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Genoa National Fish Hatchery
Lake Sturgeon Culture
Standard Operating Procedures

Department of the Interior
U.S. Fish and Wildlife Service
Great Lakes-Big Rivers Region

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Introduction:

The Lake sturgeon *Acipenser fulvescens* is currently a species of concern for the Fish and Wildlife Service, as population numbers are declining over much of their historic range. Reasons for the decline are overexploitation through historic fisheries, dam construction blocking or inundating spawning and nursery habitat, and point source and non-point source pollution (Smith, 1986). The purpose of writing these standard operating procedures (SOP) is to disseminate information to interested organizations that may initiate sturgeon culture for restoration. It is designed to be used as a guide to further the advance of lake sturgeon culture and to serve as a written record to further refine new techniques for lake sturgeon culture as they emerge. Caution should be taken by the reader as these are station specific in scope and may not apply to every culture system and water quality used for lake sturgeon culture. The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the Federal government. This publication is provided through the Region 3 Fisheries Data Series publication process. The Fisheries Data Series was established in 2003 to provide public access to unpublished study results. These reports are intended to document short-term field studies that are limited in or lacking statistical interpretation. Reports in this series receive limited internal review prior to release and may be finalized in more formal literature in the future. Consequently, these reports should not be cited without approval of the author or the Project Leader.

Lake sturgeon have been raised at Genoa National Fish Hatchery (NFH) since 1993 as part of a multi-agency effort between the US Bureau of Indian Affairs, the Wisconsin Department of Natural Resources (DNR), and the US Fish and Wildlife Service. These efforts were to restore lake sturgeon populations to Reservation waters on the Menominee Indian Reservation (Runstrom et al. 2002). Culturing techniques for Genoa NFH were originally adapted from methods developed by Wisconsin DNR at Wild Rose Fish Hatchery. Since then, the Genoa NFH Lake Sturgeon Propagation Program has expanded to include partnerships with the White Earth Indian Reservation, the Minnesota Department of Natural Resources (DNR), and the Missouri Department of Conservation to restore Lake Sturgeon to the Red River, the middle Mississippi River, and the lower Missouri River watersheds. In 2005, over 41,000 Lake Sturgeon fingerlings were stocked to aid ongoing restoration efforts, and 2,000 yearlings were held for extended rearing for the 2006 spring stocking. Three strains are currently reared at the hatchery (Table 1). The Wolf River strain is stocked into Legend Lake (WI), the Wisconsin River strain is stocked into Pools 21 and 22 of the Mississippi River in the state of Missouri, and the Rainy River strain is released into White Earth and Round Lakes on the White Earth Indian Reservation, and the Red River drainage. Strain specific restoration is based on the premise that by releasing young fish into a proximate watershed to where the parent fish originated, restoration success will be higher because of the strain's localized adaptations to the stocked river system.

Table 1. Lake sturgeon (LST) strains and spawning information for Genoa NFH including contacts.

Strain	Appr. Spawning date	Spawning location	Spawning Contact	Stocking Location	Stocking Date	Stocking Contact	Annual number produced
Wolf River	Last week of April	Upper Wolf, Embarrass River	WIDNR	Legend lake, WI	April and Sept.	Menominee Indian Reservation	2,000 spring yearlings
Wisconsin River	First week of May	Wisconsin Dells	WIDNR Wild Rose SFH	Central Miss. Riv. And Missouri River	Sept.	Missouri Conservation Dept.	5,000-10,000 six inch fall fingerlings
Rainy River	First week of May		Rainy River First Nations	White Earth, MN Red River drainage, MN	Sept.	White Earth Indian Reservation	Up to 25,000 six inch fall fingerlings

Spawning:

In order to maximize the genetic contribution to each production strain, eggs are collected from at least five female lake sturgeon from each strain per year. Adult fish in the actual act of spawning are collected over the spawning grounds with large hoop nets. 2 netters scoop the fish out of the water, one working at the head end with a netter at the tail, and the fish is brought up the bank for spawning. Male milt is aspirated with a 20 ml syringe with a piece of vinyl tubing attached. The male's abdomen is slowly compressed toward the vent to help express the milt. Care needs to be taken to avoid contact with water as this will activate the sperm and its lifespan will be greatly reduced. Roughly 2-5 milliliters of sperm is collected when a male is freely expressing milt. Males are captured as possible until at least 5 have given milt, so that the spawning matrix mentioned below can be followed. A female when captured is turned over on her back and pressure is expressed from her pectoral fins down to her vent. If eggs are flowing freely, or are fairly easily expressed through a small amount of pressure, then the female is considered a good candidate for spawning. The best candidate for spawning is when the fish's vent actually has to be blocked with a thumb/finger to prevent egg loss when handling.

A spawning matrix for sturgeon that we are directly responsible for is as follows: Eggs are then separated into 5 equal portions and each equal portion is fertilized with milt from one male. Milt is mixed with water at a 1/200 ratio and then added to the eggs. The solution is mixed by stirring with a turkey feather and left standing for 1 min. The milt mixture is poured off promptly after 1 minute and fresh water is added to reduce fertilization with multiple sperm. Due to the sturgeons tendency of polyspermic fertilization, milt is diluted to reduce the opportunity of this occurring and contact time with the sperm is reduced to one minute. The water used in this solution is clean well water brought from the hatchery. Use of river water is avoided throughout the entire spawning process to prevent transport of disease from the wild to the hatchery. The eggs of each individual female that was originally divided into 5 equal portions are combined together after fertilization has occurred. They are then rinsed in fresh well water. Lake sturgeon eggs have an adhesive layer that allows them to stick to substrate in the wild, but causes the eggs to stick together in egg jars, encouraging fungal growth. To prevent adhesion of the eggs to one another, eggs are mixed with a turkey feather for 30-40 min in a solution of Fuller's Earth and station water. The proportion of Fullers Earth to water is more of an art than science. When the Fullers Earth begins to precipitate on the bottom of the mixing container, that is an indication that the mixture is adequate for de-adhesion of the eggs.

Safe Shipping Procedure:

Eggs should be transported to the hatchery as soon as possible after spawning, unless they are going to be held until after neutralization has occurred. Eggs begin developing as soon as they are fertilized, so make sure to ship within 8 hrs after spawning to prevent mortality from shipping during sensitive stages of development. Eggs should be shipped in plastic bags filled with 1/3 water and eggs, and then filled to the top with pure oxygen. Care should be taken not to over-chill the eggs during shipment back to the station, but rather to maintain temperatures within 10 degrees of ambient river temperature and incubation temperature of the receiving water at the station.

Incubation:

Once the lake sturgeon eggs arrive on station, disinfection with a topical buffered iodophor solution such as Argentyne at 100 ppm (38.6 ml/gal of water) is administered for 10 minutes. Eggs can be tempered during disinfection to adjust for water temperature differences between the shipment water and the hatchery water supply. The eggs are then enumerated by establishing a sample count using water displacement in eggs/ml. Once this is established, an entire egg volume is obtained using a wide mouth graduated cylinder. Eggs are then dispensed into egg jars for incubation. Egg lots are separated according to female and incubated in single modified McDonald hatching jars per female egg take. A hatchery supply water of approximately 58-60ºF is desirable for incubation of lake sturgeon eggs. This temperature range is ideal for egg development and for control of fungal growth. Water temperature at Genoa NFH is controlled by a boiler system with the ability to mix cold and hot water in order to maintain desired temperature (Fig 1). To further discourage fungal growth, eggs are placed in modified McDonald jars (at least 0.5 qt per jar) with round bottoms and eggs are rolled by controlling the flow of water. Rolling should be gentle until the end of the blastula stage, approximately 37 hrs at 59ºF. If these methods are not successful for controlling fungus, a treatment of 500ppm of peroxide can be administered. Treatments with formalin can negatively affect survival of lake sturgeon eggs (Rach et al. 1997). Eggs are typically incubated for 6 - 10 days, depending on water temperature. The variance in days is primarily due to the number of temperature units the eggs received prior to delivery (Appendix A).

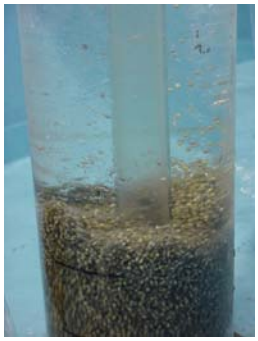

Figure 1. (left) Boiler room at Genoa NFH with a secondary heat exchanger to the left.

Figure 2. (above) McDonald jars with slightly increased water supply allowing fry to be gently lifted out while eggs are rolled gently until hatch.

A mean developmental index has been developed by the station to use as a guide for safe shipping, time of hatch, and time of initial feeding (see Appendix A). The temperature data points are derived from (Wang et al, 1985).

Hatching:

Once the fry begin to hatch, careful attention should be given to make sure fry do not "roll to death" in the jar. The water supply to the jar can be increased slightly to help lift the sturgeon out, yet too much may increase mortality (Figure 2). If fry do not swim out,

the remaining eggs and fry should be either placed directly in the rearing tank or in floating screens to complete the remaining incubation process. The mesh of the screens needs to be large enough to hold the eggs in place, but small enough to allow the hatched fry to pass through and exit the screen. Eggs need about 5-10 days of incubation to hatch (Table 2).

Table 2. Past hatching information for lake sturgeon at Genoa NFH.

Strain	Starting date	Hatching date	Incubation days	Initial feeding
RRW-2003	5/1/03	5/10/03	9	5/12/03
WIR-2003	4/28/03	5/8/03	10	5/10/03
WOW-2003	4/26/03	5/1/03	5	5/3/03
RRW-2004	5/9/04	5/17/04	8	5/23/04
WIR-2004	5/6/04	5/13/04	7	5/15/04
WOW-2004	4/29/04	5/5/04	6	5/7/04

Once all the fry have hatched (Figure 3), they become photonegative for a period of about one week. During this time a lamp can be placed by the tail screen to prevent fish from getting sucked into it while cleaning (Figure 4). The fish have a tendency to bunch up and suffocate in the corners during this period as well (Figure 5). Sunken floor brushes or some other type of media should be placed in the tank to help alleviate this problem (Figure 6). The brushes provide cover for the sturgeon to hide under. Care should be taken to lift brushes and agitate fry with a feather a minimum of twice daily. A good alternative is also non skid floor matting squares that snap together. Care should be taken to order mats that have not been treated with a fungicide/pesticide that may adversely affect the fry. Circular starter tanks are a good alternative to traditional rectangular tanks

Figure 3. Newly hatched lake sturgeon fry.

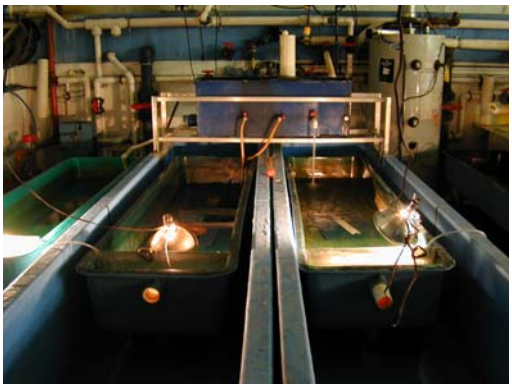

Figure 4. Lamps are placed by tail screens to encourage fry to stay away.

Figure 5. Fry may "bunch up" and suffocate without some type of media to hide under.

Figure 6. A brush or another type of media may prevent suffocation problems.

Figure 7. These 4' circular tanks were used the raise lake sturgeon fry at Genoa NFH during 2005 feed trials. The flow gently removes waste from the tank without creating too much current for young sturgeon fry. The tanks also make great replicates for different diet trials.

Because their design prevents areas of reduced flow in tank, and allows for removal of waste without creating a strong current that can push young sturgeon up against the screen. Circular tanks also retain feed/artemia cysts longer in the tanks due to low water flows needed. Circulars also keep the food at a much higher concentration for the fry than a rectangular tank due to their reduced volume, and can be drawn down before feeding to further retain food/increase feed density in the rearing unit for an extended period of time.

Figure 8. First feeding lake sturgeon fry

Initial Feeding:

Near the onset of exogenous feeding (Figure 8), water is switched from heated well water to heated pond water. Water quality problems can increase with heating well water. Well water is typically low in dissolved oxygen, and heating the water can decrease the amount of dissolved oxygen further, and increase total gas pressure of the incoming water to deleterious levels. Pond water is usually well oxygenated, and it is naturally heated by the sun. Another advantage of using pond water is that it can stimulate feeding and growth by providing zooplankton, a natural food source found in pond water (Figure 9a). Lamps are placed in ponds near intake structures to attract more zooplankton to intake water, and increase the amount of zooplankton entering the culture tanks.

Fry Diets from .75 inches to 1.5-2 inches:

Five days after hatch, live brine shrimp nauplii (Figure 9b) are fed 3 or more times throughout the day. Initially 1 hatching cone (~150 mls of cysts in 5 gallon rearing unit) can be used, but over the course of a month as many as 10 cones can be fed daily, depending on number of fish. Brine shrimp cysts should be stored in an airtight container below 50°F, but not below freezing. If properly stored, brine shrimp cysts remain viable for an extended period of time such as one production season, so a bulk order for the entire season is placed in the spring, before sturgeon eggs arrive on station. Approximately one 15 oz can of cysts (1 pound) is needed for every 1,500 fry over the period of time sturgeon are feeding on brine shrimp. The recipe for hatching brine shrimp is:

Figure 9a. *Daphnia sp.* one of the many types of zooplankton occurring naturally in pond water. Figure 9b. Artemia nauplii

1. Fill a 5 gallon cone to about 1" from top with 70-82 degree water or allow time for cold water to warm up.
2. Add 425mls of NaCl to cone and allow salt to dissolve. Flush salt plug through bottom release valve and reintroduce to top of cone. This will avoid plugging harvest valve with salt.
3. Add borax to bring pH to 7.5 - 8.5* (*optional in soft water)
4. Add 125-200 mls of brine shrimp cysts to cone and stir them into solution.
5. Place air stone to allow adequate circulation and let incubate for at least 24 hours. Expose cysts to bright light for at least 10 minutes during incubation.
6. To harvest nauplii, pull air stone out of cone and let settle for 10 -15 minutes. Unhatched cysts and empty shells should float to the top, while the artemia nauplii sink to the bottom of the cone. Be sure not to feed unhatched cysts and empty shells. There is no nutritional value to the shells and cysts, and fish will starve to death with full guts(Sorgeloos, and Persoone, 1975). Harvest shrimp from bottom and feed. A saran mesh may be used to strain artemia. This minimizes salt and bacteria added to lake sturgeon tanks, and allows for an accurate measure of artemia nauplii fed. Scrub out cone to reduce bacterial growth and let dry completely prior to starting the next batch.

Figure 10. (left) Five gallon artemia hatching cones.

Figure 11. (right) Large hatching cone 15 ounce cyst capacity.

Nauplii yield depends on egg size and quality. Check artemia supplier's website for yield estimates. Hatch rates should be at least 90 % hatch rates to reduce the number of un-hatched cysts being eaten by the sturgeon. Using a premium grade of brine shrimp eggs, one hundred mls of cysts will yield approximately 300 mls of strained artemia after a 24 hr incubation period. There are an estimated 50,000 nauplii in one ml of these strained artemia. If hatch becomes consistently poor, decapsulation of cysts is possible and accomplished by reproducing a recipe on a production scale supplied by Campton and Busack, 1975, but decapsulation is labor intensive and usually unnecessary if cyst quality is high. At Genoa NFH, an excess of artemia is fed to ensure that each fish could have as many nauplii as needed (Table 3). Daily rations are generally split into four feedings per day and measured in strained artemia nauplii. A feeding schedule with the last feeding in the evening hours may increase nauplii intake because lake sturgeon appear to be more active at night, and may actually eat more when fed during active hours. Past history has shown that young sturgeon require feeding over at least a 12 hour period each day. If young sturgeon are not fed within 12 hours of the last feeding, fish become anemic and may die.

Table 3. Feeding chart for lake sturgeon fry 8-10 days after hatch up to two inches for lake sturgeon 2005 at Genoa NFH.

Days since 1st feeding	length	#/lb	lbs/1000 fish	% BW/day fed	ml cysts to make/1000 fish	ml strained artemia/1000 fish	conversion rate
1	0.89	9519	0.11	176.62%	27.86	84.2	38.5
4	0.96	7448	0.13	125.74%	25.35	76.6	14.4
7	1.05	5741	0.17	88.34%	23.10	69.9	10.1
10	1.15	4425	0.23	52.12%	17.68	53.5	6.0
13	1.25	3411	0.29	91.08%	40.09	121.2	10.5
16	1.36	2629	0.38	66.90%	38.20	115.5	7.7
19	1.49	2027	0.49	47.94%	35.51	107.4	5.5
22	1.62	1562	0.64	52.91%	50.84	153.8	6.1
25	1.77	1204	0.83	30.75%	38.34	115.9	3.5
28	1.95	893	1.12	25.93%	45.98	131.8	6.2

Feeding sturgeon 2 - 3 inches:

The young nauplii fed sturgeon are eventually fed frozen bloodworms (chironomid midge larvae). This habituation is done while they are about 2 inches in length. Initially, frozen bloodworms, which are too large for the sturgeon to consume, are either chopped in a food processor or grated by hand using a cheese grater. The grated mixture can then be fed to the young sturgeon. To aid diet transition, grated bloodworms can be mixed with artemia nauplii, or fed at the same time to habituate the lake sturgeon to the bloodworms at feeding time. Once all sturgeon are consuming grated bloodworms, gradual weaning from grated bloodworms to full bloodworms can be accomplished by mixing grated bloodworms with full bloodworms. The proportion of artemia nauplii are reduced as the amount of grated bloodworms are increased to further aid in this switch of diets. Grated bloodworms should be fed until the average size is around 3 inches. It should be observed that the smallest fish among the lot should efficiently consume a full bloodworm before switching entirely to whole worms. Not doing so may result in a greater size variation among the sturgeon thereafter, or a loss of the smaller individuals from the population.

Figure 12. Lake sturgeon at 2 in or, about the size when they can begin the transition from strained nauplii to grated bloodworms.

Figure 13. A chironomid midge larvae, these are commonly known as bloodworms, because of their blood-red color.

Feeding sturgeon 3-6 inches:

Traditionally fish are fed either whole bloodworms, adult brine shrimp, or ¾" krill throughout the remaining months until a fall fingerling of 5-6" is achieved. A conversion rate of 5-7 is used for a growth of 1.5" a month at 68 degrees F.

Figure 14. sturgeon at conversion size

Table 4. Sturgeon feeding table for fish 2-6 inches in length

	Bloodworm/krill feeding chart through 6"					
	length	**#/lb**	**lbs/1000fish**	**conversion**	**%BW/day fed**	**lbs bloodworms/1000fish**
bloodworms	2.0	833	1.20	7	47.20	0.57
	2.3	537	1.86	7	40.80	0.76
	2.7	348	2.87	7	35.30	1.01
	3.0	249	4.02	7	31.60	1.27
	3.4	177	5.65	7	28.20	1.59
	3.7	135	7.41	7	25.80	1.91
	4.0	102	9.80	7	23.50	2.30
	4.3	81.6	12.25	7	21.70	2.66
krill	4.7	64.2	15.58	7	20.10	3.13
	5.0	52.9	18.90	7	18.80	3.55
	5.4	42.9	23.31	7	17.60	4.10
	5.7	36.2	27.62	7	16.60	4.59

Disease Prevention:
Increasing temperatures and waste from grated/uneaten bloodworms provide the perfect environment for bacterial growth. Bacteria compromises water quality and can cause bacterial gill disease in young fish (Post, 1983). To prevent this from happening, treatments of chloramine-T are administered weekly after the fish are started on grated bloodworms. Sturgeon are prophylactically treated under INAD # 9321 by lowering the water level to 1 ft in each tank. Chloramine-T is then administered in the standing bath for 1 hr at 15 ppm. Fish are watched closely during treatment. Observe sturgeon for signs of distress. If fish are noticed swimming erratically, piping at the surface or a loss of equilibrium occurs, the treatment should be terminated, water flushed from the rearing unit and a fresh flow of water should be added to the tank. Some researchers also advocate the disinfection of newly hatched artemia cysts through the decapsulation process (Gilmour et al, 1975). We have not gone to this extreme yet, but merely mention this as a possibility if bacterial problems with larval sturgeon arise.
Due to the lake sturgeon not readily accepting prepared diets, care should be taken to diagnose and treat diseases early before they become systemic, or treat with approved chemicals on a prophylactic basis if there is a station history of specific disease outbreaks. Topdressing feed is not a viable option for this species as the process of administering an effective dosage of therapeutant into current live and natural diet regimens would be impractical. There is an example of enriching artemia with antibiotics in the literature, but we currently we have not had to treat sturgeon smaller than 2-4 inches with a systemic antibiotic (Dixon et al, 1995).

Feed Trials:

In 2003 and 2005 at Genoa NFH, feed trials were run to experiment with different types of dry diets in conjunction with the traditional first diet of pure artemia nauplii. A pilot study in 2003 replacing live artemia with Biodiet starter diet resulted in a 35% conversion rate. Trials in 2005 with an artemia replacement diet, Inve Proton starter diet, resulted in an 18% conversion. Another method was used in 2005 that resulted in an estimated 65% conversion rate. This method included mixing live strained artemia nauplii with Biodiet starter diet in an 80:20 ratio, and slowly transitioning to a 20:80 ratio. This method greatly reduced the amount of artemia nauplii needed to raise lake sturgeon to two inches, and reduced the amount of other natural foods at later stages in the diet. This resulted in a large food cost savings, reduced the amount of freezer space needed to store large amounts of frozen natural foods, and resulted in larger, more robust lake sturgeon. This method can only be recommended for small lots of sturgeon that can be properly given the time and attention that this method requires to ensure that the fish are properly trained on artificial diets. It is not recommended for large scale production lots of sturgeon at this time.

Fish Health Concerns

Hatchery reared lake sturgeon are susceptible to a variety of diseases and parasites. The most common health issues will be listed, and the methods available to alleviate:
White Sturgeon Irido-like virus: This disease is carefully screened for in Lake Sturgeon populations where broodstocks are collected. This disease first surfaced in white sturgeon hatchery populations, but has found to be a cause of significant mortality in hatchery populations of pallid sturgeon. Fin clips are taken from fish that are in the returning spawning migration and histological samples are prepared and examined before eggs are brought on station. A minimum of 60 fish are examined from the wild brood populations prior to importation of the eggs. The causative viral agent creates cell disruption within the fin cell, alerting biologists to the virus. The only true method of control for viral pathogens is prevention. However, egg disinfection and using station water for processing eggs also offers a modicum of protection against any surface viruses that may be susceptible to iodophors (Erdahl, 1994).

Bacterial Gill Disease: This disease is a common disease of hatchery fish, including sturgeon. The causative agents are opportunistic flavobacteria and flexobacteria, commonly found in air and water (Post, 1983). When environmental conditions are in favor of the disease and immune systems are compromised due to elevated temperatures and poor water quality, heavy fish losses may be experienced. Losses have been controlled by a prophylactic treatment of 15 ppm of chloramine T administered as a weekly standing bath treatment just before the fish are converted to ground bloodworms. This treatment regime has been effective in alleviating mortalities associated with this disease. This regime, as stated above, can only be used under the Federal Drug Administration's Investigational New Animal Drug Program.

Columnaris: Columnaris is a gram negative bacteria that is an opportunistic pathogen of sturgeon. If not caught early, losses of up to 100% of the population can occur. Columnaris is common in pondwater and begins as a topical infection, which can quickly become systemic. Genoa has a history of columnaris infections throughout the year due to our reliance on pondwater containing resident fish populations. Outbreaks can occur suddenly, and before any external signs appear. In a typical outbreak, if external symptoms appear, it is usually too late too save more than 50% of the infected population. Spring and summer outbreaks can be severe if not controlled early due to temperature regimes favoring the pathogen (18-25 degrees Celsius). The disease is controlled by a weekly 15 ppm standing bath treatment of chloramine T administered weekly. This regime is the same as the aforementioned Bacterial Gill Disease treatment, which prevents both diseases in one application. This has been used with great success, with no outbreaks occurring within the last few years.

Eye flukes(Diplostomum spathaceum): Eye fluke parasites are common in populations of wild and hatchery fish (Marcogliese et al, 2001) and can become problematic in restoration programs due to the metacercariae settling in the lens of the eye, causing cataracts and possible blindness in extreme infections. The parasite relies on gulls as the primary host and freshwater snails as an intermediate host, so avoidance with one or both of these two species eliminates flukes if within a closed water conveyance system. Ponds at the Genoa hatchery are dried at least once per year, and the pond that is used as a water source for the lake sturgeon is dried and allowed to freeze out over the winter. This is an attempt to reduce/eliminate snail populations at the station. Another method of control being explored is to filter pondwater through crushed rock placed around the intake screens of the water intake of the pond water source. This is an attempt to filter out any free swimming cercariae that may be present in the pondwater source. Bluegill adults are also used as a biological control. The adults are stocked into the influent pond to reduce adult snail populations while the pond is in use as a water supply.

Figure 15. Cataracts in RBT due to eyefluke

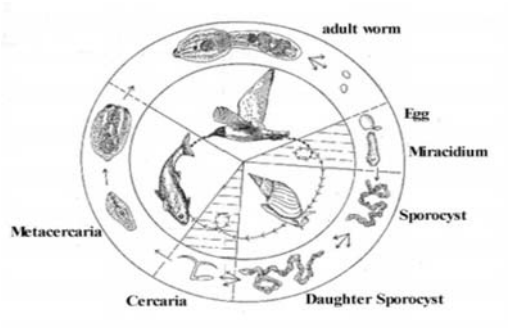

Figure 16.Lifecycle of *D. pseudospathaceum*

External Parasites

Losses of fingerling lake sturgeon due to external parasites are uncommon in healthy populations of cultured lake sturgeon. The only recorded instance at this station was when fish were received as hatched fry, and parasite loads were carried during the shipment. Parasites identified at this incidence were presumed to be high enough to actually affect fish respiration, and asphyxia resulted. The small surface area of the gills of lake sturgeon fry presumably exascerbated the mortalities. Parasite species present were Ichthyobodo, Trichodina, and Ambiphyra, all common waterborne external protozoan fish parasites. No hatched sturgeon are now brought onto the station, and all eggs are topically disinfected to reduce the possibility of disease introductions with live fish occurring.

Environmental Conditions:

Lake sturgeon are exposed to many environmental conditions that may negatively affect their overall condition and ultimately survival in fish culture systems. The following are a list of environmental factors to consider when designing fish culture systems for lake sturgeon and during unexplained fish losses.

Gas supersaturation: When using heated water and/or well water from a deep groundwater source under pressure, there is a potential for source waters to be supersaturated with atmospheric gases at levels that may be deleterious to sturgeon. This is especially the case in the earlier life stages of fry, when heating water is more likely to occur in the early spring. All waters used in the lake sturgeon culture process at Genoa are degassed with packed column degassers and aerators which reduce gas pressure in the incoming water to acceptable levels.

System failures/Low oxygen/High water temperature mortalities: These type of losses have occurred in the past at Genoa. The hatchery has installed backup blower systems with airstones for each tank, with an alarm system with backup power for pumps to alleviate power/water loss situations and restore flows in case of system failures. These systems are expensive but are a must in any attempt to culture this species as a loss of a yearclass would be very costly and highly detrimental to a long term restoration effort.

Culture system design: The importance of system design is stressed here because culture system design can negatively impact fish health and survival, especially in young life stages when the fish are just beginning to accept exogenous feed. Fish culture systems for early life history sturgeon should be designed to allow the initial feed to be at a high enough density in the starting tank for a long enough period of time for the larval sturgeon to be able to find it, and recognize it as a food item, and consume it. This is best done in shallow circular tanks with low water flows entering the tank with little current to suspend the food and/or sweep it too quickly out of the culture system. Other methods include lowering water levels before feeding to further increase the food density in the tank to create less space for the sturgeon to have to search for the food. Then the food is also held for a longer period of time in the culture tank, resulting in the sturgeon being exposed to the food for a longer period of time.

Systems designed to feed out small amounts of artemia/dry food over a 24 hour period have not been successful due to the food density not being at a high enough level in the tank for the fish to find. Large die-offs that occur 2 weeks after the yolk sac has been absorbed can

usually be explained by the fish starving to death, and running out of energy reserves before being successfully converted onto exogenous feed.

Contaminated feed: There is a possibility of contamination when using natural feeds as a diet source. The acquisition of midge larvae is a potential source of contamination. These animals are often imported from China, where they are harvested from sewage lagoons, put in plastic bags and flash-frozen before shipment (Frank Horvath, personal communication). The potential for heavy metal contamination in this type of environment may be detrimental to the success of a sturgeon restoration program. Currently we have not found an acceptable replacement diet that performs well enough to apply to the larval sturgeon from 2-4 inches in length. Pacifica krill, which is caught off the west coast, is supplied to the fish as soon as they are large enough to accept it (from 4-8 inches) in order to minimize not only cost, but the potential of long-term effects of contaminants through the bloodworm diet.

Distribution

The final chapter in the culture of lake sturgeon is the successful stocking of healthy lake sturgeon into receiving waters. This will ensure a quick acclimation period which should reduce predation and enhance acclimation success. Stocking of fall fingerlings should produce a one year survival rate of 20 percent, with spring yearlings achieving a rate of 80% first year survival. Annual mortality rates fall drastically after the first year due to the sturgeon achieving sizes that hinder high mortality rates. (R. Bruch, personal communication). Some management agencies have held released sturgeon in net pens in receiving water for 24 hours before release. This allows monitoring of stocked fish for delayed mortality and a period of acclimation before release. Care needs to be taken to ensure that sturgeon do not get caught in the net mesh, or folds of the net, thereby incurring mortality. Sturgeon do not transport well in salt solutions of greater than 0.5%. Fish hauled should have a salt bath of .25% solution or less to ensure that equilibrium is maintained and the fish are not too lethargic at stocking. They also do not handle high loading densities well. The following table (column 1) is a guide for sturgeon loading based on station experience:

Table 5. Maximum densities, (lbs./gal), that can be safely transported for 8-10 hrs. Values are for water temperatures between 55^0F - 70^0F.

No. fish/lb.	**Lake Sturgeon**	Centrarchids	Percids/Esocids	Cyprinids
25	.75	1.25	1.30	2.20
100	.50	.75	1.30	1.50
500	.50	.50	.66	1.33
1000	.25	.40	.55	1.33

Trucks should be supplied with a source of pure oxygen administered through airstones located at the bottom of the distribution unit. 12 volt Freshflo aerators should be supplied to reduce elevated CO2 levels that occur during hauling. Aerators that have some method of speed control are recommended. Small sturgeon do not have the swimming strength to avoid being pulled against the screen of aerators pulling at full speed (8 amps). Fish should be held off feed before transportation to reduce metabolites in the hauling unit. Generally, for every 2 inches of length at stocking, a 24 hr. fasting period should be observed. This rule applies for a maximum of 4 days. Sample counts for the purpose of enumeration should be done at the end of any fasting regime to prevent stocking record inaccuracies.

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Appendix A. Lake sturgeon development at variable temperatures.

Temp F	Days to Safe Shipping 12% (neutralization)	Days to Hatch 30%	Days to Exogenous Feeding 100%
57	3.6	8.1	26.1
58	3.4	7.4	24.0
59	3.2	6.9	22.0
60	3.1	6.4	20.5
61	2.9	5.9	19.1
62	2.7	5.5	17.8
63	2.5	5.1	16.7
64	2.3	4.8	15.7
65	2.2	4.5	14.7
66	2.0	4.2	13.9
67	1.8	3.9	13.2
68	1.6	3.7	12.5
69	1.4	3.5	11.9
70	1.2	3.3	11.3
71	1.1	3.1	10.8
72	0.9	3.0	10.4

Appendix B. - Table showing individual data points on regression line, and coinciding development index per day per temperature point.
(When development = 12% (.12) safe shipping is possible)
(When development = 30% (.30) hatching begins)
(When development = 100% (1.00) exogenous feeding begins)

Initial egg take to exogenous feeding

Temp	Hours to exogenous feeding	Development per day	Days to first feed
45	2794.7	0.0086	116.4
46	2356.2	0.0102	98.2
47	2008.1	0.0120	83.7
48	1728.4	0.01389	72.0
49	1501.2	0.01600	62.6
50	1314.9	0.0183	54.8
51	1160.6	0.02068	48.4
52	1031.7	0.0233	43.0
53	923.2	0.0260	38.5
54	831.2	0.0289	34.6
55	752.7	0.0319	31.4
56	685.1	0.0350	28.5
57	626.7	0.0383	26.1
58	575.9	0.0417	24.0
59	531.5	0.0452	22.1
60	492.4	0.0487	20.5
61	457.9	0.0524	19.1
62	427.4	0.0561	17.8
63	400.1	0.0599	16.7
64	375.8	0.0639	15.7
65	353.9	0.0678	14.7
66	334.3	0.0718	13.9
67	316.5	0.0758	13.2
68	300.4	0.0799	12.5
69	285.7	0.0840	11.9
70	272.4	0.0881	11.3
71	260.1	0.0923	10.8
72	249.0	0.0964	10.4