A Synopsis of Lake Sturgeon (*Acipenser fulvescens*) Culture, Marking, and Stocking Techniques
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Cover photo – Incubating lake sturgeon eggs (Photo courtesy of Joe Hunter)

Cette publication hautement spécialisée n’est disponible qu’en anglais vertu du Règlement 411/97 qui en exempté l’application de la Lois sur les services en français. Pour obtenir de l’aide en français, veuillez communiquer avec Twyla Douaire (705-755-1963) le ministère des ressources naturelles
Executive Summary

This document consolidates information on lake sturgeon (Acipenser fulvescens) culture, marking, and stocking techniques and existing conservation stocking programs. The intent of this synopsis is to provide information to facilitate science-based management decisions for the development of Ontario’s Lake Sturgeon Recovery Strategy.

Currently in Ontario, the remaining lake sturgeon populations are remnant from the intensive unregulated commercial harvest in the late 1800s and large scale habitat alterations over the past century. Lake sturgeon populations have been identified as special concern, threatened, or endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and classified by the Committee on the Status of Species at Risk in Ontario (COSSARO) as either ‘special concern’ or ‘threatened.’

In July 2008, the Ontario Ministry of Natural Resources committed to develop a provincial lake sturgeon management strategy. During this process, the option of using culture and stocking as a management strategy to rehabilitate or reintroduce lake sturgeon populations in Ontario will be assessed by a technical and public committee to determine if culture and stocking is a feasible provincial conservation strategy for lake sturgeon.

A jurisdictional review of all predominant lake sturgeon propagation programs for the purpose of population conservation are outlined in this report. Reviewed culture techniques include brood stock collection, gamete shipping and incubation, rearing facility designs and factors affecting culture. Lake sturgeon culture for population conservation has been occurring for over 20 years in Wisconsin and Michigan, where hatchery techniques are well developed. Limited information exists for lake sturgeon stocking techniques due to their life history characteristics. This document reviews the existing information on lake sturgeon stocking age/size and frequency, density and location, marking and monitoring and factors influencing stocking success.

Overall, the application of lake sturgeon culture and stocking as a conservation strategy may be an essential tool required to rehabilitate Ontario lake sturgeon populations. This strategy should only be applied where a strong biological rationale exists and where all other management strategies have been deemed unsuitable for achieving management objectives. However, it is reasonable to believe that lake sturgeon culture techniques are sufficiently developed to enable the species to be grown in a suitable hatchery environment.
Le présent document regroupe les renseignements disponibles concernant les techniques d’élevage, de marquage et d’empoissonnement de l’esturgeon jaune (*Acipenser fulvescens*), et concernant les programmes actuels d’empoissonnement axés sur la conservation. Ce sommaire vise à fournir de l’information pour faciliter les décisions de gestion à fondement scientifique en vue d’élaborer un programme de rétablissement de l’esturgeon jaune en Ontario.

À l’heure actuelle, la population restante d’esturgeons jaunes dans la province est un vestige de la pêche commerciale intensive et non réglementée qui avait cours vers la fin du XIXᵉ siècle et des modifications à grande échelle qui ont été apportées à l’habitat au siècle dernier. Le Comité sur la situation des espèces en péril au Canada (COSEPAC) a classé l’esturgeon jaune parmi les espèces préoccupantes, menacées et/ou en voie de disparition, et le Comité de détermination du statut des espèces en péril en Ontario (CDSEPO) le considère comme une espèce préoccupante ou menacée.

En juillet 2008, le ministère des Richesses naturelles de l’Ontario s’est engagé à élaborer une stratégie provinciale de gestion de l’esturgeon jaune. Au cours de ce processus, un comité technique et public évaluera la possibilité d’inclure l’élevage et l’empoissonnement dans une stratégie de gestion pour rétablir ou réintroduire les populations d’esturgeon jaune en Ontario. On déterminera ainsi si ces techniques constituent une méthode de conservation provinciale faisable.

Le présent rapport décrit brièvement les résultats d’un examen de tous les programmes prédominants de propagation de l’esturgeon jaune aux fins de la préservation des populations. Les techniques de pisciculture examinées sont notamment la collecte des géniteurs, l’expédition et l’incubation des gamètes, la conception des installations d’élevage et certains facteurs touchant la pisciculture. L’élevage axé sur la conservation des populations d’esturgeon jaune est pratiqué depuis plus de 20 ans dans le Wisconsin et le Michigan, où les techniques de naissage sont bien développées. En raison des caractéristiques du cycle biologique de l’espèce, on dispose de peu de renseignements sur les techniques d’empoissonnement de l’esturgeon jaune. Le présent document passe en revue l’information existante sur l’âge/la taille des sujets, sur la fréquence, la densité et le lieu d’empoissonnement, sur le marquage et la surveillance, et sur les facteurs de réussite de l’empoissonnement.

Dans l’ensemble, l’application de techniques d’élevage et d’empoissonnement dans le cadre d’une stratégie de conservation pourrait être un outil essentiel au rétablissement des populations d’esturgeon jaune en Ontario. Une telle stratégie ne devrait être employée qu’en présence d’un puissant motif biologique, et seulement si toutes les autres stratégies de gestion sont jugées impropre à la réalisation des objectifs de gestion. Par ailleurs, il est raisonnable de croire que les techniques d’élevage de l’esturgeon jaune sont suffisamment avancées pour permettre d’élever l’espèce dans une installation de naissage convenable.
Table of Contents

Executive Summary ................................................................................................................................. (i)
Sommaire ............................................................................................................................................... (ii)
Table of Contents ................................................................................................................................. (iii)
List of Figures ......................................................................................................................................... (iv)
List of Tables .......................................................................................................................................... (iv)

1.0. Introduction .................................................................................................................................... 1
  1.1 Background .................................................................................................................................. 1
  1.2. History of Sturgeon Culture ...................................................................................................... 1
  1.3 Lake Sturgeon Culture in Ontario .............................................................................................. 3

2.0 Sturgeon Culture ............................................................................................................................. 4
  2.1 Wild Egg Collections ..................................................................................................................... 5
  2.2 Collecting Dispersing Larvae ...................................................................................................... 8
  2.3 Shipping Progeny .......................................................................................................................... 10
  2.4 Incubation ................................................................................................................................... 10
  2.5 Feeding and Growth ..................................................................................................................... 12
  2.6 Rearing Densities ........................................................................................................................ 13
  2.7 Rearing Tanks ............................................................................................................................... 14
  2.8 Fry Culture ................................................................................................................................... 14
  2.9 Fingerling Culture ......................................................................................................................... 15
  2.10 Streamside Rearing Facilities (SRF) .......................................................................................... 16
     2.10.1 SRF Design ....................................................................................................................... 16
     2.10.2 SRF Sturgeon Culture ....................................................................................................... 17
     2.10.3 SRF Challenges ................................................................................................................. 17
  2.11 Fish Health .................................................................................................................................. 17
  2.12 Factors Affecting Sturgeon Culture ........................................................................................... 18

3.0 Stocking Cultured Sturgeon ........................................................................................................... 20
  3.1 Stocking Considerations .............................................................................................................. 20
  3.2 Transportation ............................................................................................................................... 22
  3.3 Stocking Age, Size, and Frequency ............................................................................................... 22
  3.4 Stocking Density ........................................................................................................................... 22
  3.5 Stocking Location .......................................................................................................................... 23

4.0 Marking and Monitoring ................................................................................................................. 24
  4.1 Fin Clips and Fin Ray Removal ..................................................................................................... 24
  4.2 Scute Removal .............................................................................................................................. 25
  4.3 Floy Tags ...................................................................................................................................... 25
  4.4 Coded Wire Tags (CWT) .............................................................................................................. 26
  4.5 Visual Implant Elastomers (VIE) ................................................................................................. 26
  4.6 Radio-Sonic Telemetry .............................................................................................................. 27
  4.7 Passive Integrated Transponders (PIT Tags) ............................................................................... 27

5.0 Population Genetics ......................................................................................................................... 27

Acknowledgements ............................................................................................................................... 29
References ............................................................................................................................................. 29
Personal Communications ...................................................................................................................... 33
Glossary of Terms ................................................................................................................................. 35
List of Figures

Figure 1. COSSARO lake sturgeon designations for Ontario.

Figure 2. Determining the ripeness of female lake sturgeon.

Figure 3. Eggs being expressed from female lake sturgeon.

Figure 4. Sperm being added to lake sturgeon eggs for fertilization.

Figure 5. Lake sturgeon larvae sampling drift nets.

Figure 6. Lake sturgeon eggs hatching into larvae.

Figure 7. Circular tanks used to rear sturgeon.

Figure 8. Adult brine shrimp, *Artemia* sp.

Figure 9. Fertilized egg trays inside a streamside rearing facility.

Figure 10. Releasing lake sturgeon fingerlings.

Figure 11. Fin clipped juvenile lake sturgeon marked by removal of the right pelvic fin.

Figure 12. Recaptured lake sturgeon fitted with two spaghetti floy tags.

Figure 13. VIE markings on a juvenile lake sturgeon.

List of Tables

Table 1. Lake sturgeon development at various water temperatures. Percentages represent the proportion of development in relation to exogenous feeding.

Table 2. Composition of an experimental artificial diet for juvenile lake sturgeon.

Table 3. Recommended culture densities for lake sturgeon based on bottom surface area of rearing tanks.

Table 4. Maximum transportation densities (kg/L) for an 8-10 hour period at water temperatures ranging from 13 - 21ºC.

Table 5. Stocking densities for lake and river habitats derived from historical lake sturgeon populations.
1.0 Introduction

1.1 Background

This report provides detailed information on lake sturgeon (*Acipenser fulvescens*) culture, marking, and stocking techniques currently used in rehabilitation and reintroduction programs throughout North America. The intent of this synopsis is to provide science-based information for the rehabilitation of lake sturgeon populations in Ontario. Insight on the use of stocking lake sturgeon as a management tool in North America is provided by Smith (2009).

In Ontario, the conservation status of lake sturgeon has been designated based on three regions of Ontario (Figure 1). The northwestern Ontario and Great Lakes-Upper St. Lawrence River populations are classified as “threatened”, and the Hudson Bay-James Bay population has remained as “special concern”.

The new “threatened” designations prohibit the damage or destruction of lake sturgeon habitat and the killing, capturing and possessing of lake sturgeon under the Ontario *Endangered Species Act* (2007) for all threatened regions. In addition, a zero catch and possession quota was established for all commercial and recreational fisheries within the “threatened” boundaries.

In North America, stocking is a common management strategy used to conserve, restore, re-introduce and rehabilitate lake sturgeon populations. Stocking programs are conducted with the long-term goal of developing a self-sustaining population and/or creating a fishery for recreational, commercial, or cultural use. The rehabilitation of extirpated or depressed sturgeon stocks in Ontario may require the development of a stocking program in addition to harvest restrictions and habitat conservation initiatives. This document provides background information to be used in the development of a lake sturgeon recovery strategy and similar management processes in Ontario.

1.2 History of Sturgeon Culture

Prior to the 1860s, sturgeon were considered a nuisance species and often killed and discarded by European fishermen, when entangled in their fishing nets (OMNR 1987). This attitude changed quickly when the value of sturgeon began to rise. Sturgeon roe (caviar) and other products eventually became a highly desired commodity on the global market increasing the commercial demand for this prehistoric species.

Sturgeon were historically sold for their

![Figure 1. COSSARO lake sturgeon designations for Ontario.](image-url)
flesh, either smoked, pickled, or dried. The large swim bladder was used for isinglass to clarify wine and beer. The skin was tanned, the dorsal cord was dried, and the remains were processed for oil. However, the most valuable part of the sturgeon was the roe from female fish which was salted and sold as caviar (Post 1890). In the Great Lakes basin, lake sturgeon were the most commercially valuable species from the 1880s to 1890s (Post 1890).

The commercial trade of lake sturgeon in the U.S. and Canada peaked during the 1880s. During this period, Canada capitalized by supplying 75% of the world’s caviar (LeBreton et al. 2004). An estimated 3.4 million kg of sturgeon was harvested from Ontario (Ontario Game and Fisheries Commission 1912) primarily from the Great Lakes (OMNR 1987).

Uncontrolled harvest inevitably led to the collapse of lake sturgeon populations throughout the Great Lakes basin and, by 1905, the provincial harvest fell to a mere 190,000 kg (OMNR 1987). The remaining commercial fishery in Ontario was supported by redirecting fishing pressure to northern Ontario. Fisheries on the Lake of the Woods, Lake Nipissing, and Lake Nipigon supplied one quarter of the provincial harvest at the turn of the century, however, the northern fisheries experienced a similar fate to that of the Great Lakes and sturgeon populations eventually collapsed (OMNR 1987).

In addition to the unregulated commercial harvest of lake sturgeon in the 1800s, sturgeon habitat was also severely degraded, destroyed or fragmented with the development of dams and effluent from pulp and paper mills and urban centers. The over-exploitation of lake sturgeon and associated habitat alterations contributed to the rapid decline of sturgeon and the associated commercial fishery in the Great Lakes basin (LeBreton et al. 2004). To fulfill consumer demand, alternative stocks were sought and the majority of commercial fishing effort on the Great Lakes shifted to the Caspian Sea and Azov-Black Sea basin (Barannikova 1988). By the early 1900s the unregulated global harvests had impacted sturgeon worldwide (LeBreton et al. 2004, Mohler 2004).

The collapse of sturgeon stocks triggered inaugural propagation efforts for commercial use and population rehabilitation. A Russian scientist was the first researcher to successfully culture sturgeon in 1869 when he artificially fertilized and reared sterlet sturgeon (Acipenser ruthenus) (Vedrasco et al. 2002). Following this success, artificial reproduction of sturgeon was extensively studied in Russia (Chebanov and Billard 2001). By the first half of the 20th century, researchers in Russia had developed the first procedures for artificial sturgeon reproduction, including the use of silt for egg de-adhesion, stimulated ovulation using hypophysation (pituitary injection), and basic research on oocyte maturation, sperm biology, and fertilization techniques (Chebanov and Billard 2001).

In 1876, other researchers successfully reared sturgeon in North America (Post 1890). Throughout the late 1800s and early 1900s, North American scientists conducted lake sturgeon culture experiments and attempted to develop repeatable methods for rearing lake sturgeon. The foundation of lake sturgeon culture evolved in Wisconsin, Michigan (Anderson 1984), New Jersey and Pennsylvania (Meehan 1909).
During early culture trials, scientists were met with many challenges: obtaining gametes from both sexes at the same time; maintaining captive brood stock; and sustaining gamete development (Anderson 1984). Even when fertilization was successful, many research attempts experienced high mortalities connected to fungal infections and poor juvenile diets (Meehan 1909).

The U.S. had developed and implemented lake sturgeon stocking and culture techniques by the early 1900s in the Great Lake states. Wisconsin and Michigan have the largest lake sturgeon stocking programs of these states, and have been implementing stocking as a management strategy for over 15 years. In addition Minnesota, New York, Tennessee, Missouri and Kentucky are committed to lake sturgeon propagation and stocking programs.

By the 1980s, early culture challenges had been resolved or minimized, and the Wisconsin Department of Natural Resources (WDNR) launched one of the first lake sturgeon culture and stocking programs for the purpose of population rehabilitation (Folz et al. 1983). Wild gametes were collected from the Wolf and Fox Rivers. The fertilized eggs were reared in the Wild Rose State Fish Hatchery in Wisconsin and released as fingerlings into their natal rivers (Folz et al. 1983).

Throughout North America, lake sturgeon, Atlantic sturgeon (A. oxyrhynchus oxyrhynchus), shortnose sturgeon (A. brevirostrum), and white sturgeon (A. transmontanus) were all successfully cultured in hatcheries and laboratories from 1960-1980s (LeBreton et al. 2004). Despite the ability to maintain captive brood stock, all other North American sturgeon species require the collection of wild gametes for conservation culture in order to ensure preservation of genetic diversity. (Hatfield 2005, North/South Consultants Inc. 2002, UCRWSRT 2002, WIDNR 2002, Hay-Chmielewski and Whelan 1997). For conservation purposes, the maintenance of captive brood stock for fish species is typically preferable, but impractical for lake sturgeon due to their large size and the number of fish required to maintain a brood stock representative of a wild population.

1.3 Lake Sturgeon Culture in Ontario

Aquaculture in Ontario commenced during the 1850s (MacCrimmon et al. 1974) and focused on the production of salmonids with few resources devoted to non-gamefish species, including lake sturgeon. The initial investigations into the artificial propagation of lake sturgeon in Ontario were driven by increasing concern over the status of lake sturgeon populations during the 1890s. The Biological Board of Canada was asked to undertake Ontario’s inaugural lake sturgeon culture study in 1919, appointing Professor W. A. Clement from the Lake Erie St-Clair district; however efforts were unsuccessful (Kerr 2006). The initiative was transferred to the Ontario Fisheries Research Laboratory at the University of Toronto where the feasibility of lake sturgeon culture was assessed between 1922 and 1926. During this period, gametes were collected from the Gull River, a Lake Nipigon tributary. Attempts were made to transfer fertilized eggs to the Port Arthur hatchery but, again, rearing was unsuccessful. In a third attempt, floating hatching boxes anchored in the stream were used to
eliminate adult transfer, but only a few spawning adults were obtained during the trials as a result of the depleted population abundance. A small proportion of these adults matured and spawned in the hatchery boxes. In addition to the small number of ripe adults, expression of eggs and milt was difficult, and culture mortalities were high (Kerr 2006). Since the 1920s, there has been continued interest in lake sturgeon culture but no large-scale propagation programs have been developed to date in Ontario (Kerr 2006).

In 1988, the Lake Sturgeon Culture Techniques Manual (EAG 1988a) and Stocking Plan (EAG 1988b) were prepared for the Northeast Region of the Ontario Ministry of Natural Resources (OMNR). The plans were reviewed and incorporated into the Northern Region Sturgeon Management Strategy, which was prepared in 1989 (Northern Region Sturgeon Committee 1989). The strategy recommended a pilot project be completed prior to full-scale development of the proposed culture and stocking plan, which was estimated to cost over $1.4 million (EAG 1988b). Despite the committee recommendations, neither the sturgeon culture pilot nor the full-scale stocking and culture plan were implemented.

Lake sturgeon policy in Ontario has acknowledged culture and stocking as a possible long-term rehabilitation strategy. The Lake Ontario Management Unit has been working with New York State Department of Natural Resources to draft the Lake Ontario Lake Sturgeon Restoration Plan, a Great Lakes Fishery Commission (GLFC) document, which may involve stocking as a rehabilitation and or reintroduction management technique (A. Mathers, pers. comm.).

2.0 Sturgeon Culture

Lake sturgeon culture in North America is conducted in either a traditional hatchery facility (THF) or a streamside rearing facility (SRF). THF facilities are the most common means used to culture lake sturgeon. These permanent facilities are designed to raise multiple species throughout all life stages by mimicking natural aquatic environments (Holtgen et al. 2007). SRFs are usually temporary structures located near a stream or lake to be stocked with juvenile fish produced from the facility. The SRF are designed to utilize a local water source providing a more “natural” rearing environment in an effort to maintain wild stocks and their genetic diversity (Ritter 1997) by rearing fish in their natal water sources under natural light conditions.
The use of SRF for lake sturgeon culture emerged in the last five years (Holtgren et al. 2007) but has been used for walleye, Atlantic salmon and other anadromous species throughout North America (Ritter 1997). The majority of lake sturgeon culture programs today still use existing THF and, as a result, literature on lake sturgeon culture is primarily reflective of THF. More recently, the Great Lakes Fishery Trust has supported emerging research from Michigan and Wisconsin that focuses on optimal lake sturgeon culture and stocking techniques, specifically, analyzing the impacts of both THF and SRF rearing environments in respect to lake sturgeon population rehabilitation (Eggold et al. 2009).

There are significant differences in survival and growth as a function of rearing environment (THF and SRF) and gamete/offspring collection methods. Eggs and larvae had lower survivorship in THF than SRF. The higher mortality in the THF resulted in highly skewed family size, showing confirmable effects on the level of genetic diversity. In addition, the mean relatedness between two or more sturgeon reared in THF was higher than in SRF. This research will continue to contribute to lake sturgeon culture in North America.

The U.S. Fish and Wildlife Service and WIDNR refined and documented traditional hatchery culture methods for lake sturgeon in the ‘Genoa National Fish Culture Hatchery Lake Sturgeon Standard Operating Procedures’ (Aloisi et al. 2006). Although each culture program utilized locally-customized methods, the Genoa culture methods have been adopted by most U.S. states, and Canadian provinces that rear lake sturgeon (M. Koob, pers. comm.).

2.1 Wild Egg Collections

Sturgeon are the most primitive freshwater fish species cultured in North America. Information on Ontario lake sturgeon biology and ecology has been compiled in the OMNR (2009) document entitled “Lake Sturgeon in Ontario.” The lake sturgeon's life history and biology is unique compared to other cultured fish species (LeBreton et al. 2004). Sexual maturity for males is usually attained between the ages of 12 and 30 years, and females between 14 and 33 years (Scott and Crossman 1973). Lake sturgeon are iteroparous (spawn more than once), however, spawning is intermittent occurring in the spring every two-three years for males, and every four-seven years for females (Scott and Crossman 1973). Female sturgeon develop eggs to stage F2 (developing female also known as a “yellow egg” fish) of maturity (WDNR undated) several times before actually being ready to spawn. These are known as false spawnings in which the female sturgeon reabsorbs the eggs and directs the stored energy into growth. This process may happen several years before the female spawns for the first time and may account for the increase in growth females exhibit over male sturgeon as they approach sexual maturity. Annually, only 10-20% of the sexually mature lake sturgeon in a population will spawn in any given year (LeBreton et al. 2004).

Lake sturgeon life history and biology present obstacles when attempting to collect brood stock for culture. Due to slow sexual development, lake sturgeon brood stock are collected annually from wild adults, rather than captive brood stocks. Lake sturgeon conservation culture programs rely on the annual
collection of progeny using one of three methods: direct gamete takes (DGT); dispersing larvae (DL); or naturally produced eggs (NPE) from wild lake sturgeon stocks. To our knowledge, captive lake sturgeon brood stocks are not used in North America for conservation stocking programs. The restoration of remnant, long-lived, iteroparous fish species, such as lake sturgeon, requires collection methods that will preserve genetic diversity, local phenotypes and life history adaptations (Eggold et al. 2009).

When gametes are obtained from wild brood stock (the DGT method), sampling should occur across the entire spawning period and at all spawning locations to ensure the populations’ local reproductive ecology is reflected in the progeny (Eggold et al. 2009). Spawning adults are captured on known spawning beds using large dip nets, gill nets, set lines, baited hooks, snappers, or trammel nets. Most culture programs collect gametes on site, but adults can be transported to a hatchery facility for spawning induction (LeBreton et al. 2004).

When transporting adults for off-site gamete collection, fish are moved using stretchers (Figure 2) and transported in large insulated tanks that maintain water temperature and dissolved oxygen levels (LeBreton et al. 2004). Once in a hatching facility, fish are induced with exogenous hormones to ovulate and spermiate within 24 hours. These types of hormones now come in a manufactured pellet form and can be injected intra-muscularly on either side of the dorsal fin. Dosage is based on the weight of the fish. Hormones such as common carp pituitary material (CCP) or the mammalian gonadotrophin-releasing hormone analog (GnRHa) are used to induce ova and semen (LeBreton et al. 2004). Sturgeon are induced quickly, since most species will not feed in captive environments (LeBreton et al. 2004). As water temperature affects egg maturation it is critical to control this factor in the hatchery environment. In Ontario, lake sturgeon have been observed spawning in waters between 10-20°C (OMNR 2009). The optimal water temperature required for sturgeon spawning generally ranges between 14-17°C (LeBreton et al. 2004).

When gametes are collected on-site, hatchery water should be used throughout the fertilization process to prevent transfer of pathogens. Collected adults are transferred to a padded cradle where fresh water is run over the head and gills of the fish. This may be a precautionary measure, however, as large sturgeon are extremely hardy fish and gill irrigation is generally not required.

Figure 2. Determining the ripeness of female lake sturgeon (photo courtesy of the Saskatchewan Ministry of Environment).

The male abdominal areas are palpated to remove the milt, which is drawn into a syringe through an attached silicon tube inserted in the male’s vent. Milt is
placed on ice until female gametes are available (Ceskleba et al. 1985). Extreme care must be taken not to introduce any water into the syringe during this process. Drying the male vent area with paper towels is recommended before trying to express milt from the fish.

Eggs are removed from female fish using the “Bruch Stroke” technique (Bruch et al. 2001). This stroking technique requires firm pressure on the thick abdominal muscle and is only effective when the female is in the F5 stage (loose flocculent-like ovarian tissues with free eggs inside the body cavity). The eggs are forced out of the vent or a small abdominal incision by stroking the abdominal surface (Bruch et al. 2001, Ceskleba et al. 1985). A small incision of approximately 2-3 cm works best for this process as only a small number of eggs can be stripped from the female’s vent at a time making the process very time consuming and more stressful on the fish (Figure 3). Two or three simple sutures using a swaged semicircular needle and polypropylene thread will suffice to close the incision. An antibiotic injection to prevent infection may also be given to the female fish prior to release. Detailed methodology for this procedure is provided in ‘A Field Guide for the Identification of Stages of Gonad Development in Lake Sturgeon’ (Bruch et al. 2001).

Iodophor disinfection during de-adhesion and water hardening, using standard protocols with iodine concentrations of 10 mg/L for 10 minutes (Bouchard and Aloisi 2002), can be safely done with sturgeon allowing the eggs to be disinfected (Bouchard and Aloisi 2002). In addition, eggs can be disinfected a second time on arrival at the hatchery.

Fertilization should be conducted using a mating design or matrix, ideally predetermined within genetic hatchery guidelines. Eggs from each female are separated into equal groups and crossed with no more than two males (Eggold et al. 2009). The eggs are then fertilized with milt (Figure 4); the milt is mixed with water at a 1/200 ratio before being added to the eggs. This solution is stirred with a feather and left to stand for one minute. The milt is poured off immediately to reduce polyspermatic fertilization (egg is fertilized by more than one sperm), which is common in sturgeon species (Aloisi et al. 2006). After fertilization, the family batches are rinsed with hatchery water and a bentonite clay suspension, Fuller’s Earth, or sifted river silt to eliminate egg adhesion and prevent clumping (Aloisi et al. 2006, Bruch et al. 2001, Ceskleba et al. 1985). River clay or some equivalent de-adhesion material should also be added to incubation jars for the first day of the incubation period.

The process of de-adhesion is very important and can take upwards of 24 hours to complete. Sturgeon eggs continue to exude a jelly-like substance during the entire water hardening process. Attempts to wash away the
egg’s coating by the addition of tannic acid is generally not effective.

Figure 4. Sperm being added to lake sturgeon eggs for fertilization (photo courtesy of the Saskatchewan Ministry of Environment).

Lake sturgeon sperm are motile for approximately 30 minutes. Sturgeon gametes have much longer motility than most freshwater fishes, which remain motile for less than one minute post-activation (Toth et al. 1997).

2.2 Collecting Dispersing Larvae

Many studies have demonstrated the importance of using native stock for re-introduction and supplemental stocking programs. However, rehabilitating an imperilled species often makes brood stock collection difficult. Therefore many agencies have been using a ‘head start’ method when suitable brood collection has been unsuccessful. In this method, naturally spawned lake sturgeon are collected from the wild and transferred to a hatchery environment where they are reared for several months before being released back to their natal streams. First year survival of head start fry is higher than in the wild (Peterson et al. 2007).

In addition to increased survivorship, recent research suggests that the collection of lake sturgeon progeny should focus on maximizing genetic diversity by collecting dispersing larvae instead of direct egg collection. A Michigan study found that collecting dispersing larvae downstream of spawning sites captures the highest amount of genetic diversity present within an adult lake sturgeon breeding population (Eggold et al. 2009). Larvae represent the most unbiased cohort progeny from natural reproduction of lake sturgeon populations (Eggold et al. 2009) and rearing larvae eliminates the genetic guesswork of DGT and increases the survivorship of naturally produced cohort specific genotypes (Holtgren et al. 2007).

Collecting lake sturgeon larvae may not be feasible for all programs and populations, due to unknown spawning locations or timing and logistic requirements.

Larvae are collected downstream of lake sturgeon spawning locations approximately one week post-spawning activity. D-framed drift nets are set two km downstream of the spawning locations, equally distributed across the stream channel to capture dispersing larvae (Figure 5). The nets are set for five hour intervals, from dusk to dawn and are checked hourly. Dispersing larvae are collected until no catches are obtained for two consecutive nights (Eggold et al. 2009). Collected larvae are typically 1.2 - 2.6 cm in length (Holtgren et al. 2007).
Kick-net sampling can be used to collect NPE and deposited eggs from spawning locations. Kick-net transects should be established across the stream channel, and downstream in intervals of 0.5 m until no eggs are collected in consecutive transects (Eggold et al. 2009). Larvae or fry survivorship is known to increase when using the head start approach; however, the difference between the survivorship of eggs post-collection and wild eggs is currently unknown. As a result the collection of eggs via kick and sweep may not be the most beneficial method for egg collection of a suppressed population. Further research is required for this specific method.

The collection method used within a study should be reflective of the stocking objectives, whether it is re-introduction or supplementation as well as the feasibility of obtaining gametes by the selected methods. In general, the direct gamete take produces the highest abundance of progeny (when brood stock are available) in comparison with NPE and DL (Eggold et al. 2009). However, comparison studies show DGT collections do not reflect the genetic diversity of the wild population, whereas, the NPE and DL do (Eggold et al. 2009).

Collection efforts for DGT require approximately 24 personnel hours/day throughout the spawning run. In addition, approximately one hour per female is required for the fertilization process (Eggold et al. 2009).

The DGT method is recommended to be used for re-introduction and supplemental stocking of genetically similar stocks. The donor stock should be known to be ‘self-sustaining’ and stable enough to endure cohort takes from specific spawning runs. When wild gametes are collected directly from wild brood stock, DGT sampling should occur across spawning time(s) and location(s), and reflect the local reproductive ecology of the lake sturgeon population (Eggold et al. 2009). The number of families generated from a DGT may vary depending on the availability of eggs from each female (Aloisi et al. 2006) and whether a partial or full factorial mating scheme is used. It is recommended that population-specific genetic guidelines are developed prior to gamete collection. Optimally, a fertilization matrix will increase the number of brood stock families and ultimately the genetic diversity of the cohort (Aloisi et al. 2006).

Obtaining sturgeon offspring through the collection of naturally produced eggs and dispersing larvae requires less effort than direct gamete take. (Eggold et al. 2009). Collecting larvae or eggs
may yield a lower number of individuals, but will require less effort for collection, will eliminate the need for production of a spawning matrix (not a stocking plan), and will enhance cohort genetic diversity. NPE and DL are recommended as collection methods for re-introduction, rehabilitation, and supplementation stocking, if the donor population is known to be self-sustaining and stable enough to endure cohort takes from specific spawning runs. If a population is too depressed, the ‘head start’ method is probably more desirable since it increases juvenile survivorship.

2.3 Shipping Progeny

Wild gamete collection requires transportation of zygotes or fertilized eggs to a hatchery environment. Transportation should occur as soon as possible following fertilization but shipping may be delayed for a maximum of eight hours post-fertilization (Aloisi et al. 2006). Embryo development begins immediately after fertilization and shipping during this sensitive life stage may cause egg mortality. Eggs should be shipped in a plastic or glass jar, filled with two thirds hatchery water and one third pure oxygen. Jars should be placed in an insulated container (e.g., cooler) and padded with foam to prevent movement or shifting of the jars within the container during shipment. Water temperatures during transportation should remain within 5.5°C of the ambient river/lake temperature and hatchery water temperature (Aloisi et al. 2006). Ice can be added to the container for this purpose but should not come into direct contact with the jars containing eggs. Putting a layer of ice on the bottom of the container and covering it with foam is an effective way of keeping the eggs cool. Lake sturgeon progeny shipped to Kentucky from the Wild Rose Fish Hatchery in Wisconsin are shipped at 15°C in preparation to acclimate to the rearing temperatures of 14.6 °C (S. Marple, pers. comm.).

2.4 Incubation

Incubation of disinfected eggs occurs in modified MacDonald hatching jars in groups according to the genetic crosses, with one jar per female group (Aloisi et al. 2006). The optimal incubation water temperature for lake sturgeon eggs is between 14-15°C. Aloisi et al. (2006) suggest this temperature range is ideal for lake sturgeon egg growth and control of fungus. Modified MacDonald jars are designed to inhibit fungal growth (Aloisi et al. (2006). Water flow in jars should be adjusted to keep eggs gently rolling but not rising and falling within the MacDonald jar. Flow can be turned up slightly to facilitate the removal of dead or fungused eggs. The best method for this involves using a 5 mm diameter glass tube fitted with a suction bulb (similar to a turkey baster). This process should be repeated several times daily. Dead eggs will quickly become covered in fungus which will soon spread to other healthy eggs. The growth of fungus can be controlled by passing incoming water through an ultraviolet sterilizer. Removal of dead eggs will still be required however. Lake sturgeon eggs require six to ten days of incubation until the embryos emerge (Figure 6), however the exact duration of incubation is dependent on egg rearing densities and water temperatures (Aloisi et al. 2006). It is also very important to monitor nitrogen gas levels (TGP) in the incubation water especially if the water is pumped long distances, is heated, or comes from a groundwater source.
Newly hatched sturgeon larvae are highly susceptible to nitrogen gas supersaturation.

Some newly hatched larvae have extreme difficulty emerging from the egg shell and a gentle pulse of water from the turkey baster will remove the egg shell without having any adverse impacts on the larvae. The larvae will feed on the yolk sac for approximately ten days depending on the water temperature (Table 1).

Once the larvae have hatched they should be watched closely for signs of stress and mortality. Larvae are photonegative for one week after hatching, causing them to bunch together. This behaviour may cause suffocation and stress-related mortalities.

Artificial structures may be placed in rearing tanks to mitigate the effects of this behaviour by creating refuge areas. Structures used include floor brushes or non-skid floor matting (Aloisi et al. 2006). Shading parts of the rearing unit is also recommended.

Table 1. Lake sturgeon development at various water temperatures. Percentages represent the percent of development in relation to exogenous feeding (from Aloisi et al. 2006)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Days to safe shipping after fertilization (12%)</th>
<th>Days to Hatch (30%)</th>
<th>Days to Exogenous Feeding (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.0</td>
<td>3.6</td>
<td>8.1</td>
<td>26.1</td>
</tr>
<tr>
<td>14.4</td>
<td>3.4</td>
<td>7.4</td>
<td>24.0</td>
</tr>
<tr>
<td>15.0</td>
<td>3.2</td>
<td>6.9</td>
<td>22.0</td>
</tr>
<tr>
<td>15.5</td>
<td>3.1</td>
<td>6.4</td>
<td>20.5</td>
</tr>
<tr>
<td>16.1</td>
<td>2.9</td>
<td>5.9</td>
<td>19.1</td>
</tr>
<tr>
<td>16.7</td>
<td>2.7</td>
<td>5.5</td>
<td>17.8</td>
</tr>
<tr>
<td>17.2</td>
<td>2.5</td>
<td>5.1</td>
<td>16.7</td>
</tr>
<tr>
<td>17.8</td>
<td>2.3</td>
<td>4.8</td>
<td>15.7</td>
</tr>
<tr>
<td>18.3</td>
<td>2.2</td>
<td>4.5</td>
<td>14.7</td>
</tr>
<tr>
<td>18.9</td>
<td>2.0</td>
<td>4.2</td>
<td>13.9</td>
</tr>
<tr>
<td>19.4</td>
<td>1.8</td>
<td>3.9</td>
<td>13.2</td>
</tr>
<tr>
<td>20.0</td>
<td>1.6</td>
<td>3.7</td>
<td>12.5</td>
</tr>
<tr>
<td>20.6</td>
<td>1.4</td>
<td>3.5</td>
<td>11.9</td>
</tr>
<tr>
<td>21.1</td>
<td>1.2</td>
<td>3.3</td>
<td>11.3</td>
</tr>
<tr>
<td>21.7</td>
<td>1.1</td>
<td>3.1</td>
<td>10.8</td>
</tr>
<tr>
<td>22.2</td>
<td>0.9</td>
<td>3.0</td>
<td>10.4</td>
</tr>
</tbody>
</table>
2.5 Feeding and Growth

Sturgeon are opportunistic feeders consuming virtually any benthic organism including molluscs, small fish, benthic insects, gastropods, algae, and plants (Klassen and Peake 2007). Older lake sturgeon more frequently consume crayfish and small fish than juvenile fish. There are also reports of lake sturgeon feeding heavily on alewife that had died during winterkills (Casselman 2004).

For culture purposes, it is preferred by hatcheries to rear fish on formulated diets because it requires less labour when compared to live feeds. Formulated diets have not been readily accepted by juvenile lake sturgeon in the past (Ceskleba et al. 1985). Some diets have resulted in high mortality rates (Klassen and Peake 2007) and lower growth rates compared to other sturgeon species (Moreau and Dabrowski 1996).

The marginal success from artificial feed has resulted in the wide-spread use of live invertebrates in culture programs (Aloisi et al. 2006, Vedrasco et al. 2002). Juvenile lake sturgeon are typically fed chironomid larvae, euphausiids (krill), and Artemia sp. (brine shrimp) (Fajfer et al. 1999). The most common species fed to juvenile lake sturgeon are brine shrimp for larvae and bloodworms for fingerlings and yearlings. Fajfer et al. (1999) recommended that sturgeon should be reared on a uniform diet (Table 2) to maximize growth and reduce mortalities; however most rearing facilities administer both brine shrimp and bloodworms. Mortalities can be reduced by providing slow transitional diet changes and monitoring stocks closely (Aloisi et al. 2006).

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Diet (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein (vitamin-free)</td>
<td>36.0</td>
</tr>
<tr>
<td>Corn starch</td>
<td>14.0</td>
</tr>
<tr>
<td>Dextrin (80% water-soluble)</td>
<td>7.0</td>
</tr>
<tr>
<td>Betaine (anhydrous)</td>
<td>2.0</td>
</tr>
<tr>
<td>Krill</td>
<td>0.0</td>
</tr>
<tr>
<td>Fish protein concentrate</td>
<td>6.0</td>
</tr>
<tr>
<td>Egg white</td>
<td>5.0</td>
</tr>
<tr>
<td>Gelatin</td>
<td>4.0</td>
</tr>
<tr>
<td>Cod liver oil</td>
<td>4.0</td>
</tr>
<tr>
<td>Soybean lecithin</td>
<td>4.0</td>
</tr>
<tr>
<td>Corn oil</td>
<td>2.0</td>
</tr>
<tr>
<td>Lard</td>
<td>2.0</td>
</tr>
<tr>
<td>Vitamin mixture</td>
<td>4.0</td>
</tr>
<tr>
<td>Bernhart Tomarelli salt mixture</td>
<td>3.0</td>
</tr>
<tr>
<td>Choline chloride (99%)</td>
<td>2.0</td>
</tr>
<tr>
<td>Carboxymethyl cellulose sodium salt</td>
<td>2.0</td>
</tr>
<tr>
<td>Cellulose (Alphacel)</td>
<td>2.99</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 2. Composition of an experimental artificial diet for juvenile lake sturgeon

The percent of protein within a diet is very important for the development of lake sturgeon. Diets are typically dominated by bloodworms as they contain twice the protein content of brine shrimp. Protein enrichment formulas increase artemia protein content considerably however. The longer the artemia are kept after enrichment, the lower nutritional value they will have. Storing artemia at temperatures of 4ºC until feeding will slow their respiration but not inhibit their uptake or nutrients. Higher concentrations of protein aids in greater growth rates, body size and lipid content (Volkman et al. 2004). Larger body size, and higher lipid content are positively correlated with greater hatchery performance and winter survivorship of lake sturgeon (Volkman et al. 2004).
Formulated diets have been used successfully to rear many juvenile sturgeon species including Siberian sturgeon (*A. baerii*), Russian sturgeon (*A. gueldenstaedtii*), white sturgeon and sterlet sturgeon (*A. ruthenus*). A comprehensive study concluded that juvenile lake sturgeon can be reared on formulated diets including dry fish meal-based and semi-purified feeds (Moreau and Dabrowski 1996). Laboratory tests reveal that larval (1-5 g) and yearling (180 - 210 g) lake sturgeon feed successfully on artificial diets. Moreau and Dabrowski (1996) provided initial insight into the nutritional requirements of lake sturgeon when testing five experimental pellet diets. Larvae were fed 0.5-0.8 mm pellets at the daily rate of 3.3-3.5% (of dry food per wet body weight) administered in six meals per day for six weeks. Yearlings were fed 2.5 mm pellets at the daily rate of 1.1% (of dry food per wet body weight) administered in three meals per day for four weeks. Larval survival ranged from 33.6 – 80% within diet treatments and yearling survivorship was 100% in all diet treatments (Moreau and Dabrowski 1996).

The observed growth rate was comparable to reported growth rates of Siberian sturgeon reared under similar conditions (Moreau and Dabrowski 1996) and lake sturgeon fed oligochaetes once per day. Even so, lake sturgeon growth rates have been documented as significantly higher (2.6% body weight/day) when fed twice per day (Diana et al. 2003). Observations of lake sturgeon revealed a unique feeding behaviour where food consumption varied as much as 15-fold. In addition, food consumption is correlated to consumption history which may be linked to gorging in the wild (Diana et al. 2003). It is also known that a feeding stimulant (2% betaine) commonly added to white sturgeon feed is ineffective on lake sturgeon (Moreau and Dabrowski 1996).

Rearing lake sturgeon during early life history on artificial feed should be achievable provided the appropriate commitment from research biologists dedicated to the development of juvenile lake sturgeon feed nutrition and delivery methods (G. Hooper, pers. comm.).

### 2.6 Rearing Densities

Juvenile lake sturgeon (8-22 g) can be cultured in densities of 450 fish/m² without compromising growth rates (Fajfer et al. 1999). In Tennessee, recommended rearing densities are 116.1 fish/m² for fry and 1.6 fish/m² for juveniles (180 mm)(Table 3).

Future studies are required to identify upper limits of rearing density and to investigate if rearing densities affect stocking survivorship. Higher survivorship has been documented for other fish species when reared in lower densities (Fajfer et al. 1999). Size and growth variations within and between populations should be acknowledged as
important heritable traits. Hatchery environments should strive to preserve wild natural variations, and avoid hatchery domestication as much as possible.

Table 3. Recommended culture densities for lake sturgeon based on bottom surface area of rearing tanks. (TRLSWG 2007).

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Mean Length (mm)</th>
<th>Fish/m²</th>
<th>Fish/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>-</td>
<td>116.1</td>
<td>42</td>
</tr>
<tr>
<td>75</td>
<td>-</td>
<td>55.7</td>
<td>20.2</td>
</tr>
<tr>
<td>100</td>
<td>-</td>
<td>41.8</td>
<td>25.5</td>
</tr>
<tr>
<td>150</td>
<td>50</td>
<td>7.4</td>
<td>2.8</td>
</tr>
<tr>
<td>200</td>
<td>120</td>
<td>2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>250</td>
<td>160</td>
<td>1.9</td>
<td>0.62</td>
</tr>
<tr>
<td>270</td>
<td>180</td>
<td>1.7</td>
<td>0.56</td>
</tr>
</tbody>
</table>

2.7 Rearing Tanks

Rearing tank area is thought to be more critical than volume when culturing benthic feeding species (Fajfer et al. 1999). Circular tanks are considered the most optimal design for fry as the feed is not filtered out as fast in a circular tank compared to a traditional rectangular tank (Aloisi et al. 2006, Figure 7). Furthermore, circular tanks can achieve lower water volumes that maintain feed in higher densities than rectangular tanks without stressing the fish. Another advantage is that circular tanks can be drawn down easily prior to feeding to increase food densities (Aloisi et al. 2006).

2.8 Fry Culture

Lake sturgeon fry (2-5 cm in length) are typically reared on first larval stage brine shrimp (Figure 8). Artemia can be purchased or reared in the culture facility. Artemia cysts are easily stored in cool temperatures. Artemia are reared from purchased cysts and require less than 24 hours to emerge.

Artemia production requires three separate stages: (1) decapsulation of the dry cysts using a bleach and sodium hydroxide mix. Once decapsulated the cysts must be neutralized of all chlorine bleach using a sodium
thiosulphate/water mix. These decapsulated cysts, drained of excess water, can then be stored in a refrigerator for up to seven days; (2) hatching of the decapsulated cysts in salt water (e.g., 30 ppt) at a temperature of 25-27°C for 24 hours; (3) enrichment of the hatched shrimp using 0.6 gm/l mixture of a formulated enrichment at 25°C for 24 hours. Enriched artemia must be rinsed well to remove as much of the enrichment solution as possible to avoid any bacterial loading once the artemia are added to the rearing units.

Fry require frequent feeding for the first eight days post-hatch. Feed should be divided into four equal rations and administered throughout the night during the active feeding hours of lake sturgeon. Once added to a rearing unit containing fresh water, artemia die after approximately one hour. At that time dead artemia should be removed from the rearing unit either by siphoning or by flushing and sweeping them to a central drain. Failure to implement strict husbandry protocols will result in bacterial blooms and subsequent fish health problems.

Young lake sturgeon need to be fed for 12 hours a day and should not be left without food for more than 12 hours. If feeding does not occur within 12 hours of the last feeding event, mortalities may occur from anaemia (Aloisi et al. 2006). Feeding volume and frequency should be adjusted for individual batch development and hatchery water temperatures (S. Marple, pers. comm.).

Lake sturgeon fry require approximately one pound of artemia nauplii for every 1,500 fry during a production season. Young sturgeon can be switched from artemia nauplii to formulated diets after 25-35 days. Bloodworms are also sometimes used at this stage but bloodworms are hard to obtain in a constant and reliable supply. There is also a major risk that bloodworms may harbour some types of disease or may be contaminated. For these reasons they should probably be avoided as a food source. During the period of transitioning from live to formulated feeds, mortalities of 30-50% can routinely be expected.

2.9 Fingerling Culture

Bloodworms are traditionally integrated into the young lake sturgeon feed when fry have exceeded 5 cm in length. Bloodworms are chopped or grated in a food processor and initially mixed with artemia nauplii to aid in diet transition. The feed transition from artemia to bloodworms should be slow, monitoring all fish to ensure they are consuming bloodworms before the diet ratio of bloodworms is increased. If the feed transition is not monitored juvenile growth and survivorship may be adversely influenced. Once they have developed to 7.6-15 cm they should be fed whole bloodworms, adult artemia or krill (Aloisi et al. 2006). Emerging research suggests black fly larvae from a fish-free water source may be an acceptable bloodworm diet supplement. Black fly larvae may reduce hatchery effort and produce lake sturgeon with equal survival and growth rates to those reared on bloodworms (Klassen and Peake 2007). Once again, live sources of feed are difficult and labour intensive to obtain and, with the exception of artemia, should be avoided for these reasons.

In the Pfeiffer Fish Hatchery, Kentucky, lake sturgeon are fed grated and whole bloodworms mixed with artemia during the 5-7.5 cm growth stage. Once the sturgeon are acclimated to this transition in diet, they are started on a 50/50
mixture of soft-moist salmon diet and krill trout starter. When the batch average reaches ~10 cm, they are graded into size groups. The larger sturgeon are fed a diet of whole bloodworms and mixed artificial feed, and the smaller sturgeon are fed a combination of grated and whole bloodworms as well as artificial feed (S. Marple, pers. comm). Lake sturgeon are typically stocked as fingerlings, around 7.6-15 cm in length, for rehabilitation stocking, but individuals may be held longer. Retained lake sturgeon are typically reared in larger hatchery tanks or ponds and fed artificial pellets (S. Marple, pers. comm.).

2.10 Streamside Rearing Facilities

WDNR and MNDNR have been operating stream-side rearing facilities since 2003, developing the basic design of “portable field hatcheries” for lake sturgeon with great success (Figure 9). Streamside rearing facilities (SRF) are optimal for local rehabilitation programs because they are cost-effective and adaptable (Holtgren et al. 2007).

Figure 9. Fertilized egg trays inside a streamside rearing facility (photo courtesy of Sturgeon for Tomorrow, Black Lake Michigan Chapter).

Rearing juvenile lake sturgeon up to 13 weeks of age may be more profitable in a SRF environment than a traditional hatchery because the fish are exposed to natural environments (Crossman 2008). Lake sturgeon have been observed leaving their natal stream within four months of hatching (Auer and Baker 2002) and researchers have suggested that SRF may maximize imprinting of the natal waters (Crossman 2008) and reduce hatchery selection effects or domestication of lake sturgeon.

Lake sturgeon progeny display higher survivorship, broader variation in incubation time and hatching size (Crossman 2008), and greater genetic diversity when reared in a streamside hatchery compared to a THF (Eggold et al. 2009). Understanding the factors that influence lake sturgeon rearing in both SRF and traditional hatcheries will enable the development of system-specific management recommendations (Eggold et al. 2009).

2.10.1 SRF Design

SRF are designed to be simple, mobile and cost-effective. The existing lake sturgeon SRF are constructed from trailers or temporary shells and located in remote areas, operated and maintained by a minimum of field staff. Facility designs may vary but, at a minimum, must include a power generator and a water intake system which includes a water pump and sediment removal system as well as intake/outfall lines that transport water through the facility. All of the components necessary to rear lake sturgeon are located within the facility. A SRF functions using standard rearing equipment including larval tanks, juvenile raceways, water heaters,
nitrogen degassing systems, telemetry warning systems, and working areas. The facility shell is outfitted with numerous windows and skylights to retain the natural photoperiod.

Complete SRF designs have been described by Holtgren et al. (2007). The SRF on the Big Manistee River in Michigan cost $64,000 (U.S.) in consulting fees for planning and construction. Operational fees were under $100 monthly excluding staff wages (Holtgren et al. 2007).

2.10.2 SRF Sturgeon Culture

Larval feeding techniques are similar to the traditional hatchery feeding methods, however, diet proportions and transitional timing may vary depending on local stock/population requirements. SRF may provide additional native foods from the water source. Depending on the local basin geomorphology and degree of landscape development, the hatchery inlet water may not require filtration, thereby providing stream invertebrates, zooplankton and other micro-organisms as an additional food source for developing lake sturgeon (Dr. K. Scribner, pers. comm.). With this method there may be some serious fish health and biosecurity concerns.

2.10.3 SRF Challenges

Stream-side facilities for lake sturgeon are relatively new and facility challenges have not been well documented. However, Holtgren et al. (2007), has provided initial insight into some of the challenges experienced in the SRF on the Big Manistee River in Michigan. The major problems were associated with electronic malfunctions, or oversights, creating problems with water filtration (silt removal) and water temperature control. The reported challenges were linked to the development of new facility designs, and were resolved within a few years of operation (Holtgren et al. 2007).

In a Great Lakes Fishery Trust Progress Report on lake sturgeon SRF, Michigan and Wisconsin DNR attributed high mortalities to elevated rearing densities, the inability to collect fertile adults from spawning grounds, and the need to refine juvenile diets (Eggold et al. 2009). The SRF challenges were facility specific and not unique to all SRF. Generally, similar challenges are experienced in all hatchery environments, both traditional and SRF.

Lake sturgeon streamside rearing has been successful in the U.S. yet further empirical and experimental evaluation on hatchery rearing and stocking programs are required for lake sturgeon. A review of SRF programs in Michigan indicated the stream-side rearing method has the potential to be significantly improved through evaluation of progeny collection, rearing, and stocking (Eggold et al. 2009).

2.11 Fish Health

Fish health is one of the most important factors in successful culture of any species, including lake sturgeon. Little is known about sturgeon-specific pathogen identification, isolation and treatment (LeBreton et al. 2004). In the case of lake sturgeon, Wisconsin hatcheries have reported bacterial gill disease, columnaris and eye flukes (Diplostomum spathaceum) as the most commonly observed lake sturgeon health issues over the past 20 years (Aloisi et al. 2006). Fortunately these health issues are either treatable or preventable using simple and affordable methods, described in further detail by Aloisi et al. (2006). Weekly hydrogen peroxide and salt water treatments are used to prevent common fungal and
viral infections (E. Baker, pers. comm.) and Chloramine-T can be used to control columnaris and bacterial gill disease (*Flavobacter* sp.) outbreaks (Aloisi et al. 2006). Salt baths of 1-2% for a period of twenty minutes should precede any chemical treatments. It should also be noted that sturgeon respond negatively to formalin, and therefore it should not be used as a disinfection treatment (E. Baker, pers. comm.).

A possible fish health concern for sturgeon is the white sturgeon iridovirus (WSIV). This is a persistent problem with commercial shortnose sturgeon culture in New Brunswick. Lake sturgeon seem to be resistant to the WSIV, however, laboratory studies have confirmed that lake sturgeon can contract the virus (Hendrick 1992). The white sturgeon iridovirus was discovered in 1988 in a Californian white sturgeon culture facility, where it caused severe mortalities. It is presumed WSIV is a unique piscine iridovirus agent transferred to California hatcheries through wild white sturgeon brood stock (Hendrick 1992). Since its discovery, WSIV has been identified in pallid sturgeon (*Scaphirhynchus albus*) hatcheries where it caused severe mortalities in young sturgeon (Hendrick 1992). Adult sturgeon, however, may sometimes develop symptoms of the disease but it is rarely fatal.

External causative markings may indicate infection, however the virus may be present without physical indicators. The Wisconsin DNR applies preventative measures and visually screens a minimum of 60 wild lake sturgeon brood stock for the external symptoms of WSIV prior to egg collection (Aloisi et al. 2006). Michigan DNR have not observed WSIV in wild brood stock, but collect tissues and ovarian fluid from a sub-sample of brood stock for general health testing (E. Baker, pers. comm.).

Great Lakes sturgeon hatcheries are continuing to disinfect eggs with idophor for pathogens including viral hemorrhagic septicemia (VHS) (S. Marple, pers. comm.). The detection of VHS in lake sturgeon has not been documented to date and the susceptibility of the species to the virus is unknown. Although lake sturgeon may not be VHS-susceptible, this pathogen has been detected in many waterbodies in the Great Lakes basin. Current understanding is that disinfecting the eggs with iodophor during water hardening should prevent the possibility of any transmission; however, some facilities are quarantining eggs and fry until they can be tested for VHS. This may continue to be the norm for sturgeon culture unless a certified disease-free brood stock can be developed. Lake sturgeon gametes can be treated with iodine-based disinfectants and therefore the Ontario MNR best management practices (OMNR 2007) should be applied to prevent the transfer of disease. Furthermore, the egg disinfection and incubation procedures should be tested on lake sturgeon gametes to ensure methods provide adequate disinfection. Significant research in using ozone treatments to prevent vertical (parent to egg) transmission of pathogens including some viruses has been conducted and may have potential in sturgeon culture.

### 2.12 Factors Affecting Sturgeon Culture

The largest obstacle facing a lake sturgeon culture program is obtaining eggs or progeny. The degree of difficulty associated with progeny
collection is dependent on the identification and access to lake sturgeon spawning populations. The lack of sexual dimorphism in adult sturgeon also makes recognition and identification difficult. Generally, intrusive biopsies where a small sample of the gonad is examined is the only certain way to determine the sex of a non-spawning adult. Examination by ultrasound has limited effect and, due to power requirements and expense of equipment, can generally only be done in a hatchery setting. Use of this equipment also requires highly trained staff. Genetic analysis should then be conducted in order to design a genetic stocking plan appropriate for the program stocking method (reintroduction, supplementation, or augmentation). The plan should identify the number of wild brood stock required for gamete collection, or the effort required for naturally produced progeny collection (fertilized eggs or larvae collection). Once these parameters have been determined, the feasibility of implementing the stocking program should be based on access to spawning locations and the ability to collect sufficient gametes or progeny. If collecting progeny is logistically feasible, impacts to the native donor population must also be assessed.

It terms of hatchery logistics and daily operations, lake sturgeon are susceptible to the same common fish culture problems experienced by all facilities such as common bacterial/viral outbreaks, equipment failure, and limitations of equipment design (OMNR 2000). Each lake sturgeon culture facility is unique, differing by facility structure and hatchery rearing objectives and capacity.

Hatchery environments can negatively influence lake sturgeon survivorship and should be considered carefully when rearing lake sturgeon. Gas supersaturation, system failures, low oxygen, light and high water temperatures can all induce stress and mortality in lake sturgeon (Aloisi et al. 2006). One of the most important aspects of lake sturgeon culture is tank design. The rearing tanks must allow feed to be delivered in high densities for long periods of time; ensuring juveniles can find and consume the feed. This is achieved most effectively by using circular tanks, with low water flow and sufficient current which allows food suspension without immediate filtration. Additional methods include temporary lowering of water levels prior to feeding. This extends food exposure to fish by increasing food density and reducing the foraging area. Traditional lake sturgeon feeding systems were designed to deliver small amounts of food over a 24 hour period. This method has been inappropriate for sturgeon due to the low density of food delivery resulting in large scale die-offs from starvation (Aloisi et al. 2006).

Live feed can present more problems than artificial feed. Optimal water temperatures and uneaten live food in the rearing tanks may increase the probability for bacterial growth. Diligent husbandry protocols must be followed to ensure the cleanliness of the rearing units. Bacterial growth can affect water quality, cause bacterial gill disease and mortality in young fish (Masouleh et al. 2006). Weekly treatments using the recommended dosage of Chloramine-T can control bacterial growth without harming young lake sturgeon if administered and monitored correctly (Aloisi et al. 2006).

Live feed should also be monitored for disease and tested for contaminants. Bloodworms originating from China are
often collected from sewage lagoons and may contain heavy metal contaminants. Food sources should be investigated before administration to fish and supplemental food sources should be incorporated when available. Lake sturgeon reared by WDNR are supplemented with Pacific krill to reduce the long-term effect of contaminated bloodworms and minimize food costs (Aloisi et al. 2006). This method of obtaining a supply of bloodworms from an outside source can be a risky endeavour. Firstly, the risk of disease transmission and the subsequent time involved in testing/screening can sometimes make feeding timeliness un reachable. Secondly, costs involved would be far greater than with the use of specialized formulated feeds. Finally, the nutritional value of live feed is not always measurable because of inconsistencies in quality.

Lake sturgeon should be monitored closely for signs of disease. Preventing disease or health issues is essential for lake sturgeon because antibiotic treatments are limited (Dr. K. Scribner, pers. comm.) and the addition of medicine to live feed is currently not a viable option (Aloisi et al. 2006).

3.0 Stocking Cultured Sturgeon

3.1 Stocking Considerations

Stocking is a technique used in both short-term (supplemental) and long-term (re-introduction and rehabilitation) management strategies. The long history of sturgeon exploitation and habitat destruction has influenced many sturgeon populations, some more severely than others. For certain populations, stocking may be the only method capable of preventing collapse until long-term management actions can be implemented (UCRWSRT 2002).

Re-introduction stocking involves the release of lake sturgeon into extirpated waters (OMNR 2002). This method of stocking may occur in a waterbody isolated from other sturgeon populations where sturgeon have been extirpated or a ‘locally’ extirpated tributary connected to a waterbody where sturgeon populations are still present in adjacent streams or basins (Figure 10).

Figure 10: Releasing lake sturgeon fingerlings (photo courtesy of Sturgeon for Tomorrow, Black Lake Michigan Chapter).

Genetically and geographically similar stocks are cultured for the purpose of restoring ecosystem function, maintaining local biodiversity and preserving social culture (Drauch and Rhodes 2007, TRLSWP 2007, Gale et al. 1986). Reintroduction plans are dependent on stocking as a preliminary strategy to establish a naturally reproducing population and sufficient habitats must be available for all life stages.

Supplemental stocking involves the addition of individuals to an existing population (OMNR 2002), typically a
remnant “at risk” population. Supplemental stocking is a compensation strategy used to address population deficiencies such as insufficient population numbers or failed cohorts.

In the case of supplemental stocking, a good understanding of the population and available habitat is required to ensure the addition of individuals will not have an adverse impact on remnant stocks.

Stocking evaluation requires at least one lake sturgeon generation (minimum of 15-20 years) for complete program assessment, therefore most long-term stocking techniques have not been evaluated. Despite these challenges, multiple agencies are researching short-term stocking techniques (WIDNR 2002, Hay-Chmielewski and Whelan 1997). Management implications of this research includes effective brood stock selection, retention of genetic diversity including rare alleles, stocking survivorship of different life stages, and overall stocking success.

Long-term information gaps are focused on natal stream imprinting and fidelity, and natural recruitment of stocked fish. These two long-term gaps are critical indicators of rehabilitation stocking program success and will take more than one lake sturgeon generation to assess.

To date, only two studies have looked at the long-term results of re-introduction stocking for lake sturgeon. Schram (2007) reported on a mark-recapture program performed on lake sturgeon stocked into the St. Louis River, a Lake Superior tributary. Sturgeon were tagged from 1985-2007 and monitored during routine fisheries assessments. Data revealed the majority of stocked lake sturgeon remain close to their stocking sites and do not migrate to other areas of the lake. The second study by Drauch and Rhodes (2007) analysed the lake sturgeon re-introduction program in the Mississippi and Missouri Rivers in terms of their ability to transfer genetic diversity from source populations to re-introduced populations. The re-introduced population showed similar levels of genetic diversity to the source population, however, genetic bottlenecking was observed in hatchery fish, therefore multiple-year stocking strategies are recommended for lake sturgeon re-introduction programs (Drauch and Rhodes 2007).

Currently, stocking programs rely on intermittent or short-term indicators to inform scientists on program success. The relatively new development and implementation of lake sturgeon rehabilitation programs has resulted in a time lag of peer-reviewed literature.

In many cases, the experimental release of native fish into a population provides a valuable method for studying remnant populations, by identifying or confirming the cause of population decline (e.g. recruitment failure and over-harvest). Scientific information obtained from release studies has enhanced the understanding of lake sturgeon movements (Schram 2007, Smith and King 2005), life-stage specific habitat use, responses to environmental changes such as flow and temperature (Benson et al. 2005, Thuemler 1988), and potential exposure to point source contamination. Continued release experiments can provide feedback on the success of stocking methods and facilitate adaptive management.
3.2 Transportation

Transporting fish for the purpose of stocking requires proper shipping techniques and low stress environments to maximize survival of fish throughout the transportation process (OMNR 2000). Lake sturgeon are sensitive to high transportation densities and salt concentrations greater than 0.5%. Therefore, it is recommended that salinity levels should not exceed 0.25% and the transportation densities provided in Table 4 should be followed (Aloisi et al. 2006).

Table 4. Maximum transportation densities (kg/l) for 8-10 hrs at water temperatures from 13°- 21 °C, (from Aloisi et al., 2006).

<table>
<thead>
<tr>
<th>Density (gm/fish)</th>
<th>Density( kg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.091</td>
<td>3.4</td>
</tr>
<tr>
<td>0.022</td>
<td>2.3</td>
</tr>
<tr>
<td>0.004</td>
<td>2.3</td>
</tr>
<tr>
<td>0.002</td>
<td>1.1</td>
</tr>
</tbody>
</table>

3.3 Stocking Age, Size, and Frequency

The optimal stocking age is typically determined by the lowest production cost that ensures the highest survival rate (Aloisi et al. 2006) and recruitment (Holtgren et al. 2007). Almost all lake sturgeon are stocked as juveniles; either as fry, fingerlings, or yearlings. Fish retained longer than 12 months are usually stocked for research purposes involving marking and monitoring projects. Most stocking programs in the Great Lakes basin involve fingerling lake sturgeon ranging from 110-150 mm in length (GLFC 2009a). Lake sturgeon culture requires wild gamete and progeny collection. The timing of the spawn collections and water temperature in the fish hatchery will affect size of the sturgeon available for stocking in the spring and fall, which may affect the timing and frequency of stocking.

Typically, fry are stocked during the summer and fingerlings are stocked during the fall. Mortality rates reported by WDNR suggest fall fingerlings have a 20% survival rate and spring yearlings have an 80% survival rate during their first year (Aloisi et al. 2006). Initial evaluation of stocking efforts from the Lake Superior basin indicate stocked fry and fingerlings have survived and remained in the vicinity of release sites (Schram 2007).

3.4 Stocking Density

Most lake sturgeon stocking projects in North America to date may be considered experimental. Fish have been released in relatively low densities and numbers. Consequently, the maximum and optimum stocking density for lake sturgeon is largely unknown (E. Baker, pers. comm.). The most comprehensive stocking density information for lake sturgeon is provided by Wisconsin DNR (WDNR 2002) and is based on historical population estimates. The current stocking densities for Wisconsin have been set to re-establish known historical population densities. The Menominee River and Lake Winnebago provided historical river and lake population estimates (Table 5). The stocking density targets are currently being used for culture production estimates until more comprehensive information is available. These density estimates have been adopted by the Management Plan for Restoration of the Upper Tennessee
River Lake Sturgeon population, after review by the Tennessee Lake Sturgeon Management Team (TRLSWG 2007).

Table 5. Stocking densities for lake and river habitats derived from historical lake sturgeon populations (from WDNR, 2002).

<table>
<thead>
<tr>
<th></th>
<th>Lake (fish/ha)</th>
<th>River (fish/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historic Density</td>
<td>0.6</td>
<td>402</td>
</tr>
<tr>
<td>Fingerlings</td>
<td>0.2</td>
<td>129</td>
</tr>
<tr>
<td>Yearlings</td>
<td>0.1</td>
<td>64</td>
</tr>
</tbody>
</table>

The stocking densities for lake and river habitats are being implemented as an initial reference point, helping to inform annual culture estimates for fingerling and yearling production. The true effectiveness of the density estimates are unknown, but will be evaluated as the lake sturgeon rehabilitation projects move forward. Rehabilitation stocking for extirpated or severely depressed stocks will continue annually for a minimum of 25 years or one generation. Throughout this time, monitoring and stocking evaluations are planned to provide feedback for future management (TRLSWG 2007, WDNR 2002).

The determination of optimal and maximum stocking densities should include consideration of the release environment and available habitat.

3.5 Stocking Location

The effect of stocking location has not been studied in any detail. In general, stocking locations are determined on a site by site basis. In most cases, fish are released near known spawning locations, where wild juvenile fish may be present. Recent studies have shown stocked juveniles move/drift away from stocking locations and may leave a tributary within a week (Eggold et al. 2009); therefore stocking locations should incorporate juvenile habitat that provides adequate food sources. Habitat selection is primarily influenced by abundance of food sources, and annual movements are most likely determined by prey availability (OMNR 2009). Local knowledge of prey preference and availability should be integrated into stocking site selection.

Recent research from Eggold et al. (2009) indicates that release sites for juvenile lake sturgeon should occur in areas having sand substrates and moderate flows during the night. This method of release ensures high dispersal rates directly following release and may indirectly reduce predation by visual predators. Significant mortality of young lake sturgeon can result from crayfish predation; therefore stocking locations should, ideally, be located in areas with low crayfish populations (Eggold et al. 2009).

The effects of rearing tank substrate on release behaviour indicated lake sturgeon substrate selection behaviour is not altered from artificial rearing environments (Peake 1999). Hatchery-reared sturgeon and wild sturgeon from the same population displayed similar habitat substrate selection behaviours, indicating lake sturgeon habitat selection has a genetic component and is not influenced by culture practices (Peake 1999).

In northern Ontario, lake sturgeon are stocked in the vicinity of spawning locations near the brood stock collection site. This method is thought to reduce human interference and re-connect
cultured fish to their natural habitat (J. Hunter, pers. comm.). On the scale of the Great Lakes basin it is recommended that stocking should only occur in streams that have had historical lake sturgeon spawning populations but are currently not occupied. These streams should have substrate, flow regimes, and temperature regimes that support natural reproduction. In addition, stocking should occur in areas having some control of exploitation (Auer 2003).

4.0 Marking and Monitoring

Marking is usually performed to conduct population studies and/or to assess the success of a stocking program. Marking should only be performed when a comprehensive program has been established to monitor the marked fish. Marking and monitoring hatchery-reared fish can provide information on fish survival, growth, movement, migration, temporal and spatial distributions, and macro/micro habitat preferences (Lasenby 2001, OMNR 2000).

Choosing a marking type is dependent on the project objectives, fish species, life stage, mark/tag retention time, impact of mark/tag on the fish, ability to assess and recover fish and tags, and marking cost (Lasenby 2001, OMNR 2000). Several lake sturgeon stocking programs use tags to evaluate program success and answer specific research questions (North/South Consultants Inc. 2002, Hay-Chmielewski and Whelan 1997, S. Marple, pers. comm.).

Many marking methods have been used in lake sturgeon stocking programs. External marks are the most commonly used to enhance reporting of fish by the public and partner agencies.

Both external and internal marks/tags are used for lake sturgeon. Common marking methods include: fin clip/ray removal, scute removal, Floy tags, visual implant elastomers, coded wire tags, radio telemetry, and passive integrated transponders. Branding is another effective method used although long-term retention of the mark is unknown. Many lake sturgeon stocking programs apply more than one marking method to conduct comprehensive post-stocking evaluations.

4.1 Fin Clips and Fin Ray Removal

Fin clipping involves the removal of a fin from a fish (Figure 11). This method is cost-effective, easy to perform, applicable to all ages and sizes, does not affect growth, and can be applied to groups or year-classes of fish. However, fin regeneration may result in some misidentification. Fin clips have limited marking variations and mortalities may be high in some cases due to size and condition of the fish as well as the skill of the individual doing the clipping.

Figure 11. Fin clipped juvenile lake sturgeon marked by the removal of right pelvic fin (photo courtesy of GLFC 2009b)
Fin clips are used in the Kentucky lake sturgeon reintroduction program in combination with other tagging methods. This approach facilitates easy identification and reporting of stocked fish (S. Marple, pers. comm.). In the Great Lakes basin, the OMNR and WDNR have implemented fin clips as a marking method for local lake sturgeon monitoring programs (GLFC 2009b).

Pectoral fins of sturgeon are removed primarily for age analysis, resulting in an external mark. Most studies have concluded that pectoral fin ray removal does not cause harmful effects to sturgeon (Collins and Smith 1996; Parsons et al. 2003) but may be offensive to anglers.

### 4.2 Scute Removal

Sturgeon have scaleless bodies protected by five lateral rows of body plates called scutes. The scutes provide body armour for juvenile lake sturgeon and are gradually resorbed as the fish ages (Peterson et al. 2007). The process of scute resorption in adult lake sturgeon restricts long-term marking. The removal of dorsal scutes has proven effective as a marker for more than two years in white sturgeon (Rein et al. 1994).

Scute removal is used to identify stocked white sturgeon throughout the west coast. Scute removal is also used in lake sturgeon stocking programs in Wisconsin, Tennessee, and Kentucky. Agencies commonly use this marking method to identify year-class and Passive Integrated Transponder (PIT) tag retention time.

Removing lake sturgeon scutes has been successful for marking large numbers of young lake sturgeon in the upper Tennessee stocking program (TRLSWG 2007). Kentucky also uses scute removal in their stocking program, removing the first and second lateral scute from all stocked lake sturgeon (S. Marple, pers. comm.). The impacts of scute removal on lake sturgeon are unknown.

### 4.3 Floy Tags

Floy tags are typically long round plastic tags attached to the fish at one or both ends. Tags carry an individual identification code. This method does not require a specialized recovery method, allows individual tracking, is highly visible to anglers, has high retention rates, and can be used for long-term studies. Sometimes, tag retention may be relatively short due to the deterioration of the plastic tag. Floy tags should not be used on small fish or narrow-bodied fish. They may promote algal growth, become caught in vegetation, or effect fish growth (Lasenby 2001).

A spaghetti tag is a type of external floy tag used by multiple agencies including (but not limited to): OMNR, WDNR, U.S. Fish and Wildlife Service, Lake Superior State University, Purdue University, New York State Department of Environmental Conservation, Keweenaw Bay Indian Community, U.S. Geological Survey, MNDNR, Anishinabek/Ontario Fisheries Resource Centre, Grand Traverse Band of Ottawa Band Chippewa Indians and 1854 Authority (GLFC 2009b) and Missouri Department of Conservation (2009). Schram (2007) used floy tags to determine movement patterns of lake sturgeon stocked as part of the lake-wide rehabilitation effort in Lake Superior. During routine monitoring from 1985-2007, lake sturgeon were fitted with floy tags and multiple recaptures were fitted with an additional
tag (Figure 12). Floy tags are available in a range of bright colours, aiding visual identification (GLFC 2009b).

In Missouri, all sampled sturgeon (lake, pallid and shovelnose) are marked with spaghetti floy tags to acquire information on movement, age and exploitation. Anglers report tag descriptions to the angler information telephone line (MDC 2009).

4.4 Coded Wire Tags (CWT)

A coded wire tag is a small notched wire (1.0 mm x 0.25 mm) carrying a binary code. The tag is inserted into the head and removal typically requires the fish to be sacrificed; however tags can be removed without sacrificing the fish, when implanted into the fin. Tag retention is high when implanted correctly (Lasenby 2001).

Tags have little impact on fish growth, behaviour, or survival and are suitable for fish of most ages. This tag type is suitable for large scale marking projects. An external indicator should accompany a CWT to notify tag presence.

Lake sturgeon stocking initiatives in Saskatchewan have used CWT with great success and no observed tag loss or mortalities. Despite the success, CWT were found to be time consuming, expensive, and lacked the desired program benefits of external tag identification (North/South Consultants Inc. 2002). In Kentucky, snout CWT have been used to track stocked fall fingerlings (4-5 months) but they have not reported on the long-term program feasibility of this tagging method (S. Marple, pers. comm.).

4.5 Visual Implant Elastomers (VIE)

Visual implant elastomers are injected under the adipose tissues and are visible externally. The elastomer compounds have high retention time and minimal impact on survival and growth (Figure 13). They can be applied to small fish quickly and are cost-effective (Northwest Marine Technology 2008). VIE retention time is influenced by marker location, species, and application. To date, the maximum retention time of VIE in lake sturgeon is unknown.

Figure 13. VIE markings on a juvenile lake sturgeon (from Saskatchewan Ministry of Environment 2009).
4.6 Radio-Sonic Telemetry

Radio transmitters are available in external and internal models which vary greatly in size (Lasenby 2001). Radio transmitters have been manufactured in smaller sizes allowing application to small fishes, such as juvenile lake sturgeon. External radio transmitters used for lake sturgeon should be cylindrical in shape and weigh less than 1.25% of an individual’s body weight (Sutton and Benson 2003). When affixing external radio transmitters to juvenile lake sturgeon, the application of absorbable sutures are often required to ensure adequate retention.

Survivorship of re-introduced lake sturgeon in the Coosa River has been confirmed through studies using radio transmitters. The tracking studies have also provided seasonal movement and home range data (Georgia Department of Natural Resources 2009).

4.7 Passive Integrated Transponders (PIT Tags)

PIT tags are small (10 x 0.12mm) devices containing a tracking device (microchip) and an antenna. PIT tags are inserted into small fish by making a small (1-2 mm) incision on the fish’s abdomen that doesn’t require a suture to close. Tag identification can be acquired remotely, reducing additional fish handling stress. Tag retention is generally high and ideal for long-term studies. The disadvantages of PIT tags include high equipment costs and short tracking signal range (Lasenby 2001). The individual cost of tag size relative to the fish has limited the use of these tags in the upper Tennessee lake sturgeon stocking program (TRLSMG 2007).

The white sturgeon stocking program in the Upper Columbia River adopted PIT tags to identify hatchery stocked individuals and families. Each fish was paired with a unique numbered ISO compliant 134.2 kHz PIT tag. PIT tagging can only be utilized on lake sturgeon larger than 15 g, which is typically greater than average stocking size (UCRWSRT 2002).

The WDNR has implanted lake sturgeon with PIT Tags for over 6 years. Recent advances in PIT tag implantation methods have allowed more fall fingerling to be fitted with PIT tags. In 2003, 25% of the 2,000 fingerlings stocked in the Milwaukee River were implanted with PIT Tags. This marking and stocking program has been successful and is scheduled to continue into the future (WIDNR 2009).

5.0 Population Genetics

Canadian sturgeon are believed to have originated from two separate refugia in the Mississippi and St. Lawrence River drainages that were colonized after the Pleistocene period (Wirgin et al. 1997; Kjartanson 2009). North American sturgeon species have shown relatively little genetic variation and only minor substructuring among populations (Wirgin et al. 1997). However, within Ontario and its surrounding waters, genetic analysis of microsatellite loci has identified fundamental genetic differences between Ontario lake sturgeon populations (DeHaan et al. 2006, McQuown et al. 2003, Ferguson et al.1993).

The spatial genetic structure of lake sturgeon may be broken into hierarchically geographic units across the landscape from lake basin, by river,
Drainage basin or river tributary (DeHaan et al. 2006, McQuown et al. 2003) and despite anthropogenic habitat fragmentation and population declines, life history characteristics of longevity and iteroparity, remnant lake sturgeon populations of the Great Lakes appear to have maintained their genetic diversity (DeHaan et al. 2006).

On a broad geographic scale three distinct lake sturgeon clusters exist: Hudson Bay drainage (northern Ontario); upper Great Lakes (Wisconsin); and the lower Great Lakes-St. Lawrence River (McQuown et al. 2003). Further population genetic differences exist within these geographic groupings, indicating high levels of natal fidelity despite long distance movement patterns (DeHaan et al. 2006, McQuown et al. 2003). Analysis of lake sturgeon population structure and genetic diversity in Canada by Kjartanson (2009) showed that sturgeon have relatively high levels of genetic diversity across Canada and that most rivers have genetically distinguishable lake sturgeon populations (Kjartanson 2009).

These findings are integral within the planning process for lake sturgeon management and recovery plans. Stocking is a valuable tool that may be required for the recovery of lake sturgeon populations; however it may have negative impacts on remnant stocks. The release of genetically similar or closely related lake sturgeon can cause outbreeding depression (see Glossary), resulting in reduced genetic plasticity of native sturgeon populations. The degree of impact depends on the number of breeding individuals in a population per year (Ludwig 2006). Since many sturgeon populations are currently below critical population thresholds, the loss of phenotypic and genotypic diversity may become more critical, depending on the population (Ludwig 2006). The success of a long-term stocking program is influenced by demographic and genetic components, both of which need to be considered prior to stocking.

Analysis of a lake sturgeon re-introduction program in the Mississippi and Missouri Rivers indicated that a multiple-year stocking plan can transmit the source genetic diversity from Lake Winnebago stocks to Mississippi and Missouri River lake sturgeon (Drauch and Rhodes, 2007). Single-year stocking plans may not adequately transfer the available genetic diversity from a source population into a stocked population (Drauch and Rhodes, 2007). In addition, native brood stock from the drainage systems should be used for introduction programs where possible to maximize local adaptive genes and maintain overall genetic integrity and fitness (Drauch and Rhodes, 2007).

Native stock movement and preferred habitat should be understood before stocking non-native lake sturgeon brood stock to ensure the selected stock behavioural patterns correlate with stocking goals and objectives. Juvenile lake sturgeon from lake and river stocks have different movement patterns, and these patterns are displayed when stocked in the same location (Thuemler 1988). For re-introduction programs, behavioural traits should be assessed during the brood stock selection processes.

There are many issues surrounding potential genetic impacts of stocking including obtaining a suitable donor strain for stocking, assessing the potential impacts on remnant stocks and obtaining access to enough spawning individuals to provide representative
genetic diversity of the donor stock or a new population. All of these issues must be reviewed and considered for each lake sturgeon population. Native populations should be used for brood stock until basic genetic structures are understood (Auer 2003). Lake sturgeon stocking guidelines were developed for the Great Lakes basin and document underling principles that should be integrated into any lake sturgeon stocking program in Ontario. The guideline is based on four management steps: (1) identify genetic stocking units; (2) identify priority preservation populations; (3) develop a stocking evaluation decision tree; and (4) design a stocking program design for implementation (Welsh et al. 2010).

Preservation of lake sturgeon genetic diversity is a goal identified in most lake sturgeon management plans. Essential genetic information required for culture should be established prior to long-term program commitment. Hatchery practices should include brood stock collection, mating, and release protocols. Spawned populations should preserve existing native genetic diversity, frequencies of rare alleles and ensure family contributions are preserved and balanced to avoid swamping of hatchery or domesticated families (Eggold et al. 2009).

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Glossary of Terms

**Benthic** – refers to the bottom substrate and the species which inhabit that area.

**Caviar** – a highly valued delicacy comprised of salted, unfertilized eggs from female sturgeon or paddlefish.

**Conservation** - the act of preserving, guarding, or protecting; the keeping (of a thing) in a safe or entire state; preservation.

**Conservation Stocking** – stocking fish to protect and preserve existing populations from declining in population and or diminution of their ecological role and function.

**Conservation Culture** - rearing fish to protect and preserve existing population genetics for the purpose of population rehabilitation, re-introduction, or restoration, compared to commercial farming.

**Commercial Farming** – rearing fish for the production of fish products (ie., meat and roe) or fisheries supplementation.

**Extirpation** – the elimination of a species of subspecies from a particular area but not from its entire range.

**Habitat Conservation** - a land management practice that seeks to conserve, protect and restore habitat areas for wild plants and animals.

**Introduction** – to add hatchery fish into the wild.

**Isinglass** - a substance obtained from the swimbladders of fish, specifically sturgeon. It is a form of collagen used primarily for the clarification of wine and beer.

**Juvenile** – a young fish that has not reached sexual maturity.

**Negatively phototactic** – the movement of an organism away from a source of light.

**Outbreeding depression** – reduced fitness, often measured as reproductive success, resulting from interbreeding between genetically distinct populations or species.

**Negatively phototactic** – the movement of an organism away from a source of light.

**Polygamous mating behaviour** – spawning activity which involves more than one mate.

**Polyploidization** – a state where there are more than two homologous sets of chromosomes. The occurrence of polyploidy is a mechanism for speciation.
**Rehabilitate**- to resort, repair or make habitable again, or to regain maximum self-sufficiency and function in a normal or as near normal manner as possible,

**Rehabilitation Stocking** - stocking hatchery fish to restore populations to a point of maximum self-sufficiency and function within the current ecosystem.

**Reintroduction** - the act of introducing a species again, specifically the release of a captive or hatchery species into the wild.

**Re-introduction stocking** - stocking hatchery fish into an area they historically occupied.

**Restoration** - the return of a landscape, ecosystem, or other ecological entity (sturgeon populations) to a predefined historical state.

**Stock** – a grouping of fish usually based on a genetic relationship, geographic distribution or movement pattern.

**Supplementation Stocking** – stocking hatchery fish into a population to make up for a population deficiency, acting as a compensation not conservation management tool.

**Transfer** - to move wild fish from one waterbody into another waterbody.