STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-80-R-6

Study No.: 230732 **Title:** Factors Affecting Lake Sturgeon Recruitment: A model system for species recovery in Michigan waters of the Great Lakes

Period Covered: October 1, 2004 to September 30, 2005

Study Objectives: The objectives of this study are to (1) develop models that relate timing of spawning to environmental conditions, (2) build on demographic and genetic data collected in 2001 and 2002 to determine contributions from individual adults to annual recruitment, and to estimate adult spawning efficiency and effective population size, (3) estimate fertilization rate as a function of spawner number and sex ratio, (4) determine sources of egg predation and its magnitude prior to larval emergence, (5) determine factors that influence larval survival during downstream drift from spawning sites to rearing habitats, (6) develop a system for assessing juvenile survival and growth in river and lake systems that will be applied to potential restoration sites in Michigan, (7) test predications of timing, sources and magnitude of impediments to recruitment in other streams in Michigan using eggs and larvae of different sizes that are obtained from Black Lake, and (8) use data from Black Lake to parameterize models to predict the efficacy of alternative hatchery supplementation strategies in future restoration activities in Great Lakes tributaries.

Summary: Lake sturgeons were once abundant in the Great Lakes but current abundance is likely less than 1% of historic levels. Lake sturgeon rehabilitation is a high priority throughout the Great Lakes. However, little is known about fundamental aspects of the species' reproductive ecology and early life history. For example, information regarding inter-annual variation in natural recruitment and of natural environmental or biotic agents that are responsible for inter-annual variation is lacking. We lack quantitative estimates of egg or juvenile survival or of proportional contributions of adult spawners to recruitment. We know little of the importance of adult body size, age, and timing of spawning events to reproductive success. Understanding the importance of factors affecting lake sturgeon recruitment, survival, and philopatry will be critical to designs of restoration or reintroduction programs in Michigan drainages of the Great Lakes.

Most populations in the Great Lakes basin are too small or too broadly dispersed for research that concurrently seeks to estimate spawner contributions and progeny survival. Black Lake is ideal for this research and may serve as a model for lake sturgeon recruitment research in all Michigan waters of the Great Lakes. Using the Black Lake system as a "living laboratory," we seek to capitalize on extensive baseline information developed by collaborative Michigan State University, Central Michigan University, and MDNR research to further characterize early life history characteristics and population recruitment in this system. Findings from the Black Lake system will be used to experimentally examine factors that may impede recruitment in other Great Lakes drainages that are candidate locations for repatriation or supplementation.

One potential explanation for the low abundance of lake sturgeon is that recruitment is too low to rebuild existing populations. For example, low rates of recruitment could be attributed to high rates of predation on eggs and/or low larvae or juvenile survival. Therefore, we seek to determine the sources of egg predation and its magnitude prior to larval emergence and the factors that

influence larval survival during downstream drift from spawning sites to rearing habitats. Low rates of recruitment could also be attributed to low fertilization rates due to an Allee effect owing to low numbers of spawning adults. The species' mating system is characterized by aggregate spawning where males and females extrude gametes into the water column in absence of nest construction or site preparation. In historical times when spawning aggregations were large, this strategy may have been adaptive. However, since many Michigan streams support breeding populations that are characterized by low adult numbers, fertilization rates could be low. Estimates of fertilization rates and the impact of potential predators on lake sturgeon eggs and/or larva will be critical to restoration efforts.

Restoration of lake sturgeon may ultimately require translocations or hatchery supplementation, yet information about the efficacy of different supplementation programs is non-existent. The numbers of fish stocked, the number of adults contributing progeny, and the mating scheme currently used in stocking are all based on "best professional judgment" instead of quantitative data. We also know little of the effects of rearing environment and the degree of site fidelity or degree to which juvenile sturgeon imprint to streams. Therefore, we seek to empirically determine the effects of different gamete-takes, rearing conditions and stocking strategies commonly used by management agencies on juvenile lake sturgeon growth, survival, movements, and levels of genetic diversity. Results from parentage analysis will also provide much needed guidance for the hatchery production of lake sturgeon for stocking in waters targeted for rehabilitation. The availability of suitable habitats during larval drift and during early life are also critical but are not fully understood. Although spawning and adult habitat requirements are well known, very little is known about the habitat requirements of larval and juvenile lake sturgeon. Our results will facilitate efforts to locate, restore, and protect key juvenile habitats in several streams within the Cheboygan River watershed and potentially other tributaries of Lake Michigan.

Findings: Jobs 1 through 12 were scheduled for 2004-05, and progress is reported below.

Job 1. Title: <u>Determine rates of egg fertilization and sources/rates of egg predation.</u>–Egg catchment and egg predation devices were constructed and used in both egg fertilization and predation studies. These devices were used to estimate rates of egg fertilization for each spawning segment of adult population and to estimate rates of egg predation by invertebrates and fish.

Rates of Egg Fertilization: We collected approximately 200 eggs from the water column using collection devices that were deployed at one location for five consecutive days during the peak spawning period. Eggs were collected on circular porous filters that were attached to metal poles and positioned in several locations and at multiple depths downstream from the spawning group. Filters were removed from the stream after 12 hours, taken back to the stream-side hatchery, and then placed in heath trays until fertilization success could be determined. Fertilization rates appear to be high based on samples taken during the 2005 field season. However, high incidence of fungus on eggs and the amount of silt collected by the porous filters confounded any interpretation. In the coming year, we will use formalin baths and filtered water to minimize egg death due to confounding environmental and biotic factors. We will also design and construct portable collection devices that will facilitate collections of larger sample sizes. We will also be able to conduct a more extensive sampling of eggs from all sections of the river. During this field season we sampled solely at fixed locations based on our previous experience of site use. Modifications to the current experimental design will allow us to provide more conclusive results on the probability of egg fertilization as a function of spawner abundance and sex ratio.

Rates of Egg Predation: Prior to spawning, experimental devices were fabricated to experimentally estimate rates of egg predation before larval hatching and to make inferences about which stream predators (i.e., fish vs. invertebrates) were consuming eggs. We used wire

mesh of different sizes that were differentially accessible to predators of different size (Figure 1). Several adult lake sturgeon were captured from one of the three known spawning sites located on the Upper Black River. Unfertilized eggs and milt were artificially spawned from each captured individual and stored in separate containers until enough gametes had been collected to fill all devices. Eggs were split into lots (N~50) based on a standardized volume. Approximately 200 fertilized eggs were placed on circular porous filters (50 eggs on four sections). Filters were randomly assigned to one of the exclusion treatments (Figure 1). Eight experimental devices were deployed and anchored to the bottom of the stream at one of two previously identified locations near the spawning sites. Devices were monitored over a 5-day period. The numbers of eggs remaining on each section of the filter were counted daily by lifting up the entire block of treatments from the bottom of the stream and removing each exclosure. All devices were cleaned of stream debris after each assessment period. Results from the 2005 field season indicated that egg loss is moderate over time, and that lake sturgeon eggs are extremely prone to fungus infection even under stream conditions. Data analyses will attempt to demonstrate differences in egg loss between treatment groups (i.e., if certain size classes of predators are consuming eggs at different rates). Egg predation devices will be deployed again next field season at several different locations on the Upper Black River and after each spawning run. Finally, approximate hatching times will be back-calculated from the larval drift data collected during Job 4 and will be correlated to environmental variables for each year.

Job 2. Title: Identify release streams, stream characteristics and species composition.–We worked with Basin Teams, local biologists and citizen members of Sturgeon For Tomorrow over the last several years to identify release streams and release and rearing site characteristics for larval lake sturgeon. After consultation with these groups, it was determined that any release stream or putative release site should be kept within the Cheboygan River Watershed, and even more specifically, within the Black Lake drainage including the Upper Black River. Species composition data for this release site within this watershed are currently being complied from larval drift and stream shocking data collected during Jobs 4, 5, and 6.

Job 3. Title: Record stream environmental data.–A total of 154 lake sturgeon (46 females and 108 males) were captured and tagged during the Black River spawning run in 2005. This is the largest number of fish captured since beginning the spawning surveys in 2001 (Figure 2). Sex ratios varied over the last five years (Figure 3). Of 46 females captured this year, 33 were untagged and 13 had been tagged during previous years. Of the 108 males captured this year, 45 were untagged and 63 had been previously tagged. Nearly half of all fish (49.4%) in the 2005 spawning run were recaptured previously. A large proportion of all adults (31%) have also been recaptured several times at the spawning grounds over a five year period (Figure 4). To date, we have tagged 423 individuals (257 males, 166 females) during the spawning runs from 2001-2005. Biological information including weight, total length (Figures 5 and 6), fork length, girth, and sex/stage were collected for all individuals.

We also recorded the PIT tag number from individuals that had been captured and marked during previous field seasons. A PIT tag was injected underneath the fourth dorsal scute of fish that were captured at the spawning site for the first time.

Fin clips were taken from the tip of dorsal fin for genetic analysis regardless of capture status (see Job 10). The first adult sturgeon was captured on 05/03/05 and the last was captured on 05/25/05. At least four different spawning runs were observed in 2005.

Estimates of spawning site retention time for several males and females will be derived based on tagging data. We will attempt to estimate that stream retention time of both males and females using a fish weir constructed at the mouth of the Upper Black River during future field seasons.

We recorded stream environmental data during the entire field season. Five temperature loggers were deployed at several locations along the Upper Black River (Kleber Dam, Spawning Site B, Spawning Site C, the traditional larval drift site (D3) and at the mouth of the river) several weeks before the adult lake sturgeon migrated upstream to spawn. Temperature loggers were programmed to record the water temperature every hour during the entire field season. Stream depth and discharge was also evaluated each night using a stadia rod to determine stream depth and a flow-meter (March and McBirney Model 2000) to calculate the stream velocity. Our discharge measurements will be coordinated with measurements of discharge taken by operators working at Kleber Dam during each year of this study.

Job 4. Title: Estimate larval abundance for lake sturgeon and other species.–D-frame drift nets (76 cm across the base, 54cm high with a knotless 1600 µM mesh nylon bag 317.5 cm long with a detachable collection cup on cod-end) were used during the 2004 field season to sample out-migrating larval sturgeon. Drift nets were deployed at the same location on the Upper Black River (D3) throughout the entire larval sampling season. Within this location, five drift nets were deployed approximately two meters apart in a straight line along a transect across the stream channel. Sampling was conducted during a 5-hour time period, beginning at dusk and ending in the early morning. Majority of the larval fish were captured during several "peak" hours (between 11:00 pm and 1:00 am) within a particular sampling evening. Even though larval sturgeon were observed every evening over the entire sampling period, the majority of all larval fish were captured this spring during several consecutive evenings of "peak" drift activity that occurred in mid-June. From this one sampling site, 7,434 lake sturgeon larvae were collected (Figure 7). Annual larval drift varied greatly among years (Figure 8). Half of all larvae capturing this past spring were transported to Wolf Lake State Fish Hatchery and the other half were transported to the Upper Black River Sturgeon Research Facility for temporary housing. The total number of larval lake sturgeon over the past six years will be estimated using the following formula (Veshchev et al. 1994).

$$P = \frac{(Q * N)}{O}$$

where Q is the flow volume passing the site (m^3/hour), N is the number of larvae collected in each net after 1 hour and O is the volume of water sampled. The volume of water sampled is calculated from the current velocity observed in the net and the total sectional area. The composition and abundance of other fish and invertebrate species in drift was also noted during this past field season. We will attempt to obtain estimates of the relative abundance or other larval species in drift during future field seasons as well.

Job 5. Title: Estimate sources and rates of larval lake sturgeon mortality.–Repeated drift net sampling was used to estimate rates of larval lake sturgeon mortality during the 2005 field season. Larval drift samplers were deployed at two locations on the Upper Black River throughout entire larval drift period. These locations include just below the furthest downstream spawning site and the traditional larval drift sampling site also known as D3 (downstream from the spawning grounds). Figure 9 shows the relative locations of each sampling sites. Within each sampled location, five larval drift nets were deployed approximately two meters apart in a straight line down the center/deepest part of the stream channel where drifting primarily takes place. Information was recorded on the current ambient conditions (water and air temperature) and the weather conditions observed over the past 24 hours before sampling begins. Stream discharge and depth was also evaluated at meter intervals across the stream at each site. Sampling was conducted at night over a 5-hour time period, beginning at dusk and ending in the early morning (2100 and 0100 hours). We began sampling for newly hatched and outmigrating larval lake sturgeon directly below the spawning grounds approximately 5 to 12 days after spawning activity

was observed. All sturgeon larvae collected at this site were counted and removed from examination trays and immediately placed into a separate container. After each sampling hour, at least 10 individuals captured in each net were measured to the nearest millimeter and then all individuals collected will be released. The number of other species collected each hour in every net was also determined. Larval drift sampling began at the downstream location as soon as the first out-migrating larval fish was captured at the spawning site. Individuals captured at downstream locations were retained for the Black Lake head start program and so that genetic samples can be collected from these individuals in the form of fin clips. Figure 10 shows a comparison of the absolute number of larvae captured at each site during every evening of larval sampling. Numerical estimates will be compared for statistical differences in order to determine the rates of larval lake sturgeon mortality between these two sampling locations on the Upper Black River.

Job 6. Title: Estimate sources and rates of mortality for other larval fishes.–Estimating the magnitude of predation on larval lake sturgeon and other larval species by fish predators down stream from the spawning sites was accomplished by passively sampling the stream community and electroshocking. Passive sampling was employed previously, resulting in small sample sizes. We were unable to either determine whether predation was occurring or quantify the rate of predation. During this past field season, predation on newly hatched and drifting larval lake sturgeon was assessed by electro-shocking Shocking was conducted using tow barge equipment at several times during the peak of drifting activity in two pre-identified reaches of the river between the two larval sampling locations. This method of stream sampling resulted in a much greater sample size (N > 200) than the passive sampling technique. Once target species were captured, we examined their stomach contents in order to quantify the extent of predation on larval sturgeon and other species. Since sampling was conducted during the peak of evening larval drift, we assumed that larval sturgeon would be distinguishable from other prey that may have been consumed. For majority of potential predators, stomach contents were examined non-lethally by using gastric lavage, a commonly used technique by fisheries biologists to empty the fish stomach of its contents. Predators were measured for total length (+ mm) and weight (+ 0.1 g) and released. Stomach contents were preserved in 95% ethanol. Larvae observed in the stomachs of predators will be identified, measured, and their dry weights obtained later this year in the lab. A subsample of potential predators that could not be examined using gastric lavage was preserved in 95% ethanol and their stomach contents will also be analyzed in the lab at a later date.

Job 7. Title: Rear larval lake sturgeon for release.–Larvae collected during natural drift or larvae reared from other types of collection strategies (e.g., artificial crosses, stream sampling) were transported one of two locations: 1) a stream side rearing facility located at the mouth of the Upper Black River and 2) at a more traditional hatchery setting at the Wolf Lake State Fish Hatchery. Flow-through tanks set-up at the stream side rearing facility were filled with filtered water taken directly from the Upper Black River (Figure 11). Flow-through tanks at Wolf Lake were filled with treated well water. Larvae were reared for 8 and 12 weeks at both hatchery locations before release into the pre-identified experimental restoration site on the Upper Black River (Figures 12 and 13). In order to follow growth rates at each hatchery, random samples were taken from each tank every four days and each individual was measured for total length, fork length, and weight. Two different weeks of release post hatch (8 and 12) were also used to ensure marked differences in the size of individuals at release. Every individual released from both hatcheries were uniquely tagged with an elastomer dye.

Job 8. Title: Estimate rates of larval mortality in stocked sites.–Approximately 7,500 individuals from both rearing locations were released over the course of two months (at 8 and 12 weeks of age). Repeated drift net sampling was used to estimate mortality rates of lake sturgeon stocked into the experimental release site. Sources of mortality due to in-stream predators were also assessed using electro-shocking and netting methods described above. Just over 900 individuals

were recaptured during our assessment efforts. Data are currently being analyzed to determine rates of mortality.

Job 9. Title: Determine movements of lake sturgeon using telemetry (03/04 locales).–This job is will be initiated in late October or early November of this year. Acoustic telemetry equipment (receiver, 40 transmitters, hydrophones and 3 submersible buoys) has already been purchased from Vemco, Inc. At least 40 juveniles are currently being housed and maintained at Wolf Lake State Fish Hatchery. Transmitters will be surgically implanted into these individuals early this fall using available methods with the assistance from the Michigan State University Fish Containment Facility. Telemetry fish will be released at the experimental restoration site identified previously and then tracked periodically over the next several years using both manual (receiver) and automated methods (submersible buoys) in order to determine over-winter mortality rates and long-term survival. Movements (daily, weekly, seasonal) and habitat usage based on geo-referencing tools will be recorded on each individual when a "recapture" occurs. We anticipate that juvenile sampling will provide us with a clear picture of movement and its correlations with environmental gradients, habitat, season, and juvenile abundance.

Job 10. Title: Conduct genetic analyses.–Fin clips were taken from every adult collected during this past spawning season (Job 3). All fin clips were dried and stored individually at ambient temperatures. Tissue samples were also taken from out-migrating lake sturgeon larvae that were collected using drift nets deployed downstream from the spawning sites (Job 4). DNA has been extracted, quantified, and diluted from the tissue collected from each adult using a QIAGEN DNeasy Kit (Qiagen Inc., Valencia, CA). Several microsatellite loci have been amplified using PCR protocols developed for use with fluorescent-labeled primers. PCR products for each locus have be run onto 6% denaturing polyacrylamide gels and scanned using either an FM BIO II (Hitachi, Inc.) or LICOR IR2 scanner, both located in the Scribner lab. Genotypes have been assigned based on molecular size standards and by running individuals of known genotype on each gel as standards. DNA will be extracted from all larvae during this upcoming year, parents will be assigned to each individual, and the proportional contribution of different adults to the total larval recruitment will be determined. Sampling and genotyping efforts will also continue into this next year.

Job 11. Title: Supervise staff.–I currently supervise two graduate students, one full time employee, and four seasonal undergraduate workers that are directly associated with this project.

Job 12. Title: Write annual performance report.–Results of our research have been communicated to MDNR biologists, natural resource managers and concerned members of non-for-profit organizations such as Sturgeon for Tomorrow throughout the entire year. I and members of my laboratory have represented the State of Michigan at the 2004 Great Lakes Lake Sturgeon Coordination Meeting (Dec. 2004), the 2005 DNR Research Coordination Meeting (Sept. 2005), and at several other meetings concerning lake sturgeon. Our group has made presentations at a several professional meetings including the American Fishery Society meeting in Madison, WI. We have also presented the results and future directions of our research to Sturgeon for Tomorrow members at several annual banquets and board meetings. Finally, we have also made presentations to the Lake Huron and Lake Michigan Basin Teams, Wolf Lake State Fish Hatchery personnel and MDNR Gaylord Fisheries Division in order to coordinate future research efforts. The objectives and results of our research have been communicated to the general public through local and state-wide press releases. Publications will be submitted to peer-reviewed journals in the upcoming years.

Prepared by: Kim T. Scribner, Patrick Forsythe, and Ed Baker
Date: September 30, 2005

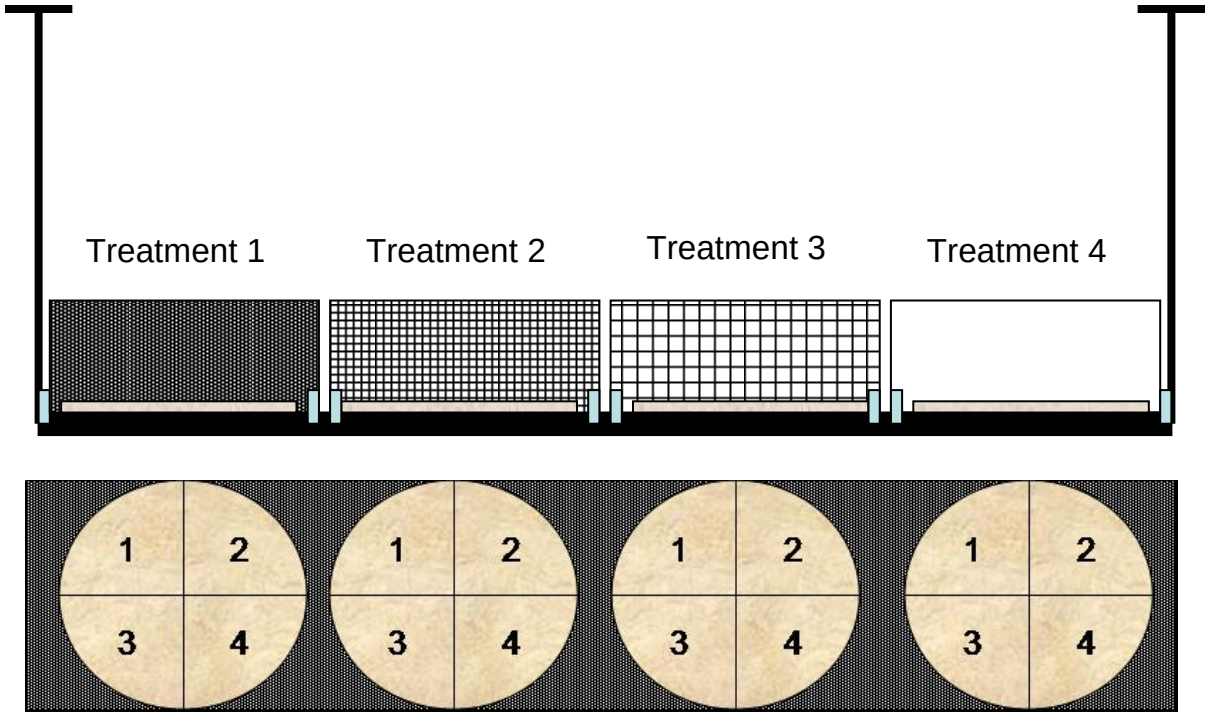

Figure 1.–Diagram of experimental devices used to examine the sources and magnitude of egg predation. The four treatment groups were defined by wire mesh of different sizes. Circular porous filters provided the egg attachment surface. All four corners of the frame are secured to the bottom of the stream by using metal fence posts.

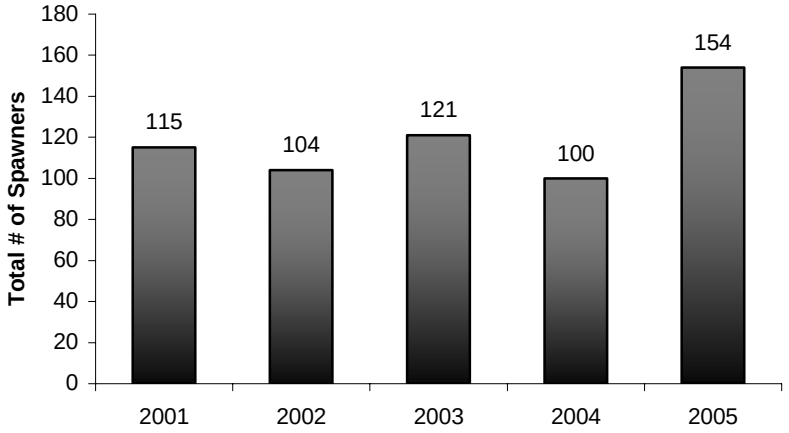

Figure 2.–Total number of adults captured during our survey of spawning adults in the Upper Black river since 2001.

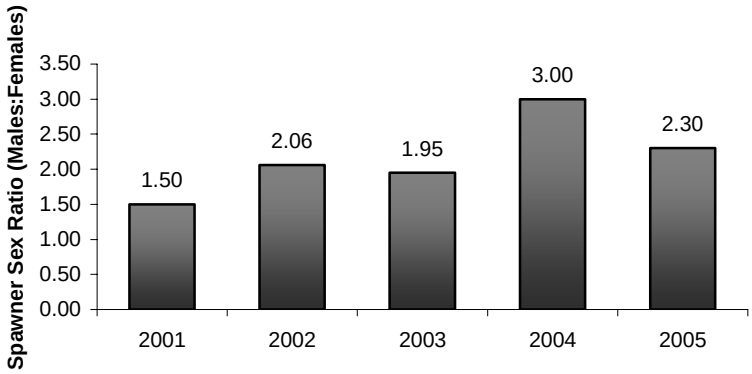

Figure 3.–Total sex ratio of spawning groups for each year.

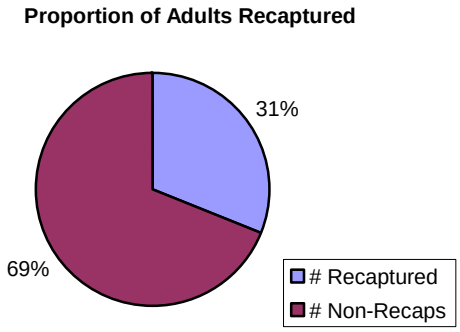

Figure 4.–Proportion of all adults that have observed spawning (recaptured) multiple times over the past five years of sampling.

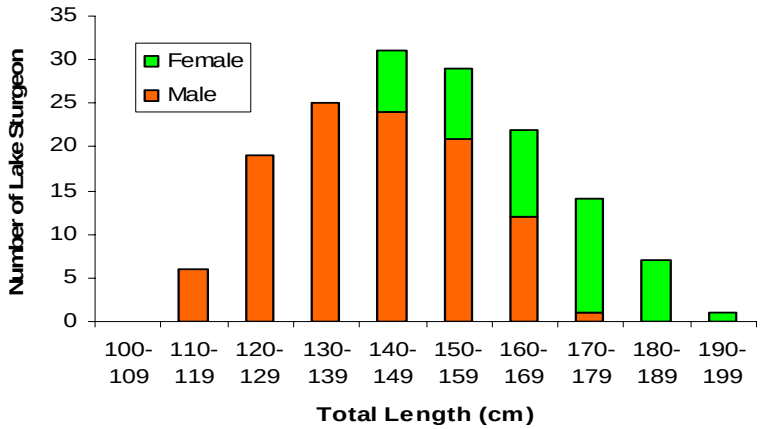

Figure 5.–Length-frequency histogram for adults captured at the spawning sites in 2005.

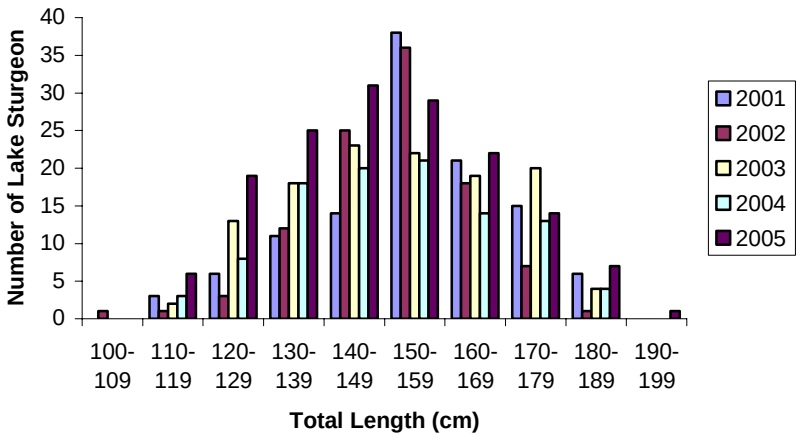

Figure 6.–Length-frequency histogram of adult lake sturgeon captured at the spawning sites to date.

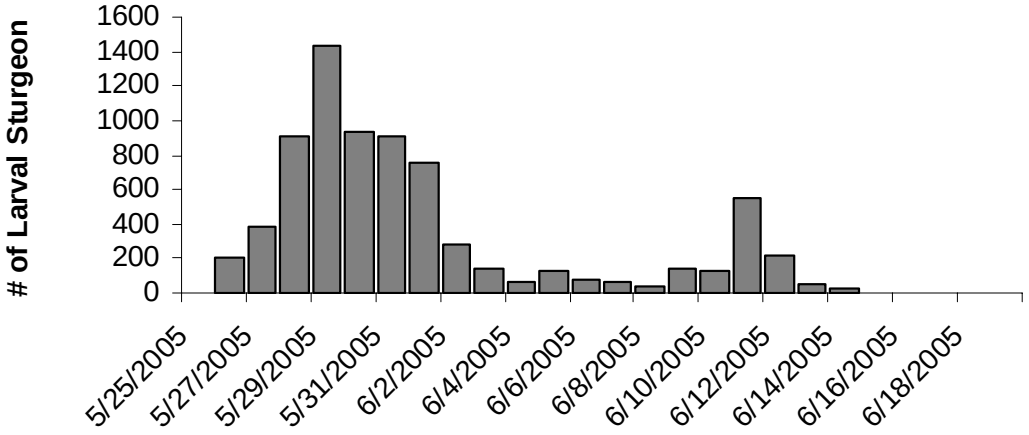

Figure 7.–Number of larval sturgeon captured at the traditional larval drift sampling site during the 2005 field season.

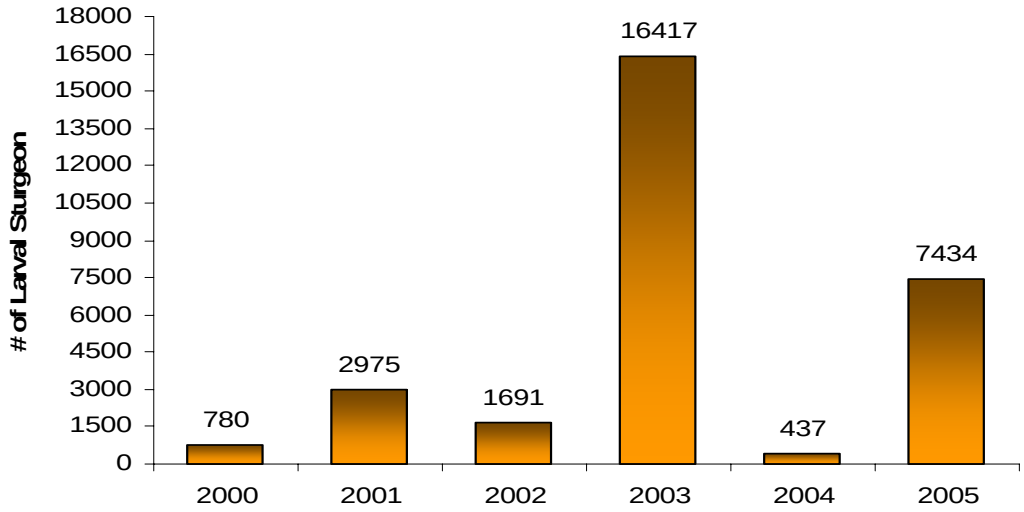

Figure 8.–Number of larval sturgeon captured at the traditional larval drift site (D3) for each of the six years of sampling.

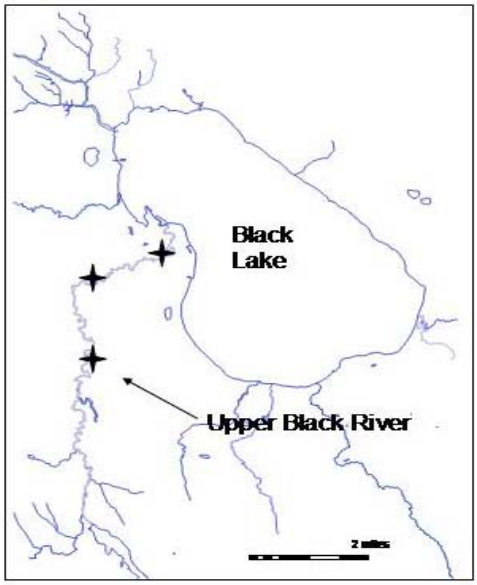

Figure 9.–Map of the Upper Black River showing the three proposed larval drift sampling locations.

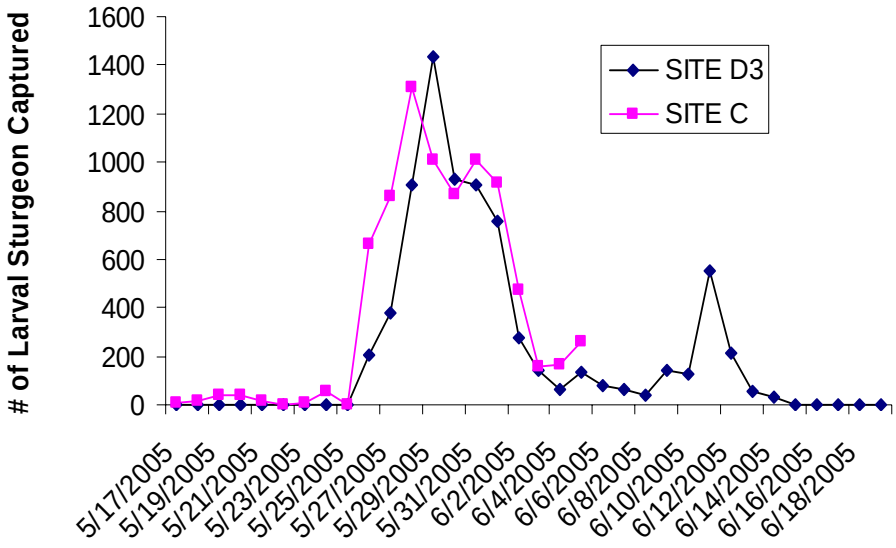

Figure 10.–Comparison of larval sturgeon captured at both larval drift sites.

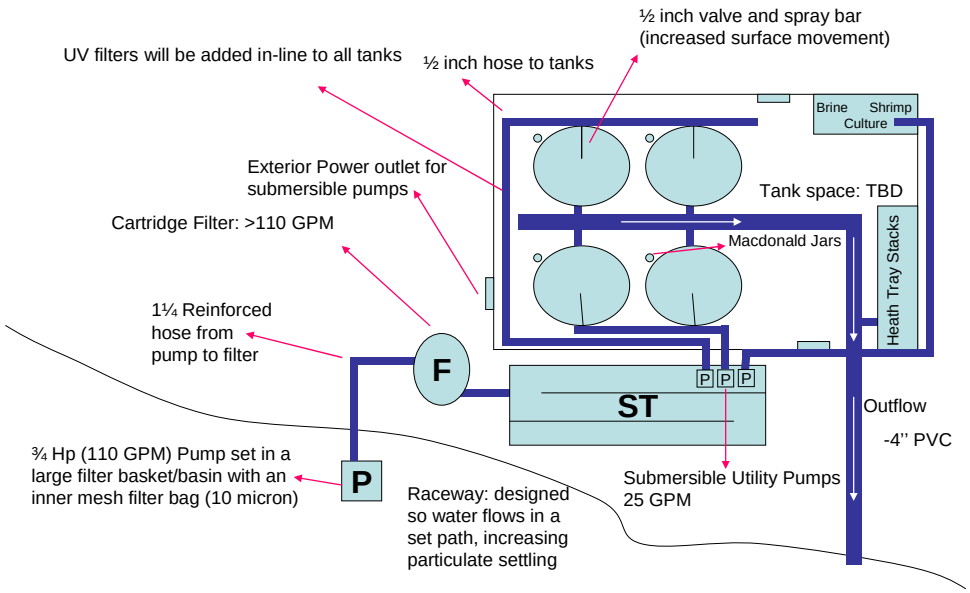

Figure 11.–General overview of the stream side rearing facility constructed on the Upper Black River.

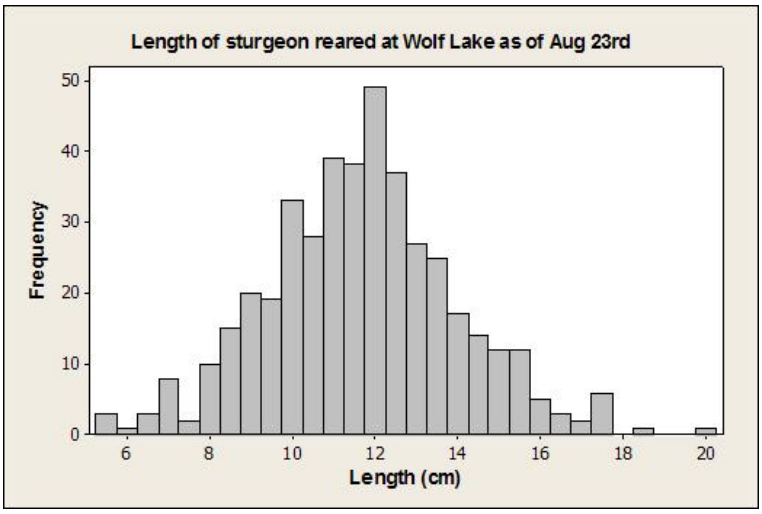

Figure 12.–Length-frequency histogram of juvenile lake sturgeon reared at Wolf Lake State Fish hatchery before the second scheduled release.

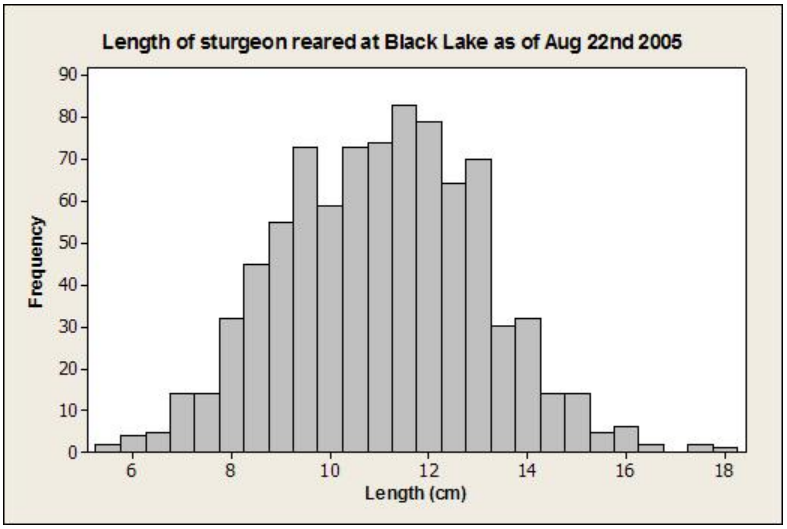

Figure 13.–Length-frequency histogram of juvenile lake sturgeon reared at the Upper Black River Sturgeon Rearing Facility before the second scheduled release.