Final Report

Lake Sturgeon Population Enhancement as a Strategy for Improvement of Ecosystem Function and Controlling Invasive Species

Submitted to the Fish Enhancement Mitigation and Research Fund

US Fish and Wildlife Service
New York Field Office

and the

Fisheries Advisory Committee

May 26, 2009

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Executive Summary

This study examined the potential for development of a stocking program with a goal of restoring the lake sturgeon (*Acipenser fulvescens*) population of the upper St. Lawrence River to levels that could recreate its role as an important benthivore in the fish community and potentially reduce invasive species (e.g. Dressenid mussels). A graduate student seminar was held at SUNY-ESF at the beginning of the project to examine the problem of lake sturgeon decline and the potential for population rehabilitation and encourage debate (Appendix I). This study considers what lake sturgeon stocking levels would be required to effect detectable improvement in ecosystem function and aid in controlling invasive species. In addition, hatchery facilities and the cost of sturgeon rearing were identified, and current populations were evaluated as potential egg sources. Two stocking objectives for the proposed hatchery were evaluated; one was annual production of 125,000 fall fingerlings (6.5") and the second was 50% of that level, 62,500 fingerlings. We developed a crude model of post-stocking survival necessary to develop population projections with 25 years of stocking and no fishing mortality or natural recruitment. These projections were used with limited information on total annual food consumption rates developed independently with bioenergetics modeling to assess the potential impact on the benthic environment. A culture survey was sent to all North American hatcheries active in lake sturgeon culture and information was summarized and used to inform the culture process. Site evaluations were completed to determine feasible locations to develop a hatchery and a floor plan for the facility was completed. The planning provided here should suffice as a preliminary evaluation needed to move forward to development of hatchery specifications by architects and engineers.

Introduction

Sturgeons, which historically have been a significant component of native fish communities and supported culturally important tribal fisheries, are in serious decline throughout the world (Bemis et al. 1997, Auer 1999). Lake sturgeon (*Acipenser fulvescens*) is listed as either locally threatened or endangered across the majority of its range (Harkness and Dymond 1961, Bush and Lary 1996, Auer 1996, Brooking 2000). In New York the status of lake sturgeon is classified as either uncommon or extirpated in inland waters. In the St. Lawrence River, lake sturgeon are considered uncommon or rare above the dam at Massena and present but at lower levels of former abundance below the dam. The stated goal of the New York State Department of Environmental Conservation (NYSDEC), is to "reestablish lake sturgeon as a viable, self-sustaining component of the fish community in New York State to the point of it no longer being classified as threatened" (Carlson 2000). State, federal, and native American fisheries managers have identified lake sturgeon as a target species for recovery and restoration in the Lake Ontario - St. Lawrence River system (Bouton 1994, Carlson 1995, LaPan et al. 2002).

Historically, lake sturgeon inhabited larger tributaries of the St. Lawrence River upstream to the first natural barrier (Carlson 1995, Bush and Lary 1996). One effective lake sturgeon management tool is stocking of hatchery reared fish to re-establish populations in known historic sturgeon waters (Wiley 1999, Schram et al. 1999). In 1993 the NYSDEC initiated a project to restore lake sturgeon as a viable-self sustaining component of the fish community of the St. Lawrence tributaries including the Oswegatchie and St. Regis rivers (LaPan et al 1994). Survival of juveniles stocked into these two systems has been good (Schlueter 2000, Dittman et. al. 2008).

This primitive, very large (up to 2.5m), long lived (100 to 150 years), benthivore is known to consume large quantities of macroinvertebrates (ephemeropterans, dipterans, trichopterans, oligochaetes and molluscs) and is considered an integral food web link needed for restoration of stable native fish communities and improving aquatic ecosystem function (Kelso et al. 1995, Kempinger 1996, Chiasson et al. 1997, Threader et al. 1998, Hay-Chmielewski and Whelan 1997). The loss of the main benthic predator throughout much of the Great Lakes region likely contributed to the establishment and proliferation of the two major invasive species that currently plague the region, dreissenid mussels and round goby (*Apollonia melanostoma*). Both of these invaders occupy the benthic trophic level which was made vulnerable because of the absence of lake sturgeon. Lake sturgeon consume both dreissenids and round goby in the wild (Thomas and Haas 1999, Belanger and Corkum 2003, Jackson et al. 2002, Hayes and Werner 2004). However, because lake sturgeon populations are generally considered to only be at 1% of historic abundance (Carlson 1995, Hay-Chmielewski and Whelan 1997, COSEWIC 2006) there is no demonstrated evidence that sturgeon can help control dreissenid and round goby populations. It is possible; however, that restoration of this large native benthic forager could make a significant predatory impact on these benthic invasive species resulting in improved ecosystem function and health and improved resistance of this community to new benthic invaders. The project goal was to assess the potential and recommend an approach to restore lake sturgeon to the upper St. Lawrence River downriver to Akwesasne in order to improve food web dynamics and improve the overall health and resiliency of the river ecosystem. Specific objectives that contributed to our overall project purpose were to:

1) Determine lake sturgeon stocking levels that would be required to effect detectable improvement in ecosystem function and aid in controlling invasive species in the St. Lawrence River.

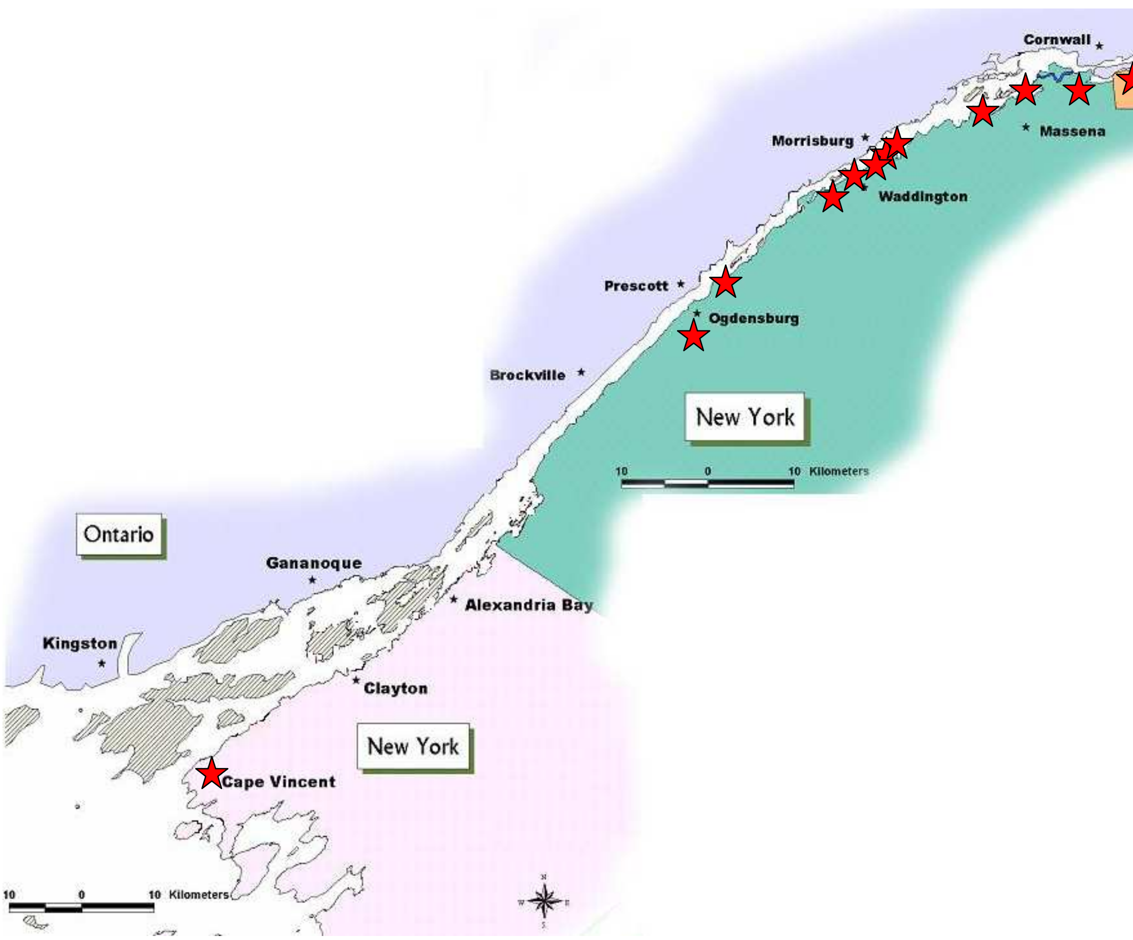
2) Evaluate potential sites for a lake sturgeon hatchery and identify facilities and costs for sturgeon production

3) Evaluate current spawning populations of lake sturgeon as sources for eggs.

Study Area

The study area encompassed the international section of the St. Lawrence River from the mouth of the river at Cape Vincent NY to the Akwesasne lands of the St. Regis Mohawk Tribe within Lake St. Lawrence. Area of this section was estimated using ArcGis and NYS Clearinghouse Orthoimagery as approximately 80,000 hectares (Figure 1).

Figure 1. Target area for the St. Lawrence River Sturgeon Population Enhancement Strategy from the mouth of the river at Cape Vincent NY to the Akwesasne lands of the St. Regis Mohawk Tribe within Lake St. Lawrence. Stars indicate locations of 12 potential hatchery sites evaluated by this project.



The decline in sturgeon populations to < 1% of historic levels in many Great Lakes tributaries is considered to be a level from which populations cannot recover from in the foreseeable future. Habitat changes and life history characteristics (late maturity and infrequent spawning) make rebuilding from a remnant population an unlikely prospect (Beamesderfer and Farr 1997). At very low population levels, mitigation of habitat quality and access issues are not enough so reintroduction of threatened fish is often the most effective strategy (Bearlin et al. 2002, Pikitch et al. 2005, Vélez-Espino and Koops 2007).

Recommendations for sturgeon restoration are: “Annually stock at the suggested minimum densities for rehabilitation purposes for a recommended duration of 25 years of: Fingerlings (rivers: 80 per mile, lakes: 1 per 2 acres, Yearlings (rivers: 40 per mile; lakes 1 per 4 acres)”. Thus, the current standard stocking rate for restoration projects in WI & MI: is 1.24 / ha / yr or 25 / km / yr for 20-25 yrs using > 6” fall fingerlings (Hay-Chmielewski et al. 1997, BFMHP 1999). Each adult population size goal is a minimum 750 individuals. Because the large size of the St. Lawrence stocking by river km is not appropriate and use of area methods is recommended. We estimated the St. Lawrence River project area at approximately 80,000 ha, and following these recommendations a restoration program will require a minimum of 99,200 sturgeon per year for 25 years.

Size at stocking

We selected the size at stocking for fall fingerlings to be 6.5 inches total length. This recommendation is intermediate to sizes achieved for rearing lake sturgeon on formulated and natural food diets. Both types of feeding programs are examined subsequently (see Culture of Lake Sturgeon section), but fall fingerlings fed formulated diets are about 7-10” in total length at stocking compared to 6” for natural diets. Previous culture and survival experiences for St. Lawrence lake sturgeon reared at the Oneida Fish Cultural Station (OFCS) and compared to other locations. The sizes of the sturgeon stocked into the St. Regis River from OFCS averaged 184 mm (SD=26.5) over five years of stocking between 1998 and 2004. Similar sized OFCS lake sturgeon released into Oneida Lake had high survival rates (Jackson et al. 2002). The average size of 900 lake sturgeon stocked into from OFCS in the Genesee River for 2003 was 204 mm. The Schnabel estimate of the presence of these fish 1 year later was 366 individuals, a 40.6 % survival rate (95 % CI 248 to 563). In Wisconsin, measurements of YOY lake sturgeon in the Winnebago System over the period from 1953–2007 were generally greater in total length and averaged 216 mm (Bruch 2008). In comparison, wild lake sturgeon YOY from the Peshtigo River, WI had an average length of 235mm (Benson et al. 2005).

Population projections following stocking

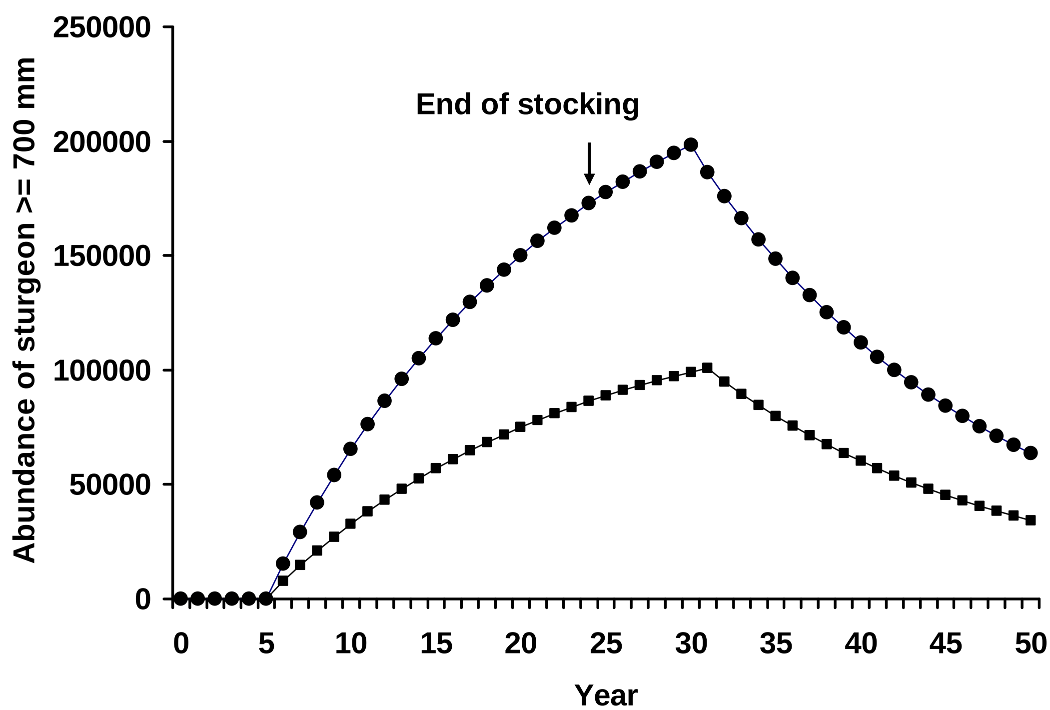
We developed a crude sturgeon population model to make ballpark estimates of future population sizes given stocking rates of 125,000 and 62,500 fingerlings annually for a period of 25 years. The model was developed in Microsoft Excel and accepts the input stocking levels and computes population size based on a first year survival of 50%, second year survival 65% followed by a 0.055 annual mortality rate for Lake Winnebago (Bruch 2008). No other sources of mortality were included and it was assumed no natural reproduction would occur. We computed population density projections by dividing abundance by the total area (hectares) targeted for restoration. Using ArcGIS and orthoimagery from the NYS GIS Clearinghouse we determined an estimated study area of ~80,000 hectares above the FDR Power Project in Massena to Cape Vincent, NY. It should be noted that the St. Lawrence River is an open system and has direct connection to all of Lake Ontario the 12^{th} largest lake in the world (an area of 7,540 square miles).

Stocking alone produces an annual density of 1.56 fish/ha at a rate of 125,000 fingerlings stocked annually. Survival relationships from these stockings indicate populations would peak at 5.91 fish/ha in year 25, and would continue to increase if stocking continued. Population levels gradually increase to 472,606 individuals at the upper stocking rate with 25 age-classes represented (Figure 1). In Wisconsin management has helped boost the number of spawning adults on the Winnebago System from about 11,500 total spawning adults in the 1970s to an estimated 9,000 adult females and 27,000 adult males in 2000. To mimic the known density of sturgeon in the

Winnebago system at 0.5 fish/ha (Bruch 2008) in the St. Lawrence an annual stocking rate of 10,500 fish would be required according to the modeled relationships.

In Minnesota the goal is to reestablish sturgeon throughout their former range. They are following a policy of managing for densities of Age 2+ fish of 1.5 fish/acre (3.7 /ha) in lake systems. In the population model developed for the St. Lawrence to achieve this density with 25 years stocking rate would require a rate of 80,000 fingerlings annually. For comparison, other notable systems have greater natural adult population densities than those that would be achieved at the highest evaluated stocking level. Little Eva Lake in Ontario has a lake sturgeon density of 7.9/ha (McLoed 2008) and in the lower Groundhog/Mattagami R. Nowak and Jessop (1987) found 7.2/ha.

Figure 1. Population projections for sturgeon stocking in the upper St. Lawrence River simulated for a 25-year period with first year survival of 50%, second year survival 65% followed by a 0.055 annual mortality rate for Lake Winnebago (Bruch 2008). Initial stocking levels are shown for 125,000 fingerlings (circles) and 62,500 fingerlings/year (squares).



Potential ecological effects on invasive species

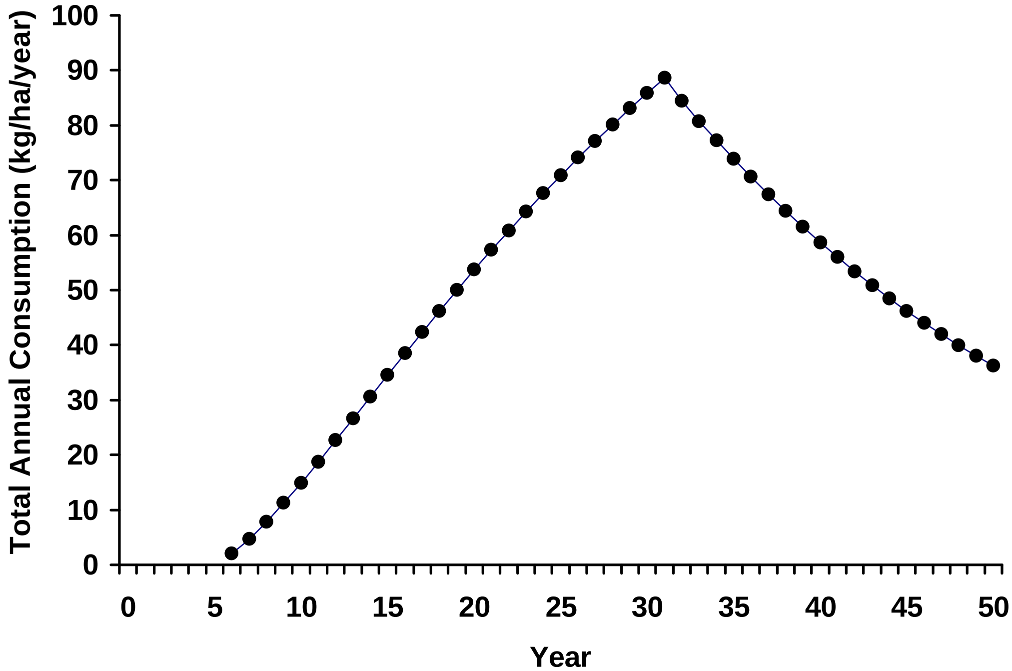
Invasive dressenid mussels have dramatically altered the Lake Ontario (Mills et al. 2003) and the St. Lawrence River ecosystem. Increased light penetration associated with their filtering activities and affects on nutrient cycles have generally led to increase levels of benthic production and a crust of invasive zebra and quagga mussels is known to encrust much of the profundal zone. In recent years, the round goby, an exotic predator of dressinids has flourished and has reached high densities in the St. Lawrence and other Great Lakes waters (Johnson et al. 2005). This increased benthic productivity could potentially be used to fuel the recovery of lake sturgeon and reduce the influences of invasive species in the system.

An evaluation of the potential effect of the benthic fish community including lake sturgeon on zebra mussels were developed using bioenergetic modeling projections for 8 river and lake systems in the US was completed by Eggleston et al. (2003). Projections for eastern Lake Erie near the Buffalo Harbor provide a comparison likely similar to that of the upper St. Lawrence River due to a similarity in thermal and forage conditions. Large and abundant omnivores were considered the most likely to have an impact, and results indicated that lake sturgeon had the greatest total annual consumption due to their rapid growth and large size. Estimates of 400kg/year of consumption were purported for an age 7-8 lake sturgeon as an average for eastern Lake Erie. Upon further examination of the reported data and comparisons to data available for lake sturgeon, it appears estimates of the size of the sturgeon were significantly overestimated.

Eggleston et al. (2003) reported an estimated weight of 7.3 kg for age 3-4 lake sturgeon using length weight relationships provided in Carlander (1969). Data from Bruch (2008) for Lake Winnebago provides an estimate averaging ~0.89 kg between and age-3 and age-4 lake sturgeon, a size only 12.2% of that used by Eggleston et al. (2003). The length weight data from Bruch (2008) is similar to that provided in Jackson et al. (2002) for St. Lawrence fish stocked in Oneida Lake NY. This apparent discrepancy likely significantly influenced the total annual consumption estimates via bioenergetics. Estimates of approximately 120 kg/year of total annual consumption were provided for the 7.3 kg age 3-4 fish and represent a reasonable daily consumption of ~4.5% of body weight. This ration for a 0.9 kg fish at age 3-4 provides an annual consumption of 4.4 kg/year. Expanding this relationship to the age 5-6 and 7-8 year classes evaluated by Eggleston et al. (2003) yields annual consumption of 11 and 14.7 kg/year, respectively.

Based on this limited information, the population projections developed from two stocking scenarios allows some very crude estimates of the potential effect of lake sturgeon population recovery on the benthic environment. It was assumed that sturgeon about 6 years of age would begin to shift diets from insects to include mollusk consumption, and therefore only fish >700 mm were included in the analysis. Hayes et al. (2004) reported that dressenid first appeared in diet samples in the St. Lawrence below the FDR Power Project in Massena, NY for sturgeon sizes 651-1001 mm along with gastropods and became the dominant prey for the 1002-1352 size class. An individual 682 mm had intact dressenid mussels in the gut. We fitted the three annual consumption estimates adapted from Eggleston et al. (2003) with a log function to provide a crude estimate of age-specific consumption to apply to the age-specific population projections described previously. Expansions of total consumption to population projections reveal that total annual consumption peaked at 88.6 kg/ha or 8.86 g/m^2 consumed by lake sturgeon at peak abundance (Figure 2). For comparison, benthic samples collected from July to August annually with 36 in^2 ponar grabs from stations in the upper River study area indicate biomass values of 50-60 g/m2 in the mid 2000s but have since declined to 2-3 g/m2 (Farrell et al. 2009). Although these samples are far from system wide biomass estimates, densities suggest the ballpark sturgeon consumption rates potential could potentially influence the benthic environment. We caution that these estimates (population and consumption projections) are extremely crude and large assumptions were taken that may significantly effect actual outcomes. Despite these shortcomings, restoration of lake sturgeon to abundant levels could have significant ecological significance not only through consumption but also by disturbance associated with foraging activities.

Figure 2. Projection of total annual consumption by lake sturgeon adapted from bioenergetic simulations developed by Eggleston et al. (2003) for eastern Lake Erie and population projections based on an annual stocking rate of 125,000 fingerlings.



Culture of Lake Sturgeon

General Overview

In 1983, lake sturgeon (*Acipenser fulvescens*) were classified as a threatened species in New York State (Carlson, 2000). They were once an important part of the fisheries in the St. Lawrence River, Lake Ontario, and a few other waters. The decline of lake sturgeon was caused by habitat and water quality degradation, and over-harvest (Carlson, 1995). In 1993, the NYSDEC began a lake sturgeon restoration program with the goal of ultimately removing the lake sturgeon from the threatened list of fishes in NYS. As part of this plan, a rearing and stocking program was initiated at the NYSDEC Oneida Fish Cultural Station (OFCS). The first stocking of St. Lawrence River tributaries occurred in 1993, and was followed by other stockings of fingerling sturgeon up through 2004 (LaPan et al. 1997, Carlson et al. 2004). The fingerlings produced at the OFCS were reared in conjunction with a walleye fingerling program; they were treated in a similar manner to the walleyes in terms of rearing protocol, but specific techniques used were not well documented or reported. In general, lake sturgeon eggs were incubated on a small jar battery; the fry were fed brine shrimp for 30 to 50 days, and then were transitioned to formulated diet and fed only formulated diet until stocking in the fall. Annual production of fingerlings produced from the OFCS was variable in number (from 35 to 12,800) but were consistently large in size, generally ranging between 7 and 10 inches in length (Table 1). In just a few years, it became obvious that these stocked fingerlings were surviving very well in many waters (Schlueter 2000, Dittman & Zollweg 2006, Dittman pers. obs.), and interest in the hatchery program grew.

Lake sturgeon have been cultured in other States for many years. Some of the earliest descriptions were from the Wild Rose Fish Hatchery, operated by the State of Wisconsin, and date back to the early 1980's (Ceskleba, D.G. et al. 1985). As time progressed, other States, the federal government (U.S. Fish and Wildlife Service) and provinces in Canada became interested in lake sturgeon and developed hatchery programs. The work from the Wild Rose Hatchery served as a basis for many of these programs.

The project involving lake sturgeon restoration in the St Lawrence River was conceived, in part, because of the impact stocked fingerlings from the OFCS had made on waters such as Oneida Lake, and the Oswegatchie River. The high survival of stocked lake sturgeon presented the possibility of perhaps altering the benthic community in the St. Lawrence River, by reducing the biomass of invasive zebra/quagga mussels and round gobies, through stocking large numbers of sturgeon. However, stocking "large" numbers of lake sturgeon had not been done from the OFCS. Federal and state hatcheries in Wisconsin have been able to stock 40,000 fingerlings on an annual basis. After significant consideration, two annual stocking objectives for the lake sturgeon hatchery were set; one at 125,000 and the second at 62,500 fingerlings, both with a minimum stocking length of 6.5 inches. To accomplish this, conceptually, would require an examination of rearing protocols from the OFCS, as well as the other state, federal, and provincial hatcheries.

Table 1. Lake sturgeon fingerlings stocked, length and survival at the Oneida Fish Cultural Station (OFCS).

Year*	**Eggs**	**Fingerlings**	**Length**	**% Survival**
1993	unknown	35	3-4	------
1994	unknown	500	7-9	-------
1995	94,000	12,800	10	13.6
1996	80,000	3,628	7.0	4.5
1997	117,000	4,244	6.5	3.6
1998**	83,000	4,400	7.5	5.3
1999	50,000	1,500	9.5	3.0
2000	58,000	1,825	7.0	3.1
2003**	36,000	2,510	9.0	7.0
2004	74,100	4,600	7-8	6.2
Total	592,100	36,042	---	---

* in 2001, 75,000 eggs were collected but all fry died

** additional eggs were collected, but never hatched.

Lake Sturgeon Hatchery Survey and Information

Hatchery data were supplied from the OFCS by hatchery manager, Mark Babenzien. The data were present for all years that sturgeon were produced and represented 1993 through 2001, 2003, and 2004. The data were reviewed and summarized to establish survival during critical periods in the rearing program and to establish details associated with the OFCS program (feeding protocol, rearing densities, growth rates). Since 1993, the OFCS has successfully stocked lake sturgeon in 10 years; hatchery production in other years was impacted by poor females and eggs (possibly contaminants) and disease considerations, especially VHS. Estimates of lake sturgeon surviving at the end of live food feeding (brine shrimp) were available in 6 years. This data allowed for the calculation of survival in lake sturgeon produced at the OFCS during the periods of live food feeding, formulated diet transition, and post diet transition (Table 2 and 3). Data on typical lake sturgeon growth and timing of rearing periods at the OFCS is presented in Appendix II.

To collect information from other hatcheries in North America that produce lake sturgeon, a letter request (Appendix III) and culture survey was developed and sent to hatchery managers at nine facilities (Appendix IV). Six surveys were returned from the following hatcheries: Genoa National Fish Hatchery, Genoa, Wisconsin; Wild Rose State Fish Hatchery, Wild Rose, Wisconsin; Peter W. Pfeiffer State Hatchery, Frankfort, Kentucky; Pittsford National Fish Hatchery, North Chittenden, VT; Warm Springs National Fish Hatchery, Warm Springs, GA; and Saskatchewan Provincial Fish Hatchery in Fort Qu'Appelle, Saskatchewan.

Summary of Survey Results and Data from OFCS

A significant finding from hatchery survey was that lake sturgeon are cultured using natural food diets; the use of formulated diets was only experimental (Table 2). This was opposite to the OFCS where formulated diets were the primary feeding method (following a brief brine shrimp feeding period). Secondly, it was noted that the overall hatchery survival of fingerlings produced at the OFCS was much lower than that produced at the surveyed facilities (Table 3) and that much of this mortality occurred during diet transition (Table 4). Finally, fall fingerlings stocked from the OFCS were much larger at stocking than those from the surveyed hatcheries. Other less significant difference existed between the surveyed facilities and the OFCS in areas such as water supply, and feed conversions. Despite difference described above, rearing periods and water temperatures were similar among hatcheries and in comparison to OFCS (Table 5).

Table 2. Comparison of feeding methods as an average number of days by period for the OFCS and surveyed hatcheries. Feeding Program is designated with asterisks and number of hatcheries (sample size) given in parentheses. NA=not applicable.

Feeding Program	**Surveyed Hatcheries (days)**	**OFCS (days)**
brine shrimp	29 (N=6)	28
zooplankton	13 (N=2)	NA
bloodworms/krill/other	30-320** (N=6)	NA
formulated diet	NA	15-320**

* feeding various diets may overlap

Table 3. Mean and range of lake sturgeon survival (%) during rearing periods at the OFCS and surveyed hatcheries (n=6).

Rearing period	OFCS	Surveyed Hatcheries
Green to eyed egg	----	74 (35-95)
Green egg to hatch	75	68 (35-90)
Yolk absorption & swim-up	75	86 (75-90)
Natural food feeding	67	74 (50-90)
Diet transition	18	-----
Post diet transition to stocking	-----	95
Green egg to fingerling stocked	6.4	43.3

Table 4. Numbers of lake sturgeon surviving at the OFCS during critical developmental periods in selected years. Assumes 75% hatch of eggs; 75% swim up of fry; 95 % survival of fingerlings following diet transition.

Year*	green Eggs	hatch	swim-up	end live food	end diet transition	stock**
1995	94000	70500	53000	40000	13473	12800
1996	80000	60000	45000	46000	3820	3628
1997	117000	87750	65800	36000	4470	4244
2000	58000	43500	32625	25000	1920	1825
2003	36000	27000	20250	5000	2640	2510
2004	74100	55575	41700	20000	4842	4600
mean	76516	57387	43062	28666	5194	4935

*selected years with estimates available for fish surviving at the end of live food feeding (brine shrimp) **numbers are based on actual estimates

Table 5. Range and (mean) water temperature (˚F) comparison for specified developmental periods in sturgeon culture for the OFCS and surveyed hatcheries.

Rearing period	OFCS	Surveyed Hatcheries
Egg Incubation	55-65 (60)	57-60 (59)
Yolk Absorption	60-65 (62)	57-62 (60)
Fingerling Rearing	60-80 (68)	55-80 (68)

** fall fingerling stocking ~120 days; yearling stocking ~350 days

Most of the surveyed hatcheries had single pass water delivery systems with some capability for recirculation, generally the water supplies were open with some well water augmentation. The OFCS has an open, single pass water supply with capability for recirculation even though it is not used in the sturgeon program. Feed conversion (pounds of food required to produce a pound of sturgeon) when using natural food items such as bloodworms and/or krill is 7; feed conversion when feeding formulated diet was estimated at 4.

Maximum rearing densities for lake sturgeon were also quite variable. The most reliable information from surveyed hatcheries was about 450 fish per square meter (Fajfer et al. 1999), while the OFCS was 1 pound per cubic foot (at a water depth of 1.5-1.75 feet). These two expressions of rearing densities are very similar, which becomes important to facility design.

Egg collection

At the Genoa NFH (Aloisi, et al. 2006) sturgeon are collected on the spawning grounds, and eggs and milt are gathered manually, generally without the need for hormones or surgery. The collection of lake sturgeon eggs in NYS has been time consuming, since females are not caught in a ripe (egg deposition ready) condition (Klindt 2005). As a result, most females must be injected with pituitary hormone, checked periodically over the next 48 hours, and to cause eggs to release; males are also injected. It is not uncommon for the entire egg take, including gill netting of adults, to take up to 8 days of work (for 2-5 people) to obtain fertilized eggs from as little as two or three females and the appropriate number of males (LaPan, et al. 1996). Lake sturgeon relative fecundity is 9,000 to 12 000 eggs per kilogram (Harkness and Dymond 1961; 8,744, Scott and Crossman 1973, Bruch 2008; 12,767). Thus a typical female would approximately have between 400,000 and 600,000 eggs.

Lake sturgeon eggs are very sticky and must be treated with fuller earth (or a similar material) to coat this adhesive layer and allow the eggs to be stirred and handled. After treatment, the eggs are allowed to water harden, for up to two hours, at which time they are ready for transport to the hatchery. This is usually accomplished by placing the eggs in sealed plastic bags with water and pure oxygen, and then into a cooler for transport (Klindt 2005).

Egg incubation and hatching

Once at the hatchery, eggs are rinsed, enumerated and placed into McDonald jars for incubation. Usually between 1 and 2 quarts of eggs are placed in each jar; the jars are then placed on a battery where the eggs will incubate from 4 to 7 days, depending on temperature. Upon hatching, the fry will swim from the jar and from the jar battery to collect in a rearing tank.

Swim-up

Newly hatched fry progress through a yolk absorption period during which they do not feed, become photo negative, and collect in darkened areas of the tank; this period will last up to 7 days, depending on temperature. At the onset of exogenous feeding, fry will be actively swimming in the tanks and appear to be seeking food.

Brine shrimp feeding

Procedures for feeding brine shrimp vary considerably between facilities. The lake sturgeon must receive enough shrimp to grow and maintain health. Aloisi et al. (2006) developed an excellent feeding protocol and feeding chart for brine shrimp where about one pound of cysts are needed for every 1500 fry that are fed up to 2 inches (30 days), and daily feedings are performed four times over a minimum period of twelve hours. At the OFCS, sturgeon were fed brine shrimp to satiation using a 24 hour daily feeding schedule with a minimum of 4 feedings per hour.

Later feeding and stocking

Two major feeding methods, discussed previously, are used to culture lake sturgeon from about 2-3 inches (end of brine shrimp) to fall fingerling or yearling stocking. The OFCS method involves a transition from brine shrimp to formulated diets; this is cheaper, requires less manpower, produces poor survival (6.4%), and the potential for very large fingerlings or yearlings. The natural food method consists of a transition from brine shrimp to other foods like zooplankton, krill, and/or bloodworms; this is more expensive and labor intensive, produces much better survival (43.3%) but smaller fingerlings or yearlings.

Most fall fingerling lake sturgeon produced using a natural food method are approximately 6” at stocking; fall fingerlings produced at the OFCS are generally between 7 and 10 inches at stocking. The growth difference between these fingerlings is probably not entirely related to rearing temperature, especially since the average rearing temperatures are almost identical when comparing hatcheries using these two feeding methods (see Table 2). It has not been determined if this difference in size is important to the subsequent survival of the stocked lake sturgeon, however, it is suspected that fingerlings stocked from the OFCS have better survival than those from other hatcheries.

Hatchery requirements to meet stocking objectives

Two stocking objectives were considered for the proposed St Lawrence River lake sturgeon restoration hatchery. At the high end was a yearly production of 125,000 fingerlings at 6.5 inches in length and 24 fish per pound (5200 pounds of annual production). At the low end was a stocking objective of 62,500 fingerlings at 6.5 inches in length and 24 fish per pound (2600 pounds of annual production).

To produce this quantity of sturgeon using a natural food protocol would require the collection of 150,000 to 300,000 eggs; using a formulated diet protocol would require between 1 and 2 million eggs. In addition to the costs associated with just collecting or obtaining eggs; this 6 to 7 fold difference in egg requirements would also impact costs of feeding (and possibly manpower) because more fish must be managed. This difference must be considered in decision- making regarding the hatchery. For example, because of low abundances of adult lake sturgeon, it could be very difficult to obtain even 150,000 eggs in NYS from the minimum of 5-10 females needed for genetic diversity. The distinction between these two types of feeding protocols will be carried through out this analysis. At some point, a hybrid-type facility, using both feeding protocols, will be presented. This approach will provide the proposed sturgeon hatchery with the greatest amount of flexibility.

An initial step in hatchery conceptualization is to estimate the maximum lake sturgeon rearing density. Using 450 fingerling per square meter (Fajfer et al. 1999), and 1 pound per cubic foot from OFCS, between 1500 and 3000 square feet and 2600 and 5200 cubic feet of rearing space will be needed to meet the low end (2600 pounds) and the high end (5200 pounds) stocking objective, respectively. These objectives can be obtained with a hatchery having between 14 and 28 fiberglass tanks (4’ x 25’ by 2.5’high) having 100 square feet and/or 175 cubic feet each and 5 to10 (5’ diameter) tanks having 20 square feet and/or 34 cubic feet each. With the volume of rearing space for the hatchery established, the water flow can be estimated. Using design criteria employed for the OFCS, a water flow rate that accomplishes 2.5 exchanges of water volume per hour should be sufficient to maintain water quality within the hatchery. For planning purposes, the flow of water required for the lake sturgeon restoration hatchery would be approximately 800 or 1600 gpm (gallons per minute), depending on the stocking objective.

CULTURE FACILITY ASSESSMENT

Hatchery Design, Floor Plan, and Site Selection

The NYSDEC Oneida Fish Cultural Station is the most recent hatchery built by the State; it was operational in 1993. This coolwater production facility has been used to produce lake sturgeon for the statewide program over the last 10-15 years. Stocked sturgeon have survived well in NY waters and their growth and survival have been better than other stocked fishes. Because of this hatchery's success in rearing lake sturgeon and because of familiarity with its design and operation, the Oneida Fish Cultural Station (OFCS) will serve as a template for the proposed sturgeon rearing facility on the St. Lawrence River.

The production goals for the lake sturgeon culture facility have been previously identified, are two fold, and are 62,500 or 125,000 fingerlings, weighing 24 fish per pound (6.5 inches in length) with an annual weight of 2600 or 5200 pounds. The hatchery will operate for 7 months; will be of steel pole barn construction, with appropriate insulation. The hatchery will have space for an office, lobby, laboratory with fish culture research capability, boiler room, UV and filter room, brine shrimp incubation space, storage space, break room and bathrooms. Flow through the facility will be a maximum of 800 or 1600 GPM, and was derived from using 2.5 exchanges of water per hour to maintain water quality. It will have a single pass water delivery system, but will have the capability to recirculate water incorporated into the design. Water will be pumped from an open water supply into an elevated head box for re-distribution to rearing tanks by gravity. There will be cooling water (depending on the location and water supply to the hatchery) and open water lines to each tank; additionally heated water lines will be supplied to 10 circular and 5 rectangular tanks. Heated water capability will be 300 GPM of water that has had a 10F rise in temperature. All water will be filtered, and disinfected with ultraviolet light. There will be 14 or 28 fiberglass rectangular tanks (4' X 25') and 5 or 10 five- foot diameter circular tanks; there will be an 18" separation between 2 tanks in a set, and a 3- foot separation between each set of tanks. Effluent treatment will be via settling tanks with sub-surface leeching, or settling with overflow to receiving water. A floor plan for the proposed hatchery that would meet the higher stocking objective (5200 pounds annually) was developed as part of this study (Appendix V). When considering the stocking objective of 2600 pounds, the production wing of the facility would be reduced by fifty per cent, from about 100 feet in length to 50 feet.

Site Selection

Twelve potential sites for the proposed St. Lawrence River sturgeon culture facility were visited and considered in this analysis (Figure 1). One site was located on the St. Lawrence River in the Village of Cape Vincent at a NYSDEC fish culture facility currently operated by a sportsmen group to produce fingerling walleye. A second site was located on the St. Lawrence River near the city of Ogdensburg at an abandoned NYSDEC hatchery, currently owned by the NYSOP&HP, and used to produce walleye fingerlings by a private sportsmen group. Three sites were considered on the Akwesasne Territory, located near Massena, and owned by the St. Regis Mohawk Tribe. Of primary importance with theses sites was the potential water supplies, one was on the St Regis River, another on the Raquette River and the third on the St. Lawrence River.

Seven sites were considered on land owned by the New York State Power Authority and located on the St. Lawrence River. Four were located on or near Howland's Island (operating NYSDEC wildlife management area). One was located downstream of the Robert Moses Power Dam and would be in close proximity to a current egg taking site. Another was located near the near Waddington at the site of a recently refurbished lake sturgeon spawning area. The final location was upstream of the Robert Moses Power Dam between Massena and Howland's Island in a shallow bay on the River

Site Evaluation

Criteria were developed to evaluate and prioritize the sites under consideration (Appendix VI). Factors taken into consideration were: hydrology, topography, proximity to broodstock, bio-security, support services, and site associated costs that could add to or reduce the ultimate cost of the facility. Using these criteria, eight sites were eliminated for various reasons including but not limited to: sites lacking sufficient acreage, sites with limited or inappropriate access, sites with excessive development costs, and sites with suspected poor water quality. The four sites that survived this examination were the Cape Vincent and Ogdensburg locations, the Raquette River site on the Akwesasne Territory and site 6 on NYPA lands near Waddington (Table 6).

The criteria used for comparison of the sites were derived in the following manner. Acreage was established at or around a minimum of 5 acres. Elevation considerations were for level ground with gentle slope to the water supply (to facilitate pumping and/or pond draining). Soil considerations were primarily for clay in the event of earthen pond development. Site costs took into consideration the current use of the land, and what it might cost to place a hatchery on the site. For example, Cape Vincent and Ogdensburg are presently hatcheries and would have minimal site development costs, while the NYPA site is heavily wooded with very limited access and would have greater site development costs. Hydrology criteria involved the water supply and its temperature during the rearing period; the water temperature data was derived from examining and comparing data from the St. Regis Mohawks for the year 2007 and historic data from Cape Vincent from 1996. Bio-security considerations involve the remoteness of the proposed site, and its water supply as it relates to potential vandalism. Support services involve the proximity of the site and the water supply to power, other public utilities, computer service, access roads, etc. Other costs are those that can be identified early on as additional or reduced costs associated with the site, such as existing earthen ponds, developed water supplies, roads, and other infrastructure.

One primary consideration in this comparison was the temperature differences between the water supplies for sites (Table 6). The Raquette River averages 7 to 9 degrees Fahrenheit above the St Lawrence River during the growing season for lake sturgeon (Table 7). The comparison of temperature these two water supplies revealed that water heating requirements will be much greater for a hatchery on the St Lawrence relative to the Raquette River. Depending on the date of egg take, a St Lawrence hatchery may require water heating in both May and early June while a Raquette River facility may only need to heat during a small portion of May. Due to more rapid growth in a warmer water supply, such as the Raquette River, fingerlings are expected to grow larger relative to the St. Lawrence. The Genoa National Fish Hatchery targets 68˚F for it rearing temperature and produces fingerling about 6.5 inches. Depending on egg sources, a Raquette River hatchery would at least produce fingerlings of this size (using natural feed only). The temperature profile of the Raquette River is very similar to Scriba Creek in Constantia, NY (site of the Oneida Fish Cultural Station); fish from the Raquette would likely be similar in size to those produced at OFCS if the same rearing methods were used (especially for the formulated diet portion of the feeding program). Conversely, cooling water (to mix with the existing water supply) would probably be needed for a hatchery on the Raquette River to help in the control of diseases and to maintain optimum rearing temperatures; cooling water would probably not be needed for a hatchery using the St Lawrence River as a water supply.

Table 6. Comparison of potential hatchery sites evaluated according to criteria including topography, hydrology, bio-security, support services, and additional costs for three locations along the St. Lawrence River and one site (Akwesasne) along the Raquette River, NY. Mean water temperature (°F) is given for April through October corresponds to the rearing period.

CRITERIA	**CAPE VINCENT**	**OGDENSBURG**	**AKWESASNE**	**NYPA**
Topography				
Acreage	20 +	10+	13+	4+
Elevation	good	good	good	ok
Soil	good	good	good	NA
Site Costs	lowest	lowest	low	high
Hydrology				
Water supply	St. Law*	St. Law*	Raquette	St. Law
Public utilities	Yes**	No	Yes***	No
Water temperature	56˚F	58˚F	65˚F	58˚F
Bio-Security	good	poor	good	poor
Support Services	good	poor	good	poor
Other Costs	low	low	medium	high

*WATER SUPPLY ALREADY DEVELOPED
** SEWER AND PUBLIC WATER
***SEWER-NO AND WATER-YES

Table 7. Average monthly water temperature (˚F) at selected sites being considered for the lake sturgeon hatchery and the OFCS. Temperature data for St. Lawrence River at Cape Vincent and Massena from 1996; Temperature data for Akwesasne (St. Lawrence River) and the Raquette and St. Regis Rivers from 2007; Temperature data for the OFCS (Scriba Creek) from many years.

	POTENTIAL SITES					
Month	**Cape Vincent**	**Massena**	**Akwesasne**	**Raquette**	**St. Regis**	**OFCS**
April	37.1	37.7	43.6	45.4	50.0	48.0
May	45.3	47.0	50.1	60.1	64.5	59.1
June	56.8	58.4	65.3	74.9	73.6	67.2
July	64.7	66.5	70.3	75.0	73.6	70.5
August	69.4	71.6	72.4	74.0	73.7	69.1
September	66.2	68.3	66.4	65.7	64.3	61.7
October	55.3	56.6	58.9	58.8	57.0	53.2
Mean	56.4	58.0	61.0	64.8	65.2	61.2

PROGRAM EVALUATION AND COSTS

Proposed Sturgeon Hatchery Construction Costs

For a hatchery construction project, facility design and cost estimates can be as much as 15% of the cost of construction. However, since this project is primarily conceptual, and there is no funding for the hatchery at this time, only rough estimates of cost are required. Since the proposed sturgeon hatchery is a template of the Oneida Fish Cultural Station, construction costs on a square foot basis for the OFCS were examined and adjusted by 5% per year for inflation. In addition, current or near current costs of construction for similar projects were identified and used as comparables to this project. These comparables were obtained from NYSDEC engineers, and from Doug Aloisi at the Genoa NFH.

Site development and storm water runoff costs were not considered in this evaluation; each of these costs could be 200,000 dollars or more and will depend on many variables. The OFCS was built in 1992-93, was approximately 18,000 square feet, and cost 2,756,000 dollars to build. The cost per square foot in 1993 was 153 dollars; when adjusted for inflation (5% per year) the estimated cost per square foot (today) is 316 dollars. Differences between the OFCS and the proposed sturgeon hatchery floor plan are primarily in space for egg incubation, generator and electrical equipment, and water filtration (Appendix V). In addition, the OFCS is a year around facility (with subsequent heating and insulation upgrades) with brick siding, and the proposed sturgeon facility is to be operational for 7 months a year and will be pole barn type construction, with metal siding.

The proposed sturgeon hatchery building, to meet the 5200 pound production capability and 125,000 fingerlings at 6.5 inches and 24 fish per pound, will be 150 feet long by 70 feet wide and occupy 10,500 square feet. A hatchery to meet the 2600 pounds annual production capacity (62,500 fingerlings at 6.5 inches and 24 fish per pound) would be 70 feet wide and 100 feet long, occupying about 7000 square feet. At a projected cost of 316 dollars per square foot, the cost to construct the sturgeon hatchery would be approximately 2.2 or 3.3 million dollars, depending on its production capacity. As comparables, recent New York State projects (not hatcheries since the OFCS is the most recent) designed by the NYSDEC engineers ranged from a maintenance building at a ski center for 180 dollars per square foot to a ski center lodge at 280 dollars per square foot. When considering the level of sophistication, the plumbing, and general equipment required, and the unusual costs associated with government contracts and construction, the estimate of 316 dollars per square foot for the proposed hatchery appears reasonable.

A recent building constructed (operational in 2004) to produce lake sturgeon was at the Genoa National Fish Hatchery in Wisconsin. The building has about 6000 square feet, with a production capacity of 40,000 to 50,000 fingerlings. The actual cost of construction was about 500,000 dollars, but since many equipment items were added later—a more realistic estimate from the current manager, Doug Aloisi, was 750,000 dollars (125 dollars per square foot). Using a 5% inflation rate each year since construction, the cost for this facility today would be 150 dollars per square foot. Potential explanations for the low cost associated with this building are: it is not a stand alone facility since it was built as an annex to an existing hatchery, it is seasonally operated, and did not have to conform to NYS contracts and regulations involved with construction (such as the wicks law).

Staffing and Staffing Costs

Staffing requirements for the proposed lake sturgeon hatchery will be established using manpower levels and titles similar to those employed by the NYSDEC fish culture section. This is probably appropriate since most hatcheries are operated by government agencies and staffing information is open and obtainable. One permanent person will be employed and serve in the capacity of hatchery manager. This person will maintain continuity in the program from year to year, hire seasonal personnel, purchase supplies and material (especially brine shrimp and other natural and formulated foods), maintain oversight of the hatchery and the grounds, plan and/or schedule egg take operations and requirements, and plan for yearly culture activities. A hatchery manager in NYS would earn near 60,000 dollars per year; with benefits (at an additional one third) this would increase to 80,000 dollars per year. Under NYSDEC guidelines, housing is supplied for this individual in exchange for monitoring and surveillance on the hatchery grounds, and other aspects of employment. Since this has not been considered here, a greater salary may be required to recruit a manager. Since the hatchery is expected to operate for 7 months, additional staffing other than the manager could be seasonal. Seasonal technicians and/or laborers can be employed to meet the work related requirements, remembering that it is a 7-day a week job. Up to 5 seasonal people may be needed for all or part of the seven months to rear and stock 125,000 fingerlings. During a normal workweek (Monday thru Friday) there will be five seasonal employees for three days and three employees for two days; two employees may be needed on weekend days. The final number of employees will be determined by the type of feeding program employed at the facility, the source and manpower associated with obtaining sturgeon eggs, sturgeon marking requirements, and other currently unknown factors. Seasonal employees are paid by the hour and receive minimal, if any, benefits. Currently hatchery technicians and/or laborers can be hired for 14 dollars per hour. A 7-month operation consists of 28 weeks; using 5 seasonal employees, each working 40 hours a week, a total of 200 man-hours will be available; the cost of this effort is 2800 dollars per week and for 28 weeks is 78,400 dollars. Yearly personnel costs at the proposed high capacity sturgeon facility (Table 8) will be around 158,400 dollars for a permanent manager and 5 seasonal employees, and 119,700 dollars for a permanent manager and 2.5 seasonal employees at a facility producing 2600 pounds annually (Table 9).

Maintenance and Operational Costs

Maintenance and operational expenses are comprised of supplies and materials, electricity, fuel costs, and other contractual costs (such as egg take) the hatchery might be incurred. These maintenance and operational costs should be proportional when considering the same hatcheries, but with different rearing capacities. Generally, a facility producing 5200 pounds of lake sturgeon will have two time the maintenance and operational costs as one producing 2600 pounds annually (using the same methods). The OFCS has a current operating budget of 66,000 dollars to cover all expenses except fish food. Since their operation is similar to the proposed, large capacity sturgeon hatchery, it would be safe to assume a 60,000 dollar operating budget for electricity (UV operation, pumping water, lights, etc.), fuel oil and/or propane, and supplies and materials. Differences to consider are the year-round operation and gravity water supply at the OFCS and the 7 month operation, and pumped water supply of the proposed sturgeon hatchery. The estimated cost of pumping water at the sturgeon hatchery is either 5,500 or 11,000 dollars per year, depending on the stocking objective. This cost should be off-set by the seasonal (non-heating) provisions of the sturgeon facility.

The cost associated with feeding sturgeon will depend on the stocking objectives of the hatchery, the type of feeding program, and the cost of the food. As with maintenance and operational expenses, fish food costs should also be proportional between the 2600 and 5200 pound production options for the hatchery. As discussed in the lake sturgeon culture section, one feeding program incorporates only brine shrimp (for 30 days), followed by other natural-type food (krill, blood worms) for the remaining 120 days or so; this is the most common feeding program currently in practice, and produces the best survival of sturgeon (43.3%). The second type of feeding program is used at the OFCS, incorporates 30 days of brine shrimp feeding, followed by feeding only formulated diets for the remaining 120 days; this program is cheaper but produces poorer survival of sturgeon (6.4%). The 30- day feeding of brine shrimp is common to both feeding programs; however the requirement for brine shrimp is 750 pounds under the OFCS program (formulated diet) and 117 pounds under the other program (natural food). This difference is due to a near 7- fold difference in survival that results in greater numbers of fry being fed brine shrimp in the formulated diet program. A reasonable, but high-end cost of brine shrimp, even though the price can vary tremendously depending upon the harvest from the Great Salt Lake, would be 30 dollars per pound. The cost of brine shrimp in a large sturgeon facility using a formulated diet, feeding program is 22,500 dollars as compared to 3750 dollars for the same facility using only natural food; the cost of brine shrimp in a small facility is 11,250 and 1875 dollars respectively. The cost of formulated diet to grow –out fingerlings, using a feed conversion of 4 (high-end estimate), would be 17,500 dollars (at 1.00 dollar per pound) and 8750 dollars in a large and small facility. The cost to grow-out fingerlings on a natural food diet, using a conversion of 7 from Aloisi et al. 2006, would be 141,000 dollars and 70,500 dollars for a large (Table 8) and a smaller facility (Table 9). The average cost of bloodworms is about 4.00 dollars per pound; even though other products may be less expensive, and may be available locally, this is the value used to establish costs of the natural food program. In summary, the cost of feeding sturgeon could range between 20,000 dollars and 145,000 dollars, depending on the size of the facility and the feeding program employed; food costs in a hybrid-type program producing some fish on formulated diets and some on only natural food would be 46,190 or 92,375 dollars depending on the output of the facility.

Table 8. Staffing, maintenance and operation, fish food and fingerling costs (dollars) at the lake sturgeon hatchery with 5200 pounds of annual production*

PROPOSED STURGEON FACILITY-5200 LBS.			
	Natural Food	**Formulated Diet**	**Hybrid**
Staffing			
Permanent	80,000	80,000	80,000
Seasonal	78,400	78,400	78,400
Sub total	158,400	158,400	158,400
Maintenance and Operation	60,000	60,000	60,000
Fish Food			
Brine shrimp	3750	22,500	13,125
Formulated diet	------	17,500	8,750
Natural food	141,000	------	70,500
Sub total	144,750	40,000	92,375
Grand Total	363,150	258,400	310,775
Cost / fingerling ($)	2.90	2.07	2.49

* does not include costs associated with egg collection

Table 9. Staffing, maintenance and operation, fish food, and fingerling costs (dollars) at the lake sturgeon hatchery with 2600 pounds of annual production*

PROPOSED STURGEON FACILITY-2600 LBS.			
	Natural Food	**Formulated Diet**	**Hybrid**
Staffing			
Permanent	80,000	80,000	80,000
Seasonal	39,200	39,200	39,200
Sub total	119,700	119,700	119,700
Maintenance and Operation	30,000	30,000	30,000
Fish Food			
Brine shrimp	1875	11,250	6565
Formulated diet	------	8750	4375
Natural Food	70,500	-------	35,250
Sub total	72,375	20,000	46,190
Grand Total	222,075	169,700	195,890
Cost /fingerling ($)	3.55	2.71	3.13

* does not include costs associated with egg take

From Tables 8 and 9, the annual cost of operating a hybrid facility producing 5200 pounds of lake sturgeon is 310,755 dollars; the cost per fingerling produced is 2.49 dollars. In a hybrid facility producing 2600 pounds of lake sturgeon, the annual operating cost is 195,890 dollars; the cost per fingerling produced is 3.13 dollars. For comparative purposes, the NYSDEC coolwater production supervisor estimated the cost to produce advanced fingerling walleye at the OFCS in 1995 to be 1.74 dollars per fish (Colesante, 1995). The factors making up these estimates are the same (the value of the building and land was not included), except that egg collection costs are omitted in the sturgeon estimates. If a 5% per year inflation factor were applied to the cost to produce advanced fingerling walleye, the 2009 cost of these fish would be about 3.40 dollars each.

Egg quantity and production scenarios

The collection of eggs required to operate a sturgeon facility is the single most important activity that needs to be completed on an annual basis. Generally, the stocking objective and the in- hatchery survival, will determine the quantity of eggs needed. In the case of lake sturgeon there is a 7- fold difference in hatchery survival between a natural food feeding program and a formulated diet, feeding program. We have evaluated the quantities of eggs required under different lake sturgeon production scenarios (Table 10). There are pros and cons to each feeding protocols discussed, but the quantity of eggs obtainable on an annual basis may ultimately determine the type of feeding program.

Table 10. Quantities of lake sturgeon eggs required for two production scenarios with three diet regimens, including natural, formulated, and a 50:50 hybrid diet. Does not include additional eggs that may be associated with a "payback" program to the donor stock.

Production scenario	**Fingerlings**	**% Survival**	**Eggs required**
2600 pounds	*62,500*		
natural food		43.3	144,350
formulated food		6.4	976,500
50:50 hybrid*		11.1	560,452
5200 pounds	*125,000*		
natural food		43.3	288,483
formulated food		6.4	1,953,125
50:50 hybrid*		11.1	1,120,900

* production of one-half of the fingerlings on natural food and one-half on formulated diet

Egg collection costs, especially with a fish like the lake sturgeon are typically high and must be incorporated into the operational expense of the hatchery. Even though the fecundity of the lake sturgeon is high, an egg requirement near 2 million (large facility-feeding formulated diet) could be impractical. An egg take up to one million (all other scenarios) is more likely. If the egg collection occurred in Quebec, on the St. Lawrence River, as in 1993-95, an agreement could be explored where the Province would be repaid for eggs they supplied with fingerlings produced at the hatchery. If this arrangement is not feasible, it egg collection will likely be contracted by the hatchery, generally to the lowest bidder. If egg take is contracted, it would significantly increase the annual operational costs of the hatchery.

Evaluation of Egg Sources

Disease and genetics are two main factors when considering donor stocks for rehabilitation of Great Lakes fish stocks. Disease issues currently greatly restrict the interbasin transfer of all fish life history stages throughout the Great Lakes. Although disease clearance can be achieved it is often costly and in some instances fishes need to be reared past optimal stocking sizes in order to attain sizes needed for disease certification. Because of disease concerns intrabasin (within a watershed, i.e., Lake Ontario/St. Lawrence River) fish transfers generally are considered more desirable.

Genetically similar donor stocks are preferable for stock supplementation by stocking. Welsh (In press) completed a genetic stocking unit (GSU) assessment of 26 lake sturgeon populations from throughout the Great Lakes. A GSU is defined as a population or group of populations that may be used as a donor source for propagation. Lake Ontario (excluding the Niagara River) and the St. Lawrence River were considered as one of seven GSU in the Great Lakes basin.

The only known potential lake sturgeon donor stock that exists in the Lake Ontario/St. Lawrence River watershed (GSU #4) with a sufficient number of individuals for egg collection for the proposed stocking objectives exists in the lower St. Lawrence River and tributaries near Montreal. This area provided the initial source of eggs for the NYSDEC lake sturgeon stocking program. Sturgeon near Montreal spawn approximately four weeks earlier than those immediately below the Robert Moses Dam allowing a longer hatchery growth period resulting in larger size at release. In order to acquire eggs from this population an agreement would need to be reached with the Province of Quebec. The most cost effective scenario may be to request Quebec collect eggs with a return of a specified number of fingerling sturgeon (e.g. # fingerlings/100,000 eggs). Any program to collect gametes, especially eggs, from lake sturgeon would need to target a minimum number of adults to avoid founder effects in the population level genome.

Acknowledgements

This study was funded by the Fish Enhancement Mitigation and Research Fund administered by the US Fish and Wildlife Service through the National Fish and Wildlife Foundation Special Project Division with oversight by the Fisheries Advisory Committee. We thank the following hatchery managers for completing the survey on culture techniques: Doug Aloisi, Genoa National Fish Hatchery in Genoa, Wisconsin; Steve Fajfer, Wild Rose State Fish Hatchery, Wild Rose , Wisconsin; Steve Marple, Peter W. Pfeiffer State Hatchery in Frankfort, Kentucky; Henry Bouchard, Pittsford National Fish Hatchery in North Chittenden, VT; Carlos Echevarria, Warm Springs National Fish Hatchery, Warm Springs, GA; Jerry Banks, Saskatchewan Provincial Fish Hatchery in Fort Qu'Appelle, Saskatchewan and Mark Babenzien and Carl Rathje, Oneida Lake Cultural Station for providing data on sturgeon culture. Kevin Kapuscinski provided assistance with population projections. We thank Kevin McGrath of NYPA, Steve LaPan of the Cape Vincent Fishery Station, Bob Flavin, and Tony David of the St. Regis Mohawk Tribe Environmental Division for providing their knowledge, information and access to potential hatchery sites.

References

Aloisi D., R. R. Gordon Jr., N. J. Starzl, J. L. Walker and T. R. Brady. 2006. Genoa National Fish Hatchery Lake Sturgeon Culture Standard Operating Procedures. USFWS Region 3 Fisheries Data Series. 1-18.

Auer, N.A. 1996. Importance of habitat and migration to sturgeons with emphasis on lake sturgeon. Can. J. Fish. Aquat. Sci. 53(Suppl. 1):152-160.

Auer, N.A. 1999. Lake sturgeon: a unique and imperiled species in the Great Lakes. pp:515-538. I*n*: Taylor, W.W. and C.P. Ferreri (eds) Great Lakes Fisheries Policy and Management A Binational Perspective. Michigan State University Press. MI

Bemis, W. E., V. J. Birstein and J. R. Waldman. 1997. Sturgeon biodiversity and conservation: an introduction. Environmental Biology of Fishes. 48: 13-14.

Beamesderfer, R. C. P. and R. A. Farr. 1997. Alternatives for the protection and restoration of sturgeons and their habitat. Environmental Biology of Fishes. 48:407-417.

Benson, A.C., Sutton, T.M., Elliott, R.F., and Meronek, T.G. 2005. Seasonal movement patterns and habitat preferences of age-0 lake sturgeon in the lower Peshtigo River, Wisconsin. Trans. of the Amer. Fish, Soc. 134:1400-1409.

Bearlin, A. R., E.S.G. Schreiber, S. J. Nicol, A. M. Starfield, and C. R. Todd. 2002. Identifying the weakest link: simulating adaptive management of the reintroduction of a threatened fish. Can. J. Fish. Aquat. Sci. 59:1709-1716.

BFMHP 1999. WI Bureau of Fisheries Management and Habitat Protection. An evaluation of stocking strategies in Wisconsin with an analysis of projected stocking needs. 36pp.

Bouton, D. 1994 A recovery plan for the Lake Sturgeon (*Acipenser fulvescens*) in New York. NYSDEC

Brooking T.E. (Ed). 2000 Update on Lake Sturgeon in New York State Waters. Syracuse NY.

Bruch, R.M. 2008. Modeling the population dynamics and sustainability of lake sturgeon in the Winnebago system, Wisconsin. Dissertation Ph.D. University of Wisconsin-Milwaukee pp 269.

Busch, W.D.N. and S.J. Lary. 1996. Assessment of habitat impairments impacting the aquatic resources of Lake Ontario. Can. J. Fish. Aquat. Sci. 53:113-120.

Carlson, D.M. 1995. Lake sturgeon waters and fisheries in New York State. J. Great Lakes Res. 21: 35-41.

Carlson, D.M. 2000. A recovery plan for the lake sturgeon in New York State. *In:* Brooking T.E. (Ed). 2000 Update on Lake Sturgeon in New York State Waters. Syracuse NY.

Carlson, D.M., R. Colesante, J.S. Hayes and S.L. Schlueter. 2002. Lake sturgeon (*Acipenser fulvescens*) and its recovery programs in New York State. NYSDEC, Watertown.. 13 pp.

Chiasson, W.B., D.L.G. Noakes, and F.W.H. Beamish. 1997. Habitat, benthic prey, and distribution of juvenile lake sturgeon (*Acipenser fulvescens*) in northern Ontario rivers. Can. J. Fish. Aquat. Sci. 54: 2866-2871.

Ceskleba, D. G., S. AveLallemant and T. F. Thuemler. 1985. Artificial spawning and rearing of lake sturgeon, *Acipenser fulvescens*, in Wild Rose State Fish Hatchery, Wisconson, 1982-1983. Environmental Biology of Fishes. 14(1); 79-85.

Colesante, R.T. 1995. Coolwater hatchery carrying capacity. NYSDEC Fish Culture Report, 625 Broadway, Albany, NY 12233.

COSEWIC 2006. Assessment and update status report on the Lake Sturgeon *Acipenser fulvescens* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa 1-106 pp.

Dittman, D.E. and E.C. Zollweg. 2006. Assessment and habitat use by stocked lake sturgeon in the Genesee River. Final Report to the USEPA :1-49.
Dittman, D.E, M. C. Chalupnicki, J. H. Johnson, and J. Snyder. 2009 Assessment of lake sturgeon rehabilitation: St Regis River. Final Draft Report to the USEPA.
Dumont, P., J. Leclerc, S. Desloges, P. Bilodeau, Y. Mailhot, P. Brodeur, R. Dumas, M. Mingelbier, R. Verdon, M. LaHaye, J. Morin, and R. Fortin. 2006. The biology, status and management of Lake Sturgeon (*Acipenser fulvescens*) in the Quebec part of the St. Lawrencs River: a summary. Lake Sturgeon Recovery Planning Workshop, Winnipeg, Manitoba. 11p.
Fajfer, S., L. Meyers, G. Willman, T. Carpenter, M. J. Hansen. 1999. Growth of juvenile lake sturgeon reared in tanks at three densities. North Am. J. Aquac. 61:331-335.
Farrell, J. M., K. T. Holeck, E. L. Mills, C. E. Hoffman, and V. J. Patil. 2009. Recent Ecological Trends in Lower Trophic Levels of the International Section of the St. Lawrence River: A Comparison of the 1970s to the 2000s. Manuscript in review.
Harkness, W.J.K., and J.R. Dymond. 1961. The lake sturgeon. The history of its fishery and problems of conservation. Ont. Dept. Lands and Forests, Fish and Wildl. Br. 121 pp.
Hay-Chmielewski, E.M. and G.E. Whelan (eds). 1997. Lake Sturgeon Rehabilitation Strategy. Michigan Department of Natural Resources. Fisheries Division Special Report 18.
Hayes, J. and Werner, R.G, 2004. Contributing Factors in Habitat Selection by Lake Sturgeon (*Acipenser fulvescens*). United States Environmental Protection Agency-Great Lakes National Program Office. Final Report, pp. 1-24
Hickey, M. B. C. 2003. Status of Lake Sturgeon (*Acipenser fulvescens*) in the Cornwall Area of Concern. Report Prepared for Environment Canada, Restoration Programs Division, and The St. Lawrence River (Cornwall) Remedial Action Plan. 30pp.
Jackson, J.R., A.J. Van DeValk, T.E. Brooking, O.A. Van Keeken, and L.G. Rudstam. 2002 Growth and feeding dynamics of lake sturgeon, *Acipenser fulvescens*, in Oneida Lake, New York: Results from the first 5 years of a restoration program. Journal of Applied Ichthyology 18:439-443.
Johnson, J. H., D. S. Dropkin, S. R. LaPan, J. E. McKenna and R. M. Klindt. 1998. Age and growth of Lake Sturgeon in the Upper St. Lawrence River. J. Great Lakes Res. 24(1):474-478.
Johnson, T.B., D.B. Bunnell, and C.T. Knight. 2005. A potential new energy pathway in central Lake Erie: the round goby connection. *J. Great Lakes Res.* 31(2):238-251.
Kelso, J.R., R.J. Steedman, and S. Stoddart. 1995. Historical causes of change in Great Lakes fish stocks and the implication for ecosystem rehabilitation. Can. J. Fish. Aquat. Sci. 53 (Suppl. 1):10-19.
Kempinger, J.J. 1996. Habitat, growth and food of young lake sturgeon in the Lake Winnebago system, Wisconsin. N. Amer. J. Fish. Man. 16: 102-114.
Klindt, R. 2005. Lake Sturgeon Egg Take Manual. New York State Department of Environmental Conservation, Region 6 Watertown, NY.
LaPan, S.R., A. Schiavone, R.M. Klindt, R.T. Colesante, W.F. Krise, and M.N. DiLauro. 1994. Re-establishment of lake sturgeon in tributaries of the St. Lawrence River. NYSDEC, Watertown, NY. 10pp.

LaPan, S.R., A. Mathers, T.J. Stewart, T.J., R.E. Lange, AND S.D. Orsatti. 2002. Fish community objectives for the St. Lawrence River. Great Lakes Fishery Commision Special Pub. 2002: pp. 27.

McLoed, D. 2008. A population estimate of lake sturgeon in Little Eva Lake, Ontario 2007. Fort Frances District Report Series No 79. 27pp.

Mills, E.L., J.M. Casselman, R. Dermott, J.D. Fitzsimons, G. Gal, K.T. Holeck, J.A. Hoyle, O.E. Johannsson, B.F. Lantry, J.C. Makarewicz, E.S. Millard, I.F. Munawar, M. Munawar, R. O'Gorman, R.W. Owens, L.G. Rudstam, T. Schaner, and T.J. Stewart. 2003. Lake Ontario: food web dynamics in a changing ecosystem (1970-2000). *Can. J. Fish. Aquat. Sci.* 60:471-490.

Pikitch, EK; Doukakis, P; Lauck, L; Chakrabarty, P; Erickson, DL. Status, trends and management of sturgeon and paddlefish fisheries. Fish and Fisheries. 2005:6:233–265.

Probst, R. T. and E. L. Cooper. 1955. Age, Growth, and Production of the Lake Sturgeon (*Acipenser fulvescens*) in the Lake Winnebago Region, Wisconsin. Trans. Amer. Fish. Soc. 84: 207-227.

Schlueter, S. 2000. Oswegatchie River Lake Sturgeon restoration project. In: Brookings, T.E. Update on Lake Sturgeon in New York Waters. Cornell, Ithaca NY.

Schram, S.T., J. Lindgren, and L.M. Evrard. 1999. Reintroduction of lake sturgeon in the St. Louis River, western Lake Superior. N. Amer. J. Fish. Man. 19: 815-823.

Scott, W.B., and E.J. Crossman. 1998. Freshwater fishes of Canada. Galt House Publications Ltd. Oakville, ON. 966 pp.

Threader, R.W., R. J. Pope, and P.R.H. Schaap. 1998. Development of a habitat suitability index model for lake sturgeon (*Acipenser fulvescens*). Ontario Hydro Report No. H-07015.01--0012.

Threader, R. W., T. Haxton, A. Mathers, and C. Pullen. 2005. Proceedings of a workshop on lake sturgeon(Acipenser fulvescens) in Lake St. Francis and surrounding waters. Cornwall, Ontario. September 22 & 23, 2004. Ontario Ministry on Natural Resources. 80p.

U.S. Fish and Wildlife Service. 2006. Lake sturgeon biology. Great Lakes lake sturgeon website. www.fws.gov/midwest/sturgeon/biology.htm.

Vélez-Espino, L.A., and M.A. Koops. 2007 Recovery potential assessment for lake sturgeon (*Acipenser fulvescens*) in Canadian designatable units. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/nnn

Welsh, A. In press. Genetic guidelines for the stocking of lake sturgeon (*Acipenser fulvescens*) in the Great Lakes Basin.

Welsh, A. B. 2004. Factors influencing the effectiveness of local versus national protection of migratory species: a case study of lake sturgeon in the Great Lakes, North America. Env. Sci. and Policy. 7:315-328.

Wiley, R.W. 1999. Fish hatcheries are a powerful tool of fisheries management. Fisheries 24(9):24-26.

Appendix I – Seminar announcement for class that met at ESF.

NEW GRADUATE SEMINAR (Fall 2007)

EFB 797 Development of a Lake Sturgeon Restoration Strategy for the St. Lawrence River (1 credit)

Instructor(s): Dr. John M. Farrell and participants from DEC, the USGS Tunison Laboratory, and the Cornell Biological Field Station

Time and Place: Wednesdays 12:45–1:40 in 334 Illick Hall

Photo: R. Klindt

Objective: Learn to develop a plan for species based plan for restoration and examine potential ecosystem responses. Work with specialists dedicated to plan implementation and potentially have an impact on outcomes.

Summary: Assist with the development of a strategy to remediate the Lake Sturgeon (*Acipenser fulvescens*) population of the upper St. Lawrence River. A thriving population of sturgeon existed in this system prior to construction of the St. Lawrence Seaway in the 1950s. Overexploitation and habitat loss associated with construction of the Robert Moses Saunders Dam in Massena NY and Cornwall Ontario have led to the loss of critical riverine habitat and a major decline in the population. Population remnants of this once abundant and important species remain, but the ecosystem services associated with this important benthivore are lost. With representatives and experts from DEC and the USGS and Cornell we will explore the feasibility of bringing back this species. Students will take on a component of the plan to develop, present, and discuss restoration in an ecosystem context in a group setting. Results, hopefully, will be used to help guide an actual restoration effort.

Contact information: John Farrell, 253 Illick Hall, 470-6990, jmfarrell@esf.edu

Appendix II. Timing of lake sturgeon rearing periods and typical growth from the OFCS rearing in 1999.

Rearing Periods

May 25---egg take
May 31----hatch
June 5-----begin brine shrimp feeding
June 29----begin formulated diet
July 6 ----end live food feeding
July 19----end formulated diet transition
Sept 30----stock

Growth

June 3	16.2 mm
June 9	20.7 mm
June 16	25.6 mm
June 22	30.3 mm
June 30	35.0 mm
July 7	40.4 mm
July 21	81.3 mm
July 28	124.5 mm
August 9	152.4 mm
Sept. 23	241.3 mm

Appendix III – Letter sent to nine hatchery managers to complete survey information

ESF
State University of New York
College of Environmental Science and Forestry

USGS
science for a changing world

Dear lake sturgeon culturist: May 5, 2008

My name is Richard Colesante, retired coolwater hatchery production supervisor for the New York State Department of Environmental Conservation. I am working on a lake sturgeon restoration project for the St. Lawrence River with John Farrell and Peter Malaty of the SUNY College of Environmental Science and Forestry at Syracuse, New York and Jim Johnson and Dawn Dittman of the Tunison Fish Nutrition Lab (USGS) in Cortland, New York, and Tony David of the St. Regis Tribe Environment Division in Akwesasne, NY. Hatchery considerations will be a major part of this restoration plan, and we are seeking the best and most current information regarding the culture of lake sturgeon. You have been identified as an individual that might be able to supply this type of information.

Attached you will find a lake sturgeon culture survey. If you are unable to answer some questions or questions do not apply to your facility please respond to the best of your ability. Your responses will be summarized and used in hatchery planning for this project; you will be supplied with a copy of the results.

I would like to thank you in advance for completing this survey. A response by early June would be greatly appreciated.

Yours truly,

Richard Colesante
Aquatic Biologist, retired

Appendix IV – Hatchery survey form sent to nine North American hatcheries.

LAKE STURGEON CULTURE SURVEY

1. Approximately how many lake sturgeon do you produce annually?

2. At what size and season are they stocked?

3. Does your facility have a single pass or re-circulating water flow?

4. What is your water source: lake__ river__ well__ both__ other_________

5. What rearing temperatures (range) are maintained during:
   egg incubation_______
   yolk absorption________
   fingerling rearing_______

6. At what date is your normal egg take?

7. What is the approximate survival (%) during the green egg to eyed stage?

8. What is the approximate survival (%) during the green egg to fry hatch period?

9. What is the approximate survival (%) of fry during the yolk absorption period?

10. If you feed live food to sturgeon at your facility, please check the items, length of time fed (days) and feeding rate (if available).

Brine shrimp_________	_____days fed	_____rate
Zooplankton_________	_____days fed	_____rate
Blood worms________	_____days fed	_____rate
Other________________	_____days fed	_____rate

11. What is the survival (%) of sturgeon during the live food feeding period?

12. If you fed formulated diets to sturgeon at your facility, please answer the following:

What formulated diet has performed the best?

What is the survival (%) of sturgeon during the period in which formulated diets are fed?

Do you feed brine shrimp (or other live food-specify) prior to the formulated diet and (if so) for how long (days)?

At what rate (% of body weight) do you feed formulated diet?

Appendix IV – con’t

13. What rearing density (pounds per cubic foot or similar measure) do you use as a guideline in your program, and what is the maximum rearing density used at your facility?

14. What are the growth rates for lake sturgeon at your facility?

15. Are you pleased with the effectiveness and operation of your lake sturgeon facility?

Appendix V – Potential hatchery site evaluation criteria.

PRELIMINARY CONSIDERATIONS IN LOCATING A LAKE STURGEON HATCHERY FOR ST. LAWRENCE RIVER STOCKING

1. An understanding of the current NYSDEC regulations impacting hatchery development in New York State
    a. license and/or permit requirements associated with the hatchery and its water supply
    b. broodstock collection restrictions
    c. disease regulations and testing requirements
    d. hatchery discharge requirements
    e. stocking requirements and permits

2. An understanding of plans being developed by other groups(including Canadian) for lake sturgeon restoration in the St. Lawrence River.

3. Establishing a target number and size of the fingerlings to be stocked annually

4. Analysis of the pros and cons associated with recirculating and single pass water flows in hatchery design, and consideration for incorporating both.

SITE SELECTION CONSIDERATIONS

1. Hydrology—availability, quantity, quality, and temperature range
    a. well water supply
    b. open water supply
    c. public water supply

2. Topography
    a. acreage available-buildings, protection of water supply, expansion
    b. elevation and distance from water source(s)
    c. soil type and suitability-building ,waste treatment
    d. effluent treatment, either sub-surface or receiving water(proximity), settling ponds

2. Broodstock
    a. source and genetic suitability
    b. distance from hatchery
    c. egg quantity available to meet hatchery objective

3. Bio-security
    a. protection of water supplies from vandals and disease
    b. protection of broodfish during egg take
    c. protection of in-hatchery fish from disease introductions(human or other)

d. protection of hatchery discharge and/or effluent
e. protection to prevent conflict with neighbors

4. Support services
    a. power availability
    b. availability of public water(for domestic use and fish culture)
    c. availability of public sewers and sewage treatment
    d. other infrastructure considerations

6. Costs
    a. availability of existing buildings and/or ponds suitable for fish culture
    b. proximity to stocking site, and broodstock

Appendix VI – Conceptual floor plan for production of lake sturgeon culture at the 5200 pound level and annual fingerlings at 125,000.