Just below the Dow Dam the 24 egg mats were lifted on April 25 to avoid a conflict with the opening of walleye season which began on April 29. On May 31 water temperatures reached 22^{o}C so the decision was made to pull the egg-mats for the season. Water levels in the river at that time were about 2 m above normal levels and ten egg-mat floats were submerged below the surface and were irretrievable. The remaining egg-mats were eventually pulled on July 20, 2006. In 2007 we reduced the effort and only placed egg-mats at the site directly below Dow Dam on the Tittabawassee River beginning on April 17. All egg mats were lifted on April 27 to avoid a conflict with the opening of walleye season which began on April 28. We reset the egg mats on April 30 and on May 29 water temperatures reached 21^{o}C so the decision was made to pull the egg-mats for the season, 3 egg mats were lost including the block with the temperature probe. The pattern of placement of egg mats roughly followed a checkerboard pattern to cover the most area. In 2005, 2006 and 2007, twenty-four egg-mats were placed within the first 200m below the Dow Dam. Further downriver, in 2005 and 2006, another 24 egg-mats were placed among four large rock aggregations near outside bends in the river where river velocities were highest.

Egg-mats were deployed on the Cass River from April 11 - May 17, 2005 from April 3 - May 9, 2006 and from April 17 – June 29, 2007. Twenty-four egg-mats were placed in a checkerboard pattern within the first 200 m below the Frankenmuth Dam. In 2006 a total of 24 egg-mats were deployed below Chesaning Dam. Most (n=20-22) were placed in a checkerboard pattern within the first 70-m of the dam with two or four mats placed parallel to a sand bar located approximately 100-m below the dam. At all locations egg-mats were placed between three and seven meters apart.

Egg-mats were deployed for periods of seven days, retrieved and checked for eggs, and then redeployed at the same locations. Each week egg-mats were lifted into a boat and were either examined on the boat or were moved to the shore and examined there. The filter material was removed from each egg-mat as it was retrieved and checked for deposition of eggs. After the filter material was examined and the material was secured on the cinderblock the egg-mats were reset from the boat at the same location. Majority of the eggs found were on the leading edge and on top surface of the filter material. Removal of eggs attached to each egg-mat involved first examining the exterior surface of the filter material and then removing the filter material from the cinder block and looking at the underside of the filter material and the cinder block. Sturgeon eggs are readily distinguishable from other species of fish spawning during the same period so during the 2005 and 2007 sampling periods just presence or absence of lake sturgeon eggs was determined while in the field. Eggs from all non-target species collected in 2005 and 2007 were not quantified or positively identified due to time and unavailable rearing space at the USGS Great Lakes Science Center (Center) laboratory located in Ann Arbor, MI. A sub-sample of eggs were hand pick from the filter material using forceps and then placed in vials containing a solution of 35% isopropyl alcohol for verification back at the laboratory. Eggs that were captured in 2006 were removed with forceps, placed in river water in a sealed 100-ml glass jar, and transported on ice, within 5-h of collection, to the Center. No attempts were made to determine the abundance of eggs, only a representative sub-sample of all of the species of eggs was collected. Collectively from all of the egg-mats each week no more than 100 eggs were collected. No attempt was made to estimate the number of eggs lost from mats during retrieval. We assumed that a like proportion of eggs were washed from each mat during retrieval. During both years water temperature, water depth and GPS coordinates were collected at each egg-mat location.

Egg development

When eggs arrived at the Center they were thermally equilibrated to the recirculating culture apparatus, in which water temperature was matched to river temperature readings, and treated for 10 minutes in 500 ppm hydrogen peroxide. Eggs were treated every other day with 500 ppm hydrogen peroxide. Any dead or diseased eggs were removed with a pipette and preserved in 10% buffered formalin. Fish larvae that hatched from the eggs were collected from the culture apparatus with a pipette and fixed in 1.6% Paraformaldehyde and 2.5% Glutaraldehyde in 0.1M Cacodylate Buffer for 24 to 48 hours. Larvae were then washed with 0.1M Cacodylate Buffer and transferred into 70% ethanol.

Eggs were cultured in a recirculating culture apparatus with a 1000 liter head tank. In the head tank were four 1 HP Frigid Unit drop-in chillers, used to closely match the egg source temperature regime (temperature range of 3.8-13.8^{o}C). The water in the head tank was continuously pumped through a filtration and UV sterilization system. This system consisted of, in order: a 1-liter priming pump for a Iwaki magnetic drive pump (WMD 20RLT-115) rated at 8.1 gal/min; a filter canister containing a 20-micron pleated filter (2.3 squared meter surface area); a filter canister containing 2000 grams activated carbon and amino chips; a 40-watt Smart UV sterilizer running at 8 gal/min, providing approximately 97,000 microWs/cm^2; and back into the head tank through a 3-bucket degassing column. From the head tank, the water was gravity-fed into McDonald hatching jars at flow rates sufficient to gently roll the eggs. The outflow from each hatching jar went into separate collection chambers secured inside a 30-gallon glass aquarium. The collection chambers were constructed of 4-inch drainage pipe standing on end, with 500 micron Nytex screening glued on the sides and bottom. The collection chambers could easily be removed from the 30-gallon aquarium to collect hatched larvae for enumeration. The 30-gallon glass aquarium had holes drilled in the bottom where bulkhead fittings and standpipes were secured. The overflow from the standpipes was gravity fed and collected into a 55-gallon fiberglass tank that contained a Danner ¾ hp (WFP 4250) submersible pump attached to a mercury pump down float switch (Aquatic Eco-systems (PL2D). When activated, the water was pumped from this tank back into the head tank. The system was filled with well water, and levels were maintained by periodic additions and exchanges of well water. Hatched larvae were removed from holding tanks with a pipette, placed in 10% neutral formalin, and identified following Auer (1982). We derived the percentage hatch rate of eggs in culture by multiplying the quotient of hatched larvae divided by the total number of eggs in culture by 100.

Bottom trawling

A 4.9-m, small-mesh, otter trawl (3.8-cm stretch mesh body, and 6.35-mm square-mesh cod liner) was used to sample for young-of -year lake sturgeon in the Saginaw River. Efforts were confined to the deep-water and dredged areas of shipping channel near the mouth of the Saginaw River. Sampling was conducted on October 4, 2006. Total effort consisted of 30 minutes trawling with individual tows limited to five minutes each with boat motor speeds limited to 1200 RPM. The catch was separated by species, and then total lengths were measured on a maximum of 15 specimens of each species. All round goby were retained and euthanized, while non-target species were returned unharmed to the water. Relative abundance was determined for all species and expressed as catch-per-minute-of-effort (CPE).

Water temperatures

In 2005 and 2006, water temperatures in the three rivers were determined weekly by using a hand held mercury thermometer and were recorded in each of the three rivers every 30 minutes for the duration of the study using an Onset Temperature Recorder (Onset Inc.). Temperature probes were placed inside of the small gap of the cinderblocks used for the egg-mats and were deployed essentially for the same period that the egg-mats were deployed.

Substrate sampling

Substrate information was collected in the summer of 2008 beginning at each of the dams on the Tittabawassee, Cass and Shiawassee rivers, and continued downriver to where the three rivers converge to form the Saginaw River and then out to Saginaw Bay. All three rivers are subject to radical changes in water levels during heavy rain events and during the spring snow melt. The Tittabawassee and the Cass rivers both have large flood planes and watersheds relative to the Shiawassee River. On the Tittabawassee the Sanford Dam, which is located above the Dow Dam, is used to generate electricity which results in a daily fluctuation in water levels of approximately 0.3 – 1.0 meter each day during the summer and fall seasons. The upper sections of each of the rivers are relatively shallow, have steeper gradients, and have generally been able to meander in a more natural pattern. A few small islands and seasonal sandbars occur in each of the rivers during the dryer times of the year. For the last 4 – 8 kilometers, each of the rivers begins to widen and slow down in velocity as they enter the lake plane area of Saginaw Bay and form the Saginaw River. While most of the Saginaw River has been dredged to form a navigation channel for large Great Lakes freighters.

Substrate collections were made using a Ponar Grab Sampler from an open boat, canoe, or by wading. As Ponar samples were collected they were emptied into a tray, and a visual analysis of each sample was conducted. Samples were categorized into one of the following: clay, silt, sand (1 – 5 mm), gravel (> 5 – 50 mm), sand/gravel mix, or cobble (> 50 mm). Sample sites were systematically determined to get a representative cross section of the river at each site. In the Saginaw River, samples were collected at intervals approximately 1.5 river kilometers apart. Depending upon the width of the river at each location, a cross section of three to five samples was collected. Paired samples were taken within ten meters of the shoreline, one from each side of the river, in an effort to quantify substrate differences due to varying current velocities. We targeted areas around islands and slack water areas to get a better understanding of all available substrate types. Percentage occurrence for each of the six categories was determined by dividing each category occurrence by the total number of sampling stations. Silt was identified as material that was easily suspended when mixed with water that did not settle after a period of forty seconds (Gee and Bauder 1986). All sampling locations were geo-referenced using GPS equipment. Depth measurements were collected using a hand-held depth sounder. Temperatures were collected using a hand-held thermometer. Geo-referenced sampling and habitat information were converted into map layers using GIS Mapping Software. In the summer of 2007, high water levels prevented substrate sampling, so all sites were sampled in the summer of 2008.

Results

Setlines

A total of 51 setlines were fished from April 11 - April 30, 2005 and then fished from May 9 - May 26, 2005 in the Saginaw and Shiawassee rivers for a total of 30,600 hook hours (51 setlines x 25 hooks x 24 hours). To avoid conflicts with recreational anglers no sampling was conducted during the opening week of walleye season which began on April 30, 2005. During the sampling period in 2005 no lake sturgeon were captured using setlines. Channel catfish

(*Ictalurus punctatus*) accounted for over 91% (n=41) of the fish species captured on setlines. The remaining fish species captured included two common carp (*Cyprinus carpo)* one walleye (*Stizostedion vitreum*) and one northern pike (*Esox lucius*). In addition to the fish species listed, various crayfish species (*Decapodidae*) were also captured. Of the 51 setlines deployed, 45 of the lines were void of bait upon retrieval after being fished for a period averaging 24 hours.

On April 19, 2005 a major cold front passed through the survey area causing a rapid drop in ambient air temperature and resulted in a snow fall event that produced approximately 0.25 m of snow accumulation. Within two days ambient air temperatures increased well above freezing and by April 22, all of the accumulated snow had melted. The resulting temperature fluctuations caused water temperatures to drop from a high temperature of 16^{o}C on April 19 to a low of 8^{o}C on the Saginaw River, 7^{o}C on the Cass River, and 6^{o}C on the Tittabawassee River by April 24, 2005 (Figure 5). Changes in river water temperature caused a significant decrease in the number of fish captured on the setlines and in fact that was the only time that setlines were lifted after 24 hours and over 95% of the bait was still on the hooks. It is unclear what a 10^{o}C drop in water temperature over a five day period would do to the development of eggs and how that would affect spawning behavior of lake sturgeon. As expected, the temperature profiles for each of the three rivers were very similar during the 2006 sampling period with a relatively steep decline (5^{o}C) in temperature beginning on May 11 and ending on May 15 followed by a steady increase (11^{o}C – 23^{o}C) in temperature beginning on May 20 and ending on May 31.

Egg-mats

No lake sturgeon eggs were collected from egg-mats placed below the Dow Dam on the Tittabawassee River or the Frankenmuth Dam on the Cass River in 2005, 2006, or 2007 or below the Chesaning Dam on the Shiawassee River in 2006. From visual observations it was noted that a progression of species including: walleye (*Sander vitreum*); sea lamprey *(Petromyzon marinus*); common Carp (*Carpiodes cyprinus*); white sucker (*Catostomus commersoni*); northern hog sucker (*Hypentelium nigricans*); and other unidentified sucker species (*Catostomus spp.*) were visually identified and spawning at sampling locations all three years. From the eggs that were collected in 2006 and reared until hatching; common carp and white sucker were most common found spawning on all three rivers, shorthead redhorse (*Moxostoma macrolepidotum*) was found on the Cass and Shiawassee rivers, while walleye were only found on the Tittabawassee River (Table 1).

Although efforts were made to limit the amount of fungus growth on the eggs with initial and periodic hydrogen peroxide treatments at the laboratory, 344 eggs did not hatch due to fungus growth during the incubation period. Of those 344 eggs, most were thought to be common carp eggs, (n=286 unfertilized and n=35 fertilized) while the remainder were unidentified sucker species (n=17 unfertilized and n=7 fertilized) (Table 1).

Although no lake sturgeon eggs were collected from any of the rivers in 2005, 2006 or 2007, one individual lake sturgeon was reported directly below the Dow Dam on May 6, 2005 to MDNR biologists. The sighting was confirmed multiple times by Service biologists over the next ten days as egg-mats were sampled. Attempts were made to capture the lone lake sturgeon, however, issues of personal safety due to high water and the proximity of the fish with the dam prevented capture.

Bottom Trawling

Lake sturgeon were not captured during small mesh bottom trawling efforts at the Saginaw River mouth in 2006 or in 2007. In 2006, six species of fish were captured including; channel catfish (*Ictalurus punctatus*), emerald shiner (*Notropis atherinoides*), freshwater drum (*Aplodinotus grunniens*), round goby (*Neogobius melanostomus*), white perch (*Morone americana*), and yellow perch (*Perca flavescens*). Channel catfish had the highest CPE at 19.3 fish/minute (Figure 9), and was the most abundant species comprising 81% of the total catch. Relative abundance for all other species captured is listed in table 2. Channel catfish averaged 94 ± 20.5-mm in total length, average lengths for all other species captured are listed in table 3. Further results from the 2007 sampling was not available at the time of this report but the 2007 and the 2008 trawling results will be included before the report is published as a manuscript.

Substrate sampling

The Dow, Frankenmuth and Chesaning dams are low-head dams, less than 4-m in height, and all are man-made. At the base of the Dow and Chesaning dams large substrates have been artificially placed in an effort to break up the laminar flow of the river as it passes over the dam. The substrates are primarily composed of granite boulders ranging in size from 1.5 - 0.5m with the largest substrates located at the foot of both dams and decreasing in size as you move away from the dam. After a distance of approximately 20m substrates are composed primarily of sand (1 - 5mm) and gravel (5 - 50mm). The base of the Frankenmuth Dam is composed of mix of granite boulders, large angular limestone and broken concrete ranging in size from 0.25 -

2.0m. After a distance of approximately 20m substrates become mostly gravel with interspersed larger materials similar in nature to those found at the foot of the dam.

In 2008 substrate samples were collected from starting points below the Dow Dam on the Tittabawassee River, the Frankenmuth Dam on the Cass River, the Chesaning Dam on the Shiawassee River, and then from the headwaters of the Saginaw River out to the mouth of the river where it empties into Saginaw Bay. Samples were collected from the dams down river to the confluence of the three rivers where they form the Saginaw River then out to the mouth of the Saginaw River where it empties into Saginaw Bay. On each of the rivers substrate samples were categorized into one of six categories with the following composition: clay, silt (which suspended for at least 45 seconds), sand (1 – 5mm), gravel (> 5 – 50mm), cobble (> 50mm).

We collected 118 substrate samples along 37 kilometers of the Tittabawassee River from Dow Dam to the headwaters of the Saginaw River. Sand and silt were the dominant substrates representing 50% and 28% respectively (Figure 10). On the Cass River, 95 substrate samples were collected along the 29 kilometers with silt then sand being the dominant substrates representing 40% and 29% respectively (Figure 11). The Shiawassee River is a much narrower river and although the distance was the longest of the four rivers sampled (39 km) there were only 83 samples collected because at many locations, only two samples were needed to get a representative sample of the river bottom. Sand and silt were the dominant substrates representing 47% and 25% of the samples collected (Figure 12). In the Saginaw River, 58% of the samples collected were composed of silt and 26% of the samples were composed of sand (Figure 13). We collected 182 samples on the Saginaw River and sampled for a distance of 36 kilometers.

On the Tittabawassee, Cass, and Shiawassee rivers we found cobble not only below each of the dams but also sporadically along eroded river banks and at road crossings. On the Tittabawassee River cobble could be found at the dam and along the outside bends of the river for the first 10 kilometers. Along all three rivers, the outer bends of each river had the highest current velocities and subsequently were dominated by either gravel or a combination of gravel and cobble. Those sites could best be described as pools and were generally deeper averaging over a meter in depth. Because many of the samples were collected in pairs, collection sites on the river opposite the deeper pools were shallower averaging less that 0.5 m and were almost always dominated by sand substrates. Although invertebrates were not enumerated during benthic sampling they were present and noted throughout the sampling of the watershed.

Discussion

Setlines proved to be an unproductive method of capturing lake sturgeon in the Saginaw River watershed with no lake sturgeon captured during the 2005 sampling period. Sampling demonstrated that even though large hooks (Kirby size 4 or 10/0 Hook) and a combination of bait types (round goby and frozen squid) were used, 88% of the setlines retrieved were void of bait after 24 hours. During one instance when setlines were deployed for a duration of less than two hours, five of the 25 hooks were void of bait upon retrieval suggesting a large number of non-target species were targeting the bait. Although that was the only effort made to quantify the rate of bait loss it is likely that most of the setlines were not fishing for the full 24 hour period. Attempts were made to use frozen squid which is more durable as bait and has been found to be more efficient on the Detroit River where non-target species were also a problem (Casewell 2003). No differences could be detected between using round goby or frozen squid for bait. Bait loss was likely due to the number of channel catfish and crayfish residing in the survey area. Although our sampling methods were not designed to capture crayfish or measure bait loss due to their abundance, crayfish were routinely clinging to the setline bait as it was retrieved. Because of the problems associated with non-target species targeting the bait, no setlines were used in 2006 or 2007. Alternatively, we focused greater effort on locating fish at the dams during each visit to sample egg mats although no lake sturgeon were seen at the dams in 2006 or 2007. If a lake sturgeon was seen at the dam we were prepared to capture the fish by using either long handled dip-nets or selectively targeting the fish with a large mesh (25 cm) gillnet.

At the outset of this project various lake sturgeon collection methods were discussed including using large mesh (20 and 25 cm) gillnets at deepwater locations and using electrofishing gear in shallow water areas near the dams. Because so few lake sturgeon were likely using the system it was decided by the Service and MDNR biologists to take a very conservative approach and limit the handling of any fish that were to be captured. The use of gillnets would likely create undue stress for a captured lake sturgeon and logistically posed a problem because of the duration of sets (a minimum of 12 hours). Potential fish by-catch posed another logistical problem with the disposal of dead non-target species. The Saginaw River watershed suffers from contaminant problems and dead fish would require special handling and disposal. Use of electrofishing gear to capture lake sturgeon was also considered too risky due to stress and potential organ traumas associated with that method.

Although a lake sturgeon was sighted at the Dow Dam in 2005 it is unlikely that spawning took place. During the ten day period that the lake sturgeon was observed just below the Dow Dam the egg-mats at that site were lifted and checked twice. Water temperatures during the same period fluctuated between 12 and 16^{o}C which is consistent with lake sturgeon spawning. Lake sturgeon egg incubation periods on systems having similar temperatures range between 9 to 11 days and since lake sturgeon spawn by broadcasting their eggs in high current areas of rivers, it is unlikely that a spawning event took place at the Dow Dam between April 11 and May 26, 2005 without it being detected (Nichols et al. 2003). Egg-mats continue to be an accepted method for rapidly assessing relatively large areas of river systems for lake sturgeon spawning. Logistically, the methods used are very efficient and the cost of deploying the egg-mats is relatively inexpensive. Although lake sturgeon spawning was not detected in the Saginaw River Watershed in 2007, we do feel it was the most effective way to sample this system.

In addition to the lake sturgeon sighted below the Dow Dam a second lake sturgeon was sighted by a credible source below the Chesaning Dam on the Shiawassee River on April 19, 2005 (James Baker personal communication). Attempts were made by Service biologists to substantiate the sighting over the following two days but the fish could not be relocated. Follow up conversations with the individual indicated that the fish was likely able to swim above the dam due to the elevated water levels at the time. During most years the Chesaning Dam would not be passable by a lake sturgeon even during a high water event. In 2005 two high water events were detected, one during the last week of March through the first week of April and a second high water event beginning on April 16 through approximately April 22. During the second high water event a portion of the Chesaning Dam had collapsed and it is speculated that by the time researchers got to the dam the fish had either swam above the dam or had moved back down river. Although water temperatures were not collected on the Shiawassee River during that period, the other three rivers located in the watershed had temperatures that would be consistent with lake sturgeon spawning. What is unknown is how the rate at which the temperature rose (from April 16-20) and subsequently fell (from April 21-24) with an overall change of possibly 14^{o}C and the effect that may have had on lake sturgeon behavior.

The amount of suitable spawning substrate available below the Chesaning is likely a limiting factor for successful lake sturgeon spawning and because of this was not initially selected as a survey site. Due to the fact that a lake sturgeon was sighted at the Chesaning Dam in 2005 egg-mats were deployed in 2006 but were not redeployed in 2007. Our research in 2006 indicated that very little spawning substrate was available below Chesaning Dam so if lake sturgeon were to repopulate the river it would likely only support a few fish, therefore we decided not to continue sampling at that location in 2007.

In 2006 and 2007 water levels on the Tittabawassee, Cass, and Shiawassee rivers were monitored using the USGS gauging stations located at or near the three dams where our sampling gear was located. Although no high water event was documented on the Shiawassee River the Cass gauging station registered one high water event from March 11-22 in 2006 with a maximum flood stage recorded at 5.2m. During a similar period in mid March (2006) a high water event caused water levels to increase on the Tittabawassee River to 7.3m above flood stage and lasted from March 14-19. Although the exact level was not determined on the Tittabawassee River in 2005, water levels were approximately the same height above flood stage based on the water levels witnessed at the boat launch area. During all three years (2005 – 2007) water levels were high enough to allow lake sturgeon to migrate above the Dow Dam. Above the dam the Tittabawassee River splits into the Pine and Chippewa rivers. Historically lake sturgeon were captured in the headwaters of the Chippewa River located near the city of Mt. Pleasant, MI. The river gradient on the Chippewa River is steepest in that region and the types of available substrates there would be well suited for lake sturgeon spawning. Historical anthropology records indicate that walleye lake sturgeon and freshwater drum were the most abundant fish species harvested by early aboriginal settlers to the Saginaw Valley with large stocks of all three species migrating up the river to spawn each spring (Fitting et al. 1972).

It is not fully understood what factors trigger lake sturgeon migration into a given river to spawn but essentially two migration patterns have been described. In other Great Lake tributaries that are similar to the Saginaw River Watershed, the arrival of lake sturgeon to the spawning grounds generally happens just a few days prior to the actual spawning event (Bruch and Binkowski 2002), yet in larger systems like the Detroit and St. Clair rivers lake sturgeon the arrival of lake sturgeon may happen months prior to the spring spawning period (Boase et al. 2003; Casewell et al. 2003). Although the Saginaw Watershed has deep water associated with the navigation channel located in the lower reaches of the river, the river is still subject to relatively quick changes in temperature and flow rates, factors that do not affect systems like the Detroit and St. Clair Rivers. Bemis and Kynard (1997) describe these two migration patterns as ‘one-step’ and ‘two-step’ patterns respectively. Fish exhibiting the one-step pattern migrate up their natal tributaries in spring and spawn within few days of reaching their spawning grounds while with the two-step pattern, lake sturgeon may stage in an area in close proximity to the actual spawning site for more than six months prior to the spring spawning period. If suitable numbers of lake sturgeon were present at the spawning locations in the Saginaw Watershed we would expect males to arrive 1-2 days prior to the females and once the females were present spawning would likely begin as soon as water temperatures reach 10-15^{o}C (Harkness and Dymond 1961; Kemperinger 1988; Auer 1996; Smith and King 2005).

Due to the periodicity of lake sturgeon spawning (males returning every 1-4 years and females returning every 2-6 years) the chance that a spawning event will be successful appears highly unlikely given so few lake sturgeon are migrating into the Saginaw system each year. Therefore a greater effort was made during the 2007 sampling season to locate lake sturgeon at the dams by visually monitoring along the spillway area when we were sampling egg mats in each river. Had we collected genetic material from adult lake sturgeon or from fertilized eggs, it likely would have helped answered one of the objectives of this study, are the lake sturgeon that are using the Saginaw River Watershed form a unique stock or are they from the same stock as the St. Clair River population? Although we have not answered that question with this research project other genetic research might help. Funding from the Great Lakes Fishery Trust has been secured to conduct a genetic assessment of the open water stock of lake sturgeon that resides in Saginaw Bay for most of the non-spawning times of the year. Analysis should be able to determine if a yet undiscovered population of lake sturgeon exists and is co-mingling with other lake sturgeon out in Saginaw Bay. Understanding those genetic questions will likely influence the direction of management of lake sturgeon in the Saginaw River watershed.

One of the objectives of this study was to not only determine the availability of lake sturgeon spawning habitat but also to quantify the habitats needed by juvenile lake sturgeon during the first year of life in the river, the period when young-of-year lake sturgeon are known to inhabit their natal streams. Recent studies have determined habitat requirements and preferred food habits of age-0 lake sturgeon (Thuemler 1988; Kempinger 1996; Chiason et al. 1997; Beamish et al. 1998; Peake 1999; Auer and Baker 2002; Holtgren and Auer 2004; Benson et al. 2005). In those studies lake sturgeon often inhabit areas dominated with sand substrates and areas of low current velocity and preferred to feed on Diptera and Ephemeroptera larvae. Preference for sand substrates and low current velocities may be a function of the weak swimming ability of age-0 lake sturgeon (Peake et al. 1997; Peake 1999). From the habitat data collected the Tittabawassee River appears to be the most suited for lake sturgeon recovery efforts having both suitable and sufficient spawning substrates located below Dow Dam and also having suitable juvenile lake sturgeon habitat with substrates composed of 50% sand. Following habitat sampling in 2008, the Shiawassee and Cass rivers both potentially could support smaller populations of lake sturgeon if they were reintroduced. Both rivers have additional spawning substrates located downstream form the spawning habitats located at their respective dams and both have sufficient substrates to support the development of lake sturgeon during the first year. Further information form the Michigan Department of Environmental Quality is being reviewed about the macro-invertebrate assemblages associated with each of these rivers and what that would mean for juvenile lake sturgeon survival. Those findings will be incorporated into the final manuscript for this project. Future habitat research should focus on what habitats are available above each of the dams which were historically the areas where lake sturgeon were known to spawn. This rational is driven by the fact that efforts are currently underway to either remove or provide fish passage around the dams (PSC 2001). In addition, no effort was made to determine if lake sturgeon were using the Flint River for spawning, as it was not identified by the Michigan DNR as a suitable river, yet preliminary habitat data suggests that much of the river is suitable for spawning, which has large continuous sections of suitable spawning habitat and suitable current velocities.

From our research it does not appear that lake sturgeon are spawning in the Saginaw River Watershed. Information from the Saginaw Bay open water stock assessment should help to clarify our findings. There is likely one of two scenarios that will result from the open water stock assessment. In scenario one, the genetics will indicate that a unique stock of lake sturgeon exists in Saginaw Bay and it is likely those fish have origins from a system close to Saginaw Bay. If that is the case, efforts should be made to determine the spawning location of that population and a renewed effort should take place with tributaries leading into Saginaw Bay. In 2003, Service personnel from the sea lamprey control program captured a young of year lake sturgeon during the course of their treatment of the upper Rifle River watershed, so it is know that lake sturgeon are at least periodically spawning in a tributary leading into Saginaw Bay so perhaps that is the next system to be surveyed. What is not known is if the fish being produced from the Rifle River are a unique population of lake sturgeon or if they are from the same stock of St. Clair River fish that dominate much of Lake Huron. If it was determined that those fish from the Rifle River were a unique stock every effort should be made to enhance that population to preserve the genetics of that population. In scenario two, the genetic composition of the stocks of fish in Saginaw Bay are not unique but are related to the lake sturgeon spawning in the St. Clair River. Then if lake sturgeon are to be reintroduced into the Saginaw River watershed, brood stock should come from an abundant close stock such as the St. Clair River stock which numbers in the thousands of breeding fish, or from the Black River stock that numbers in the hundreds of breeding fish. Either population would be suitable but the Black

River stock would most closely match the type of environment that the lake sturgeon would be spawning in.

In 2006 the entire Rifle River Watershed was treated with lampricide and no lake sturgeon were found in the watershed. Given that the Rifle River is the closest river system to the Saginaw River that might be supporting at least sporadic spawning stock of lake sturgeon, it seems prudent that the Rifle River be investigated more closely. Although the MDNR Lake Sturgeon Rehabilitation Strategy, lists the Rifle River with a 'medium' suitability level, that suitability level is likely a function of the relatively small size of the river (Hay-Chmielewski and Whelan 1997).

Having a complete genetic inventory of all the remaining spawning populations in Lake Huron can not be over emphasized and will be essential in determining what management strategies will be needed to rehabilitate lake sturgeon populations. Researchers and fisheries managers in the Lake Michigan and Lake Superior drainage basins have almost completed an inventory of tributaries supporting spawning lake sturgeon populations. In those two lake basins managers are in the process of crafting lake sturgeon management plans for stocks that have been extirpated and that planning includes the possible augmentation of existing populations using stream side rearing facilities. Within the Lake Huron basin approximately one third of the tributaries in Ontario have been surveyed while in Michigan only one of the 16 known tributaries have been inventoried. Those rivers in Michigan that have not been surveyed have very limited habitat available for spawning due to impassable because of dams. We have much work yet to be accomplished within the Lake Huron basin. Because much of the Great Lakes are an open system and lake sturgeon are free to roam especially between systems like Lake Michigan and Huron, there is the long term potential that as populations increase in the Lake Michigan basin the likelihood of straying will increase.

The funding that has been secured for the open water stock assessment for Saginaw Bay will also be looking at other stocks in the St. Mary's River, southern Lake Huron and fish from the Huron-Erie Corridor. The analysis from that research should enable researches to determine the origin of not only those fish that are reside in Saginaw Bay but also throughout much of Lake Huron. A number of scenarios are possible, the fish might all be from one population such as the St. Clair River which would be consistent with our tagging results. Another possibility is that the fish are coming to Saginaw Bay to forage but are from different population that spawn at different locations. If we have identified all of those spawning populations throughout the Great Lakes then we should be able to see the origins of those fish from the analysis. However, if the genetics show that there is a unique stock of fish but we are unable to match them with a specific population then what has probably happened is that there is a population of lake sturgeon that has not been discovered yet. If a unique remnant population of lake sturgeon is spawning in the Rifle River that type of analysis should be able to determine that.

Acknowledgements

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Figures 1 – 10

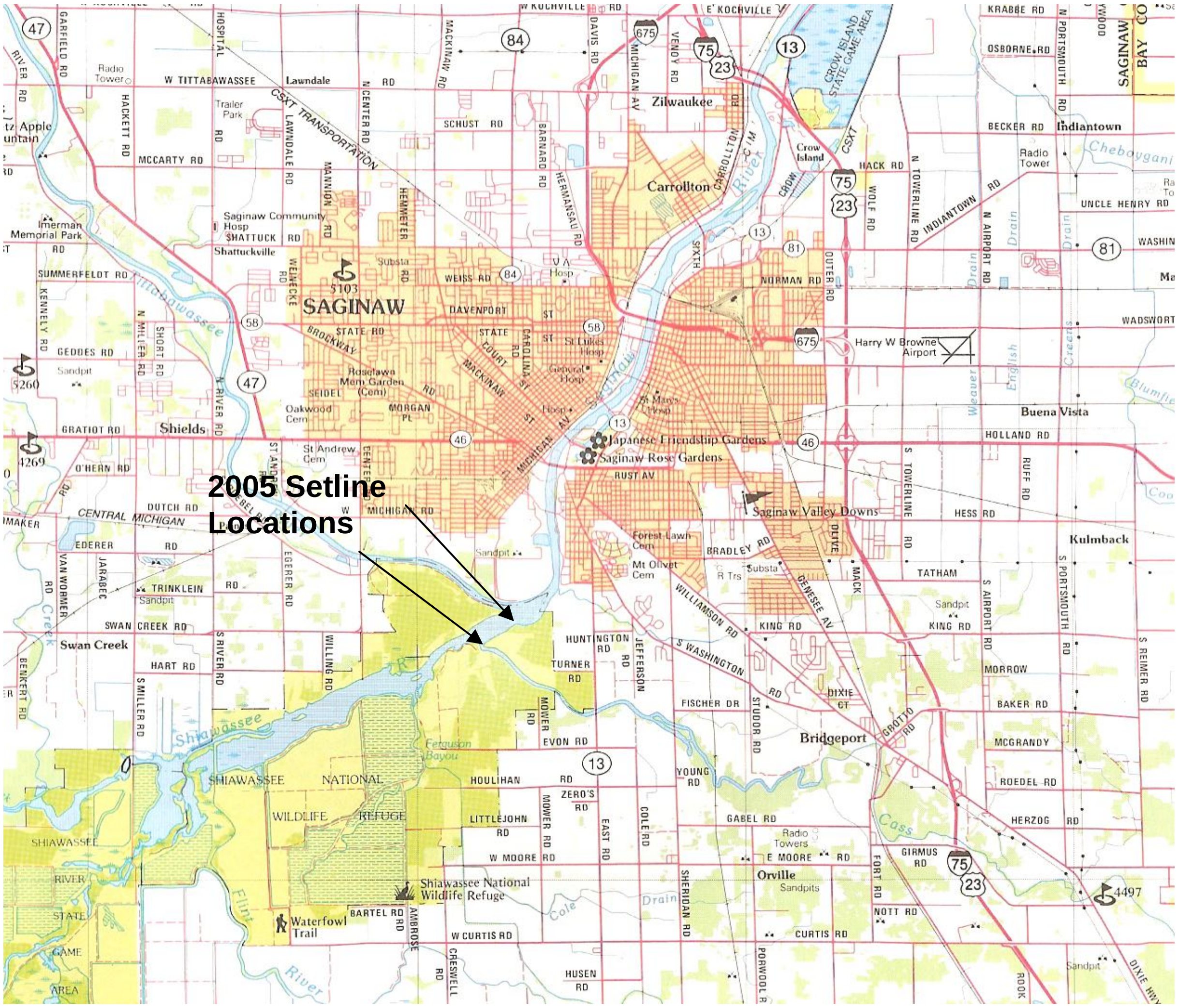

Figure 1. Lake sturgeon setline locations in the Saginaw and Shiawassee rivers during the spring 2005 sampling season (n=51).

Figure 2. Egg-mat locations on the Tittabawassee River below Dow Dam during the 2005 and 2006 sampling season (n=48).

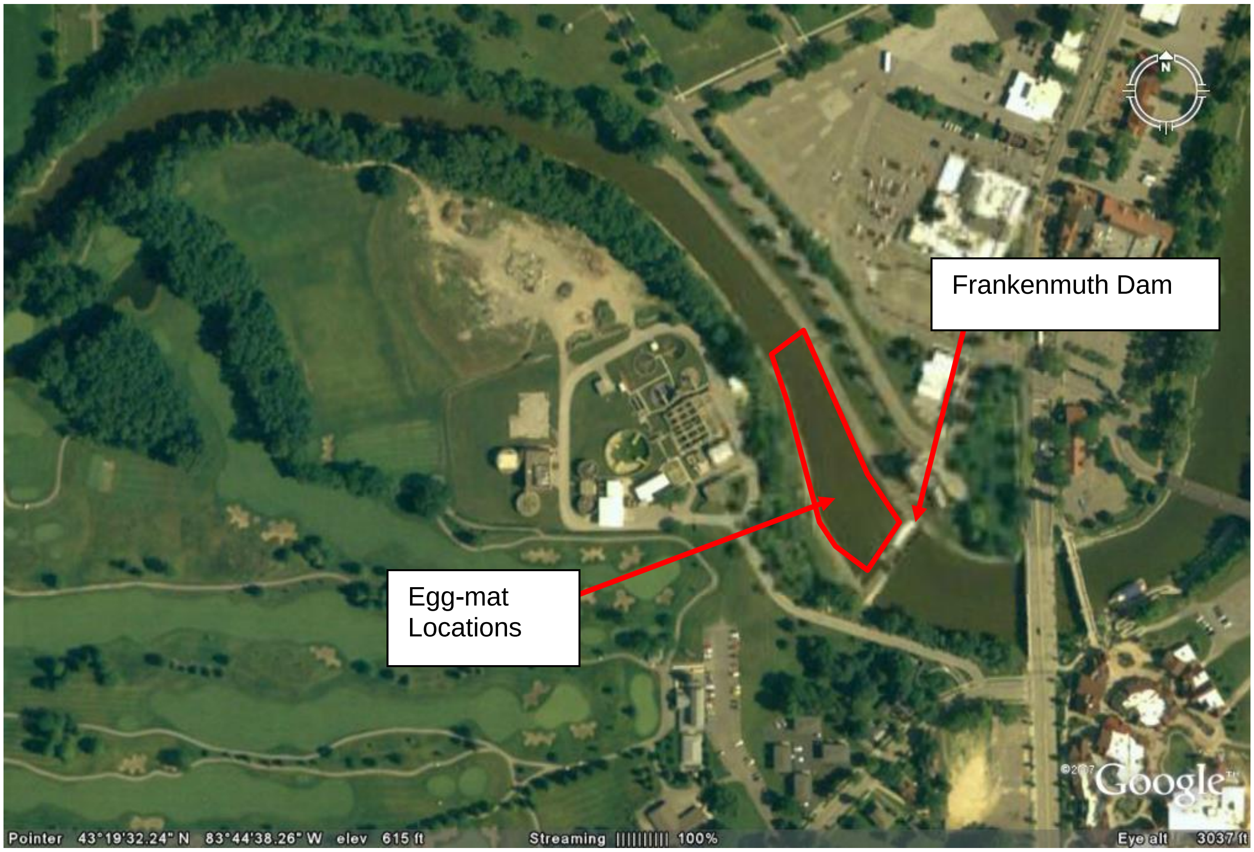

Figure 3. Egg-mat locations on the Cass River below the Frankenmuth Dam during the 2005 and 2006 sampling season (n=24).

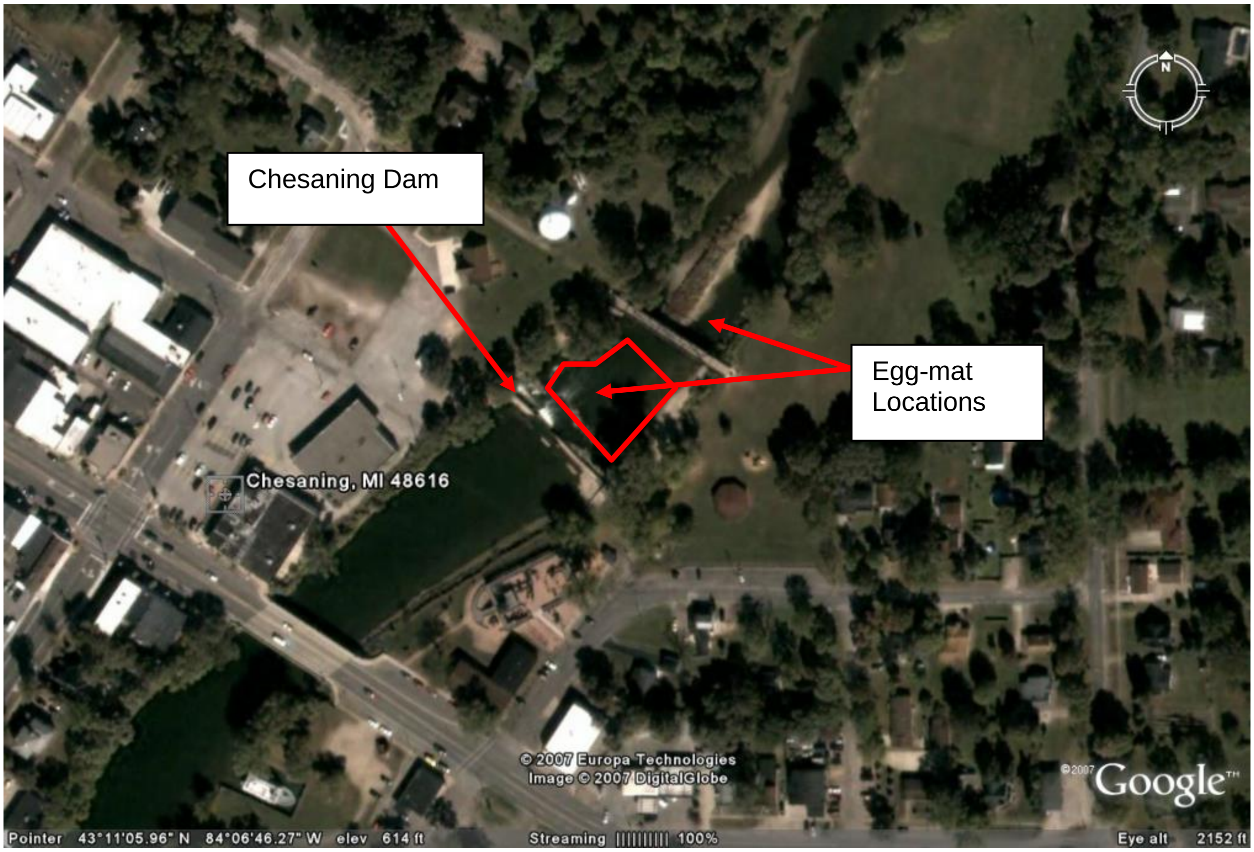

Figure 4. Egg-mat locations on the Shiawassee River below the Chesaning Dam during the 2006 sampling season (n=24).

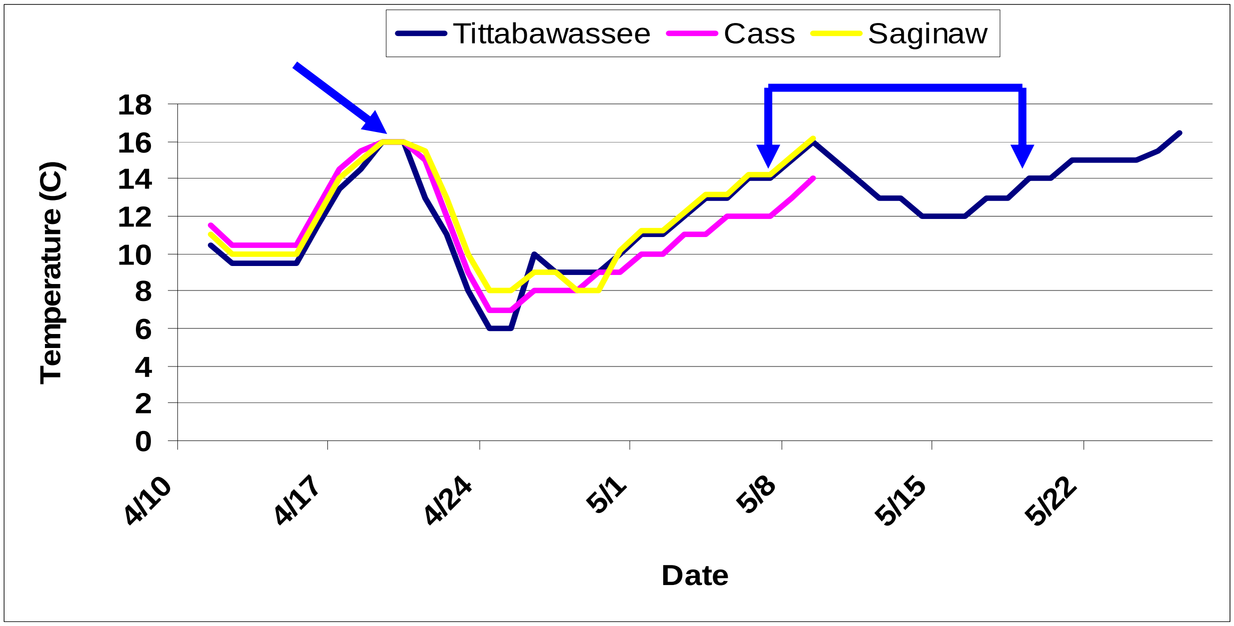

Figure 5. Water temperatures on the Tittabawassee, Cass, and Saginaw rivers during the spring 2005 sampling season, arrows depict the period that lake sturgeon were sighted below the Chesaning Dam (April 17 – April 22) and below the Dow Dam (May 8 – May 19).

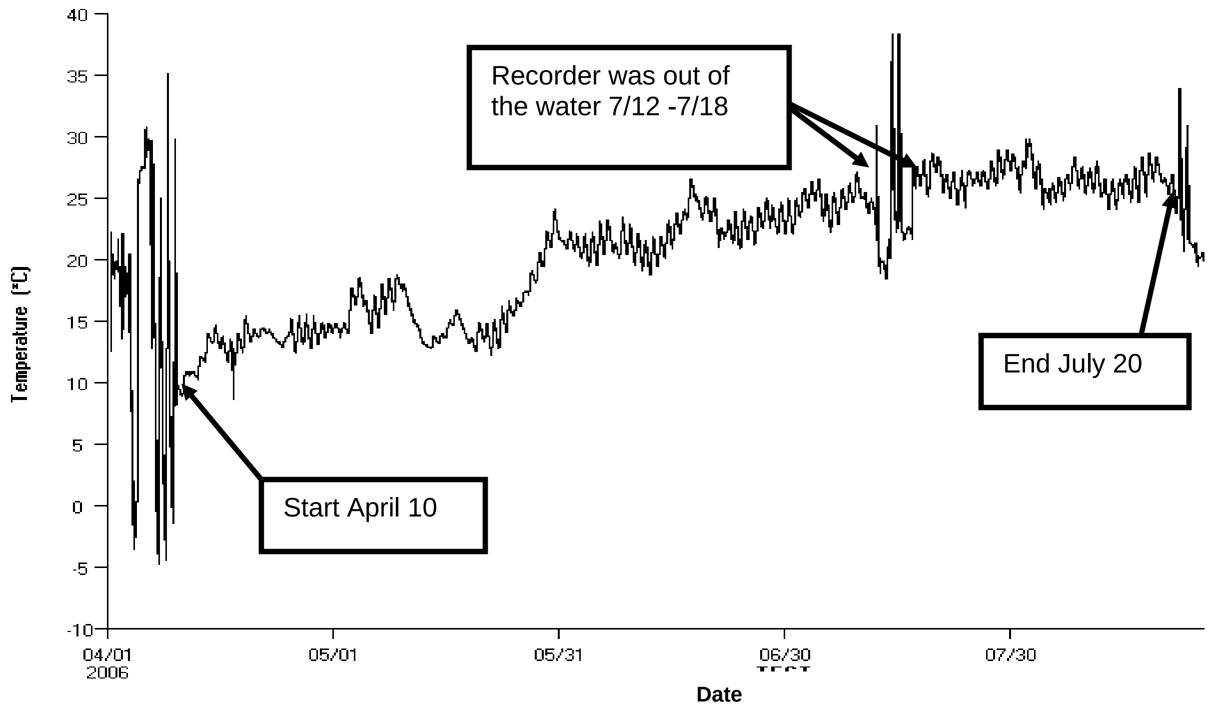

Figure 6. Water temperatures on the Tittabawassee River from April 10 - July 20, 2006.

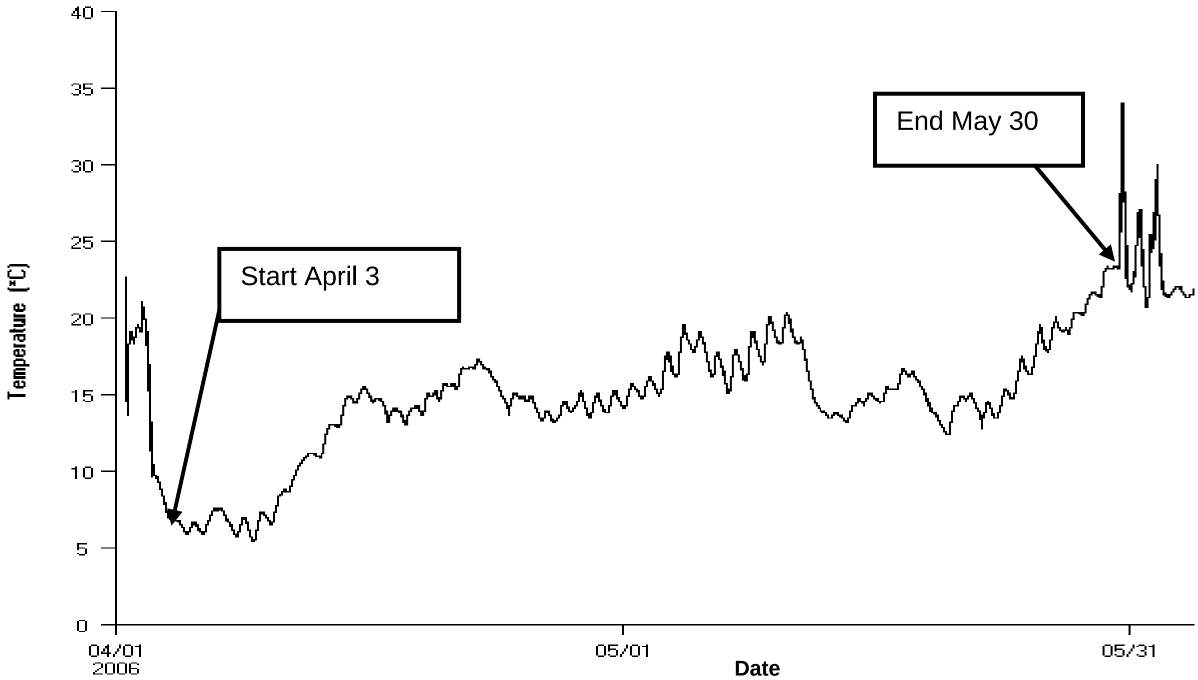

Figure 7. Water temperatures on the Cass River from April 3 - May 30, 2006.

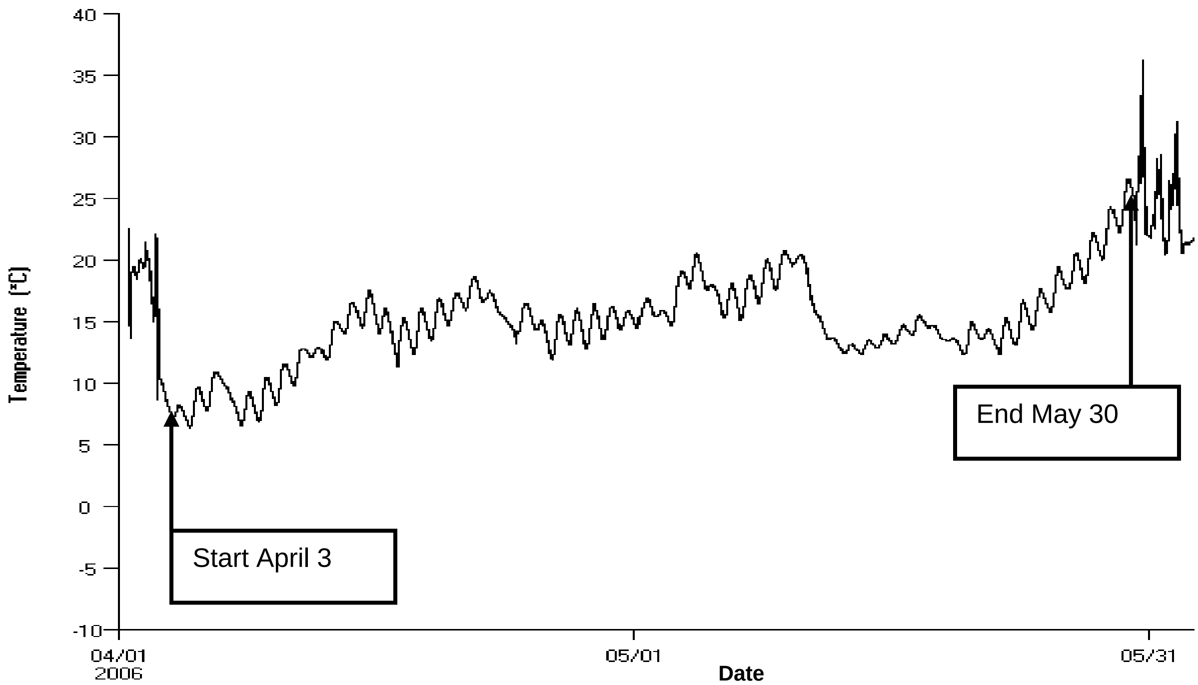

Figure 8. Water temperatures on the Shiawassee River from April 3 - May 30, 2006.

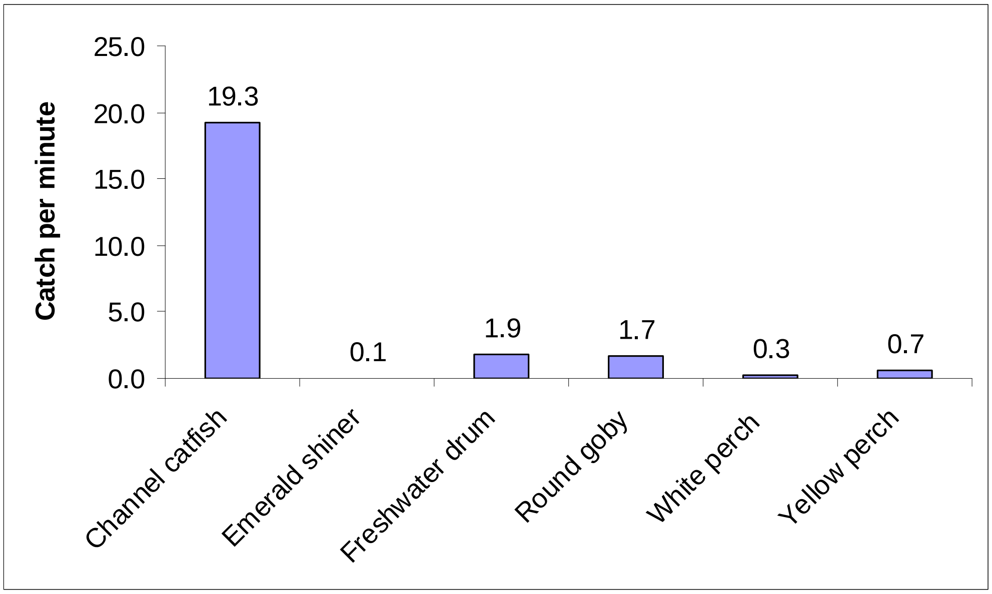

Figure 9. Relative abundance of fish species captured at the mouth of the Saginaw River October 4, 2006.

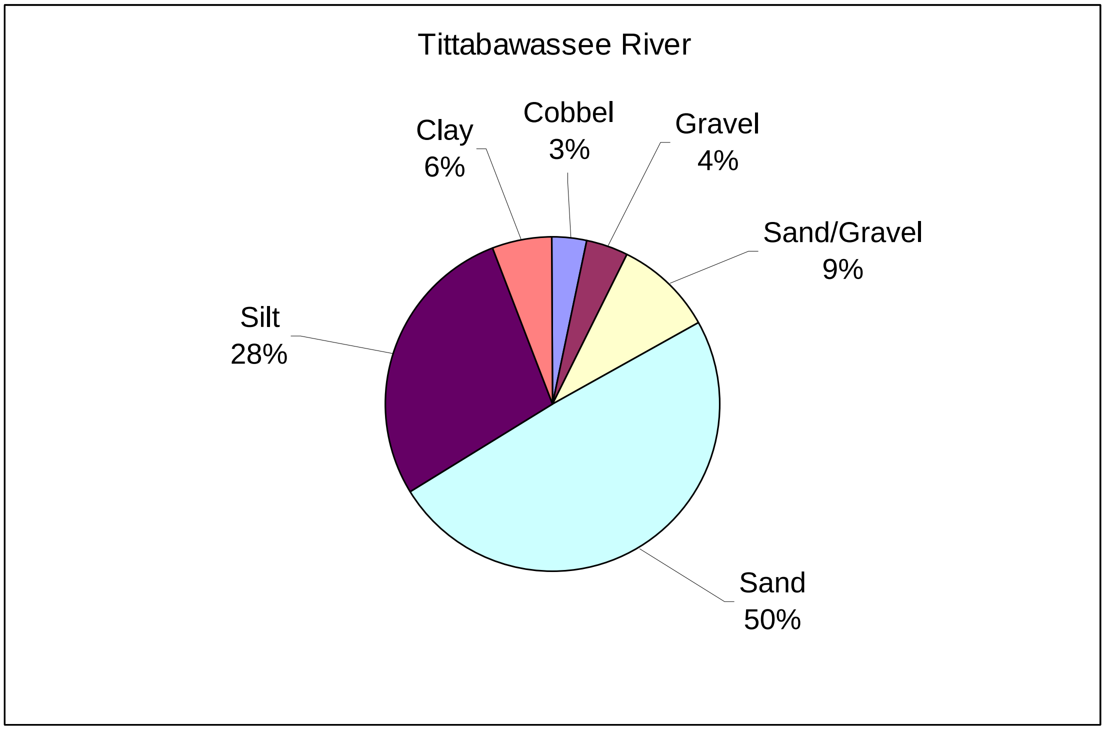

Figure 10. Composition of the 118 substrate samples collected on a 37 kilometer section of the Tittabawassee River from the Dow Dam to the headwaters of the Saginaw River.

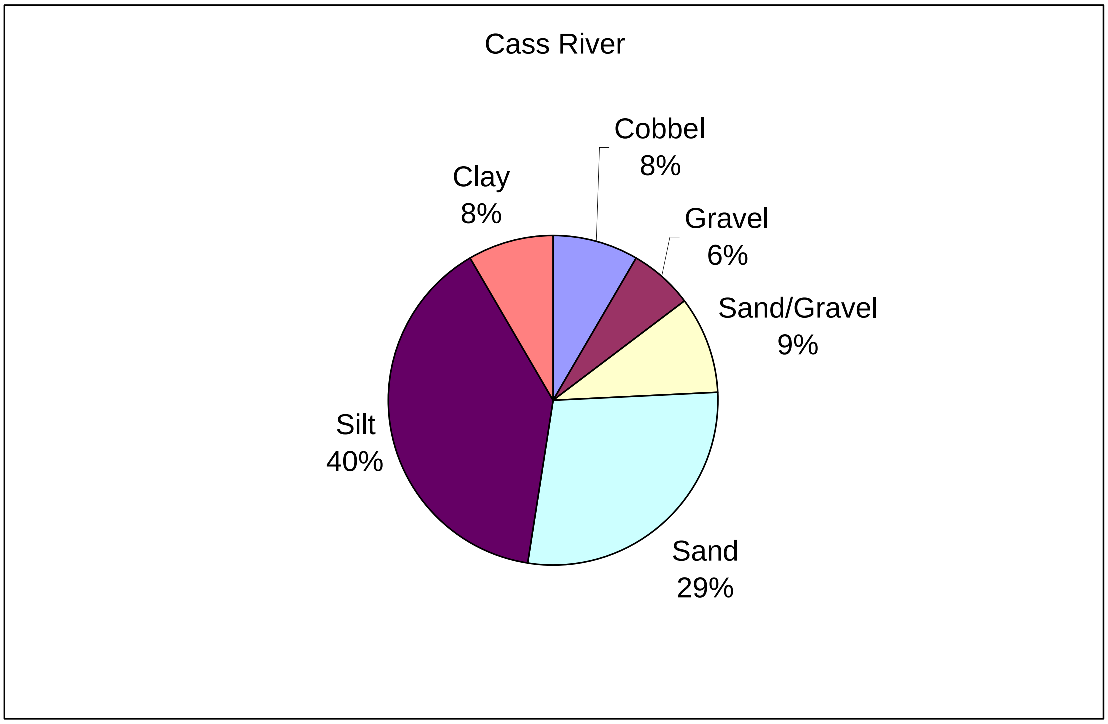

Figure 11. Composition of the 95 substrate samples collected on a 29 kilometer section of the Cass River from the Frankenmuth Dam to the headwaters of the Saginaw River.

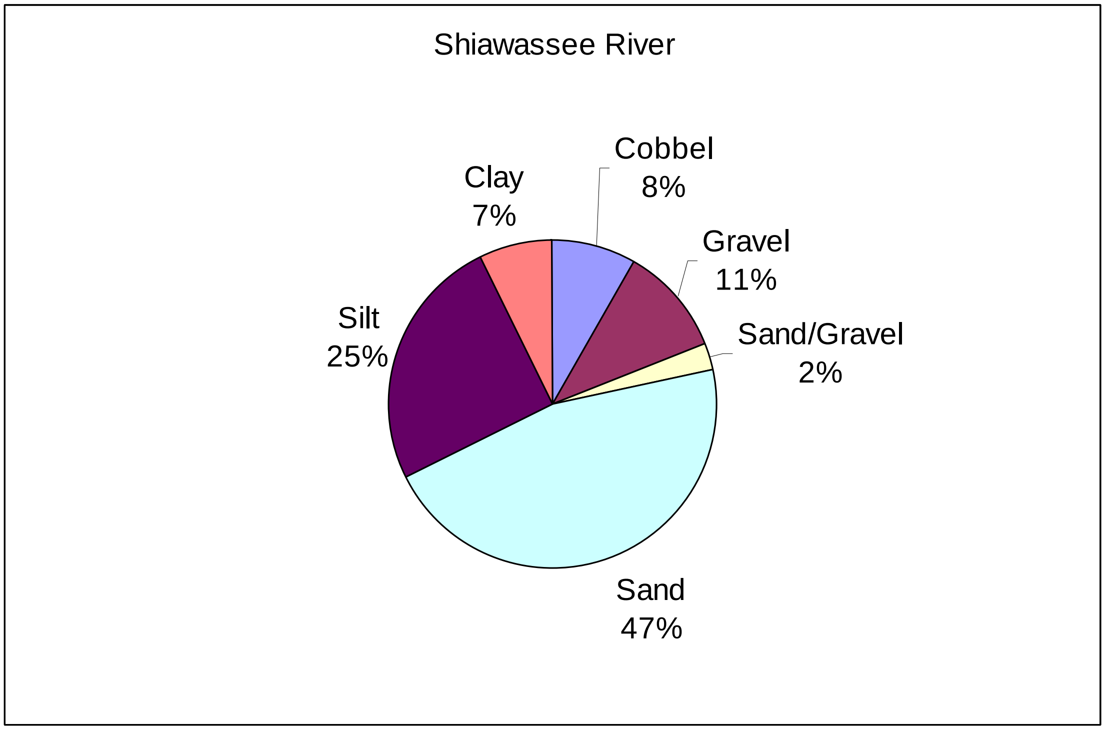

Figure 12. Composition of the 83 substrate samples collected on a 39 kilometer section of the Shiawassee River from the Chesaning Dam to the headwaters of the Saginaw River.

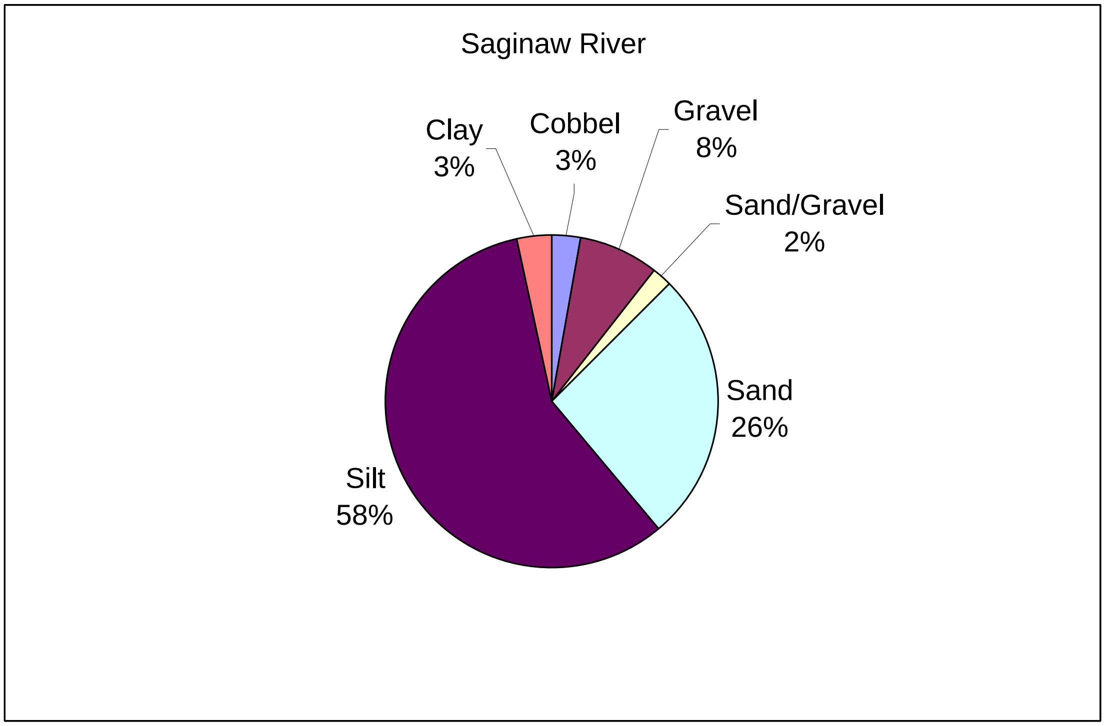

Figure 13. Composition of 182 substrate samples collected on a 36 kilometer section of the Saginaw River from the headwaters to the mouth at Saginaw Bay.

Tables 1 and 2

Table 1. Identification of eggs and fry collected from the Tittabawassee, Cass, and Shiawassee rivers during the 2006 spring sampling period.

Species	***Fry Larvae Titta. R.***	***Fry Larvae Cass R.***	***Fry Larvae Shiaw R.***	***No. Eggs Titta. R.***	***No. Eggs Cass R.***	***No. Eggs Shiaw. R.***
Common Carp (*Carpiodes cyprinus*)	9	13	5			
White Sucker (*Catostomus commersonii*)	44	93	45			
Shorthead Redhorse (*Moxostoma macrolepidotum*)		46	3			
Walleye (*Sander vitreus*)	4					
Common Carp (*Carpiodes cyprinus*) unfertilized				71	70	145
Common Carp (*Carpiodes cyprinus*) fertilized				3	22	10
UID Sucker (*Catostomus spp.)* unfertilized				4	8	5
UID Sucker (*Catostomus spp.)* fertilized					6	

Table 2. Total catch-per-minute-effort for bottom trawls on the Saginaw River on October 4, 2006.

Species	***Total catch***	***Total effort (min)***	***Catch per effort***	***Percent of total catch***
Channel catfish (*Ictalurus punctatus*)	385	20	19.3	80.9
Emerald shiner (*Notropis atherinoides*)	1	20	0.1	0.2
Freshwater drum (*Aplodinotus grunniens*)	37	20	1.9	7.8
Round goby (*Neogobius melanostomus*)	34	20	1.7	7.1
White perch (*Morone Americana*)	6	20	0.3	1.3
Yellow perch (*Perca flavescens*)	13	20	0.7	2.7
All Species Total	476			