RECOVERY POTENTIAL ASSESSMENT OF GREAT LAKES AND ST. LAWRENCE RIVER WATERSHEDS (DESIGNATABLE UNIT 8) LAKE STURGEON (*ACIPENSER FULVESCENS*) POPULATIONS

Lake Sturgeon Acipenser fulvescens
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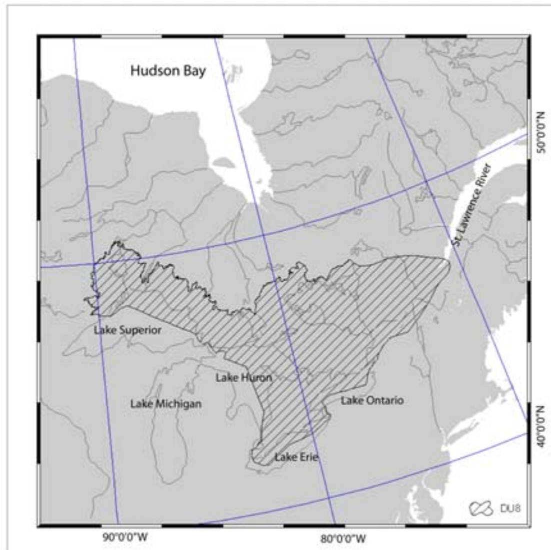

Figure 1: Great Lakes and St. Lawrence River watersheds (Designatable Unit 8).

Context :

*The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of lake sturgeon (*Acipenser fulvescens*) in November 2006. That assessment resulted in the designation of the Great Lakes - Upper St. Lawrence River populations as Threatened. Initial steps required to inform the listing decision must take into consideration the species' current situation and its recovery potential, the impacts of human activities on the species and on its ability to recover, as well as the alternatives and measures to reduce these impacts to a level which will not jeopardize the survival and recovery of the species.*

A species Recovery Potential Assessment (RPA) process was developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the Species at Risk Act (*SARA*)*, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of Fisheries and Oceans Canada regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of the Great Lakes - Upper St. Lawrence River populations of lake sturgeon.*

SUMMARY

- Lake sturgeon remain widespread throughout the Great Lakes and St. Lawrence River basin (Designatable Unit 8), but serious declines in the number and size of populations have occurred.
- A recovery target of 1188 spawning females per year was developed for 12 Sturgeon Management Units around the basin that were either genetically distinct or geographically isolated.
- Model projections suggest that recovery without intervention is possible over 170 - 300 years under the currently estimated suite of mortality rates and life history parameters.
- Based on the recovery target and assuming that current abundances are 10% of this target, the time to 95% probability of recovery range from 20 years to over 100 years (1-3 generations), depending on the recovery actions implemented.
- The presence of dams and exploitation, were the most important lake sturgeon threats in Designatable Unit 8.
- Dams result in habitat fragmentation, flow manipulation, habitat loss, and limit access to spawning habitat.
- Exploitation (commercial fishing, First Nation harvest, and poaching) impacts survival of sturgeon and changes the time to reach recovery.
- Early adult survival is the vital rate most sensitive to perturbations for DU8 lake sturgeon.
- Maximum proportional increases in population growth rates, however, can be achieved by focusing recovery efforts on age-0 and juvenile survival.
- While adult habitat is not believed to be limiting, there is much uncertainty around whether spawning habitat is limiting in some of the Sturgeon Management Units.

BACKGROUND

Lake sturgeon (*Acipenser fulvescens*) remains extant across much of Canada, from the North Saskatchewan River in Alberta, to Hudson Bay in the north, and eastward through to the St. Lawrence River estuary. Lake sturgeon were a common nearshore fish in the nineteenth century, but European settlement of the region coincided with widespread, rapid declines as habitat loss, degraded water quality and intensive fishing took their toll. A meeting of the Committee on the Status of Endangered Wildlife in Canada in November 2006 recommended that the western populations of the lake sturgeon, (Western Designatable Units 1-5), be designated as Endangered. Designatable Units 6 and 7 (Lake of the Woods - Rainy River and Southern Hudson Bay) were assessed as Special Concern, and populations in the Great Lakes - St. Lawrence River (Designatable Unit 8), were assessed as Threatened. This recovery potential assessment focuses on the lake sturgeon populations of the Laurentian Great Lakes and St. Lawrence River watersheds, and is a summary of a Canadian Science Advisory Secretariat peer-review meeting that occurred on November 5-7, 2007, in Sault Ste Marie, ON. Three research documents, one on the modelling (Vélez-Espino and Koops 2008), a second on habitat (Randall 2008) and the third detailing population status, recovery targets and threats (Pratt 2008) explain in detail what is summarized below.

ASSESSMENT

Phase 1: Assess Current Species Status

Present Status and Trajectory

Today, relatively large populations (>1000 spawning individuals/yr) are thought to remain only in a few areas in the Great Lakes basin; the Lake Winnebago system (Lake Michigan), Lake Nipissing, Lake St. Clair, and in the St. Lawrence River. Numerous smaller populations have persisted in several Great Lakes tributaries, but in most areas and rivers where they were found historically lake sturgeon are reduced to very low abundance or have been extirpated.

Lake Superior

It is believed that at least 15 Canadian tributaries of Lake Superior were home to lake sturgeon populations, along with a physically isolated population within the watershed in Lake Nipigon. Remnant lake sturgeon populations exist in 6 of those tributaries (Kaministiquia, Black Sturgeon, Nipigon, Pic, Batchawana, and Goulais rivers) and Lake Nipigon, while populations are thought to be extirpated from an additional 4 streams. It is not known whether lake sturgeon populations remain in the remaining 5 tributaries (Pratt 2008). Population estimates exist only for the Kaministiquia and Black Sturgeon rivers, with < 200 individuals estimated in either population. The conservation status of all populations is considered to be critical or cautious, with only the population trajectory of the Kaministiquia River and Lake Nipigon identified as stable; all other population trajectories were unknown (Pratt 2008).

Lake Huron

There are 23 Canadian tributaries and 3 lakes that drain into Lake Huron with historical records of lake sturgeon populations. Lake sturgeon populations are known to inhabit 15 of those tributaries (St. Marys, Garden, Thessalon, Mississagi, Spanish, French, Key, Magnetawan, Maiscoot, Moon, Go Home, Severn, Sturgeon, Nottawasaga and Sauble rivers) and two lake (Nipissing, Mississagi) systems. Lake sturgeon are believed to be extirpated from the remaining 8 tributaries and Lake Simcoe (Pratt 2008). Population estimates exist for the St. Marys (~ 500), Mississagi (~ 500), and Spanish (< 100) rivers, along with Lake Nipissing (~ 300). Mark-recapture population estimates were made on mixed stocks in the North Channel (4,000-8,000), Georgian Bay (10,000) and the southern main basin (13,000-20,000) areas of Lake Huron (OMNR 2007). The conservation status of all extant populations in the Lake Huron basin is either cautious or unknown (Pratt 2008). The population trajectory of the Lake Nipissing population is increasing, while the Mississagi and Spanish river populations are stable, and the remaining populations have no trajectory data available (Pratt 2008).

Lake Erie

There are no known Canadian tributaries that supported lake sturgeon populations in Lake Erie, but sturgeon are found in the connecting waterways shared with the United States (St. Clair River, Lake St. Clair, Detroit River). These lake sturgeon populations are quite significant, with 20,000-40,000 individuals estimated in both the St. Clair River and Lake St. Clair (Pratt 2008). The conservation status of both Lake St. Clair and the St. Clair

River populations is healthy, and their population trajectories are stable. Parameters for the Detroit River population are not known (Pratt 2008).

Lake Ontario

There were 3 Canadian tributaries, a shoal and a river shared with the United States (Lower Niagara River) that are believed to have historically supported Canadian lake sturgeon populations in the Lake Ontario basin, but extant lake sturgeon populations are found only in the Trent and Lower Niagara rivers. The conservation status on both populations is thought to be critical, with both having unknown population sizes and trajectories (Pratt 2008).

St. Lawrence River

Lake sturgeon populations in the St. Lawrence River are now fragmented due to large hydroelectric facilities progressively built in the last 80 years. There are only small, remnant populations in the upper part of the river above the Moses-Saunders generating station, the top dam in the system, and in Lake St. Francis between the Moses-Saunders and Beauharnois generating stations. There is a large extant population below the Beauharnois generating station, residing in the St. Lawrence River and its fluvial estuary, from Lac Saint-Louis to the limits of freshwater, downstream of Québec City, including the lower reaches of most of the major tributaries (Pratt 2008). The conservation status for both the upper St. Lawrence and Lake St. Francis populations is critical, while the lower St. Lawrence River population is cautious. The population trajectory is not known for the upper St. Lawrence population and decreasing for the Lake St. Francis and lower St. Lawrence River populations (Pratt 2008).

Ottawa River

The Ottawa River has been highly fragmented by dams since European colonization, and what was likely a single or few lake sturgeon populations that could freely migrate long distances are now disparate populations separated by impassable barriers. Ten isolated, remnant stocks are all that remain in these disconnected populations. The conservation statuses of the mid-Ottawa River fragment and of Lac des Deux Montagnes are considered healthy, while the remaining segments are cautious or critical. The population trajectory is increasing in 2 segments, stable in 2 segments, decreasing in 5 segments and unknown in the remaining segment (Pratt 2008).

Life History Characteristics

Lake sturgeon life history traits, including large size, delayed maturation, low natural adult mortality and high fecundity, are successful when facing extremes in environmental conditions and consequently have contributed to the long-term success of the species. Unfortunately, these traits are disadvantageous when facing human-induced mortality and habitat changes, as large, slow growing and late maturing lake sturgeon become economically valuable and susceptible to over-exploitation. Specific life history parameters for Canadian populations appear reasonably stable, though there is a range in some parameters. A thorough review of life history parameters was undertaken by Vélez-Espino and Koops (2008).

Lake Sturgeon Habitat Requirements and Use Patterns

Lake sturgeon require spatially extensive habitat, and the quantity and quality of habitat needed to support the life functions of reproduction, feeding and growth, refugia and movement varies during its extended life history. Functional habitat is defined as the physical, chemical and biological attributes of the living space of sturgeon that determine the population vital rates (survival, growth, reproduction), that together determine population production.

Habitat for spawning, eggs and larvae

Lake sturgeon spawn in spring as temperatures reach 9-18°C, and successful spawning depends on suitable flow and temperature regimes. Most populations spawn in high-gradient reaches of large rivers, often below waterfalls, with current velocities of 0.5 to 1.3ms^{-1}, water depths of 0.1 to 2m, and substrates of coarse gravel, cobble, boulders, hardpan or sand (Randall 2008). Lake sturgeon scatter their eggs and provide no parental care. Adults move quickly downstream after spawning.

Hatching of eggs takes 8-14 days, depending on temperature. Newly hatched larvae are negatively phototactic, and remain burrowed in the substrate (interstitial spaces) until the yolk sac is absorbed. Within 13-19 days after hatching, the larvae emerge from the substrate at night and disperse downstream with the current (can be up to several kilometres) and then return to a benthic habitat. Before this downstream dispersal, the utilization of the benthic spawning habitat for the egg incubation, hatching and larval stages lasts for a period of about one month (Randall 2008).

Habitat of juveniles

Age-0 sturgeon grow rapidly from 17-18mm at emergence to approximately 123mm by September. To achieve this growth, habitat that provides an adequate food supply is essential for this life stage. Sturgeon are generalist, benthic feeders; the diet of juvenile sturgeon in the St. Lawrence River includes a diversity of benthic fauna, such as amphipods, chironomids, oligocheates, ephemeroptera, trichoptera, molluscs and fish eggs (Randall 2008).

There is a gap in knowledge of the habitat preference of young sturgeon during the age-0 growth period, particularly in lakes. Age-0 sturgeon prefer flat and sand bottom conditions that may be linked to food acquisition. In the St. Lawrence River, catches of juveniles in autumn were highest in water depths of 3-6m and currents ranging between 0.25–0.5ms^{-1} (Randall 2008). There is evidence that juveniles gather at localized areas in rivers, shallow river mouths or adjacent bays during late summer and fall, but are later found in the same habitats as adults after their first year. The tendency for juvenile sturgeon to aggregate locally in the St. Lawrence River cannot be linked solely to their food habits, as their diverse prey items are widely distributed. Habitat preferences for certain depths and currents as noted previously must be related in part to life history functions other than feeding (Randall 2008).

Habitat of adults

Lake sturgeon adults feed primarily on benthic invertebrates that they detect using their barbels as they swim in contact with the bottom. Sturgeon feed actively throughout the year, though consumption may decline during winter. Prey abundance is probably a factor in determining habitat selection. Lake sturgeon are found in water depths > 5m year round and primarily utilize fine (silt) substrate, but they can also found over a variety of substrates. Some studies indicate that adults prefer depths < 9m during winter, but move into deeper water in summer (Randall 2008). Most captures (by commercial fisheries) are from about 5 to 9m, but they are occasionally taken as deep as 43m.

Lake sturgeon, at least populations in fluvial lakes of the St. Lawrence, are not believed to migrate much outside of the spawning period (Randall 2008).

The migration of adult lake sturgeon is functionally linked to movement between the adult feeding and spawning habitat. Open connections between habitats is critical for lake sturgeon, as adults migrate considerable distances (up to 225km) to find suitable spawning habitat (Randall 2008). Based on observations of natural populations with unrestricted access to lake and river habitats, it is recommended that management strategies should allow lake sturgeon access to a minimum of 250 to 300km of unobstructed habitat to provide access to feeding, overwintering and spawning areas.

There are two patterns of spawning migration in the Great Lakes; one-step or two-step movements, each of which have different implications for habitat management. One-step populations migrate in spring and spawn within a few days of reaching their spawning habitat. Two-step populations begin their spawning migration in autumn, overwinter in deep pools, and spawn the following spring. Determination of ecologically significant base flows would be needed for both migration strategies, but for different periods and durations (Randall 2008).

Recovery Target

While the selection of recovery targets is ultimately the responsibility of the Recovery Team when drafting a recovery strategy, it is necessary for this exercise to provide some preliminary recovery targets to allow an assessment of potential recovery scenarios. The mitigation component of any recovery potential assessment requires the identification of recovery targets, timeframes for recovery, and the specification of the uncertainty of outcomes associated with management actions. Separate recovery goals for abundance, distribution and range are needed as part of a recovery potential assessment. As this recovery potential assessment focuses on only DU8, no range recovery goals were considered.

Recovery Target for Abundance

There are no firm estimates of historic abundances, but there is evidence that lake sturgeon abundances in the Great Lakes and surrounding watersheds have declined to less than 1% of their historic abundances. Population viability analysis was used to set population target levels for lake populations. Demographic sustainability is considered the most conservative and quantitatively feasible way of determining population targets (Vélez-Espino and Koops 2008). The allometry between maximum population growth rate and minimum viable population was used to compute the minimum population size for demographic sustainability, defined as the adult population size required for a 99% probability of persistence over 40 generations. The modelling produced an average recovery target for each lake sturgeon management unit (SMU) of 1188 spawning females per year, with 95% confidence limits of 1160-1216 (Vélez-Espino and Koops 2008). This target implies a total population size of 11880 spawners, given a 1:1 sex ratio and an average 5 year spawning periodicity for females.

Recovery Target for Distribution

Lake sturgeon populations in the Great Lakes basin are widely distributed, separated by natural and man-made barriers, and in many instances genetically distinct. The recovery target of 1188 spawning females per year was considered to be an ambitious target for a single spawning population, so observed lake sturgeon genetic structuring and known barriers to migration were used to guide the development of twelve SMUs which, in most cases, consisted of more than one known extant population (Figure 2).

Since each SMU is either genetically distinct or geographically isolated, all twelve SMUs were identified as being important to recover to the levels identified above for abundance. Within each SMU, it is important to maintain all remaining small populations, even at remnant levels, and even if the majority of lake sturgeon contributing to the recovery of the overall SMU comes from a single spawning population.

Recovery Projections Under Current Conditions

A demographic modelling approach that requires minimal data and is based on life history information was used to provide a quantitative approach to the recovery potential assessment. Harm is defined as a negative perturbation that can target one or more vital rates and life cycle stages simultaneously (Vélez-Espino and Koops 2008). This quantitative assessment of allowable harm uses perturbation analysis, a demographic prospective technique that depends on the construction of projection matrices from which population growth rate can be calculated and the relative importance of each vital rate can be used to project the effects of management interventions. Complete details on the model and results are available in Vélez-Espino and Koops (2008).

Figure 2. The composition and distribution of Sturgeon Management Units (SMUs) within the Great Lakes basin. The SMUs are made up of the following extant populations: SMU 1 = western Lake Superior (Pigeon and Kaministiquia rivers), SMU 2 = Lake Nipigon, SMU 3 = northern Lake Superior (Black Sturgeon, Nipigon, Gravel, Pic, White and Michipicoten rivers), SMU 4 = eastern Lake Superior (Batchawana, Chippewa and Goulais rivers), SMU 5 = Lake Huron north channel (St. Marys, Garden, Thessalon, Mississagi and Spanish rivers), SMU 6 = Lake Nipissing, SMU 7 = Georgian Bay Lake Huron (French, Key, Magnetawan, Naiscoot, Moon, Go Home, Severn, Sturgeon and Nottawasaga rivers), SMU 8 = Lake Huron / Erie Corridor (Main basin Lake Huron, St. Clair River, Lake St. Clair, Detroit River and Lake Erie), SMU 9 = Lower Niagara River, SMU 10 = eastern Lake Ontario / upper St. Lawrence River (Trent and upper St. Lawrence rivers and Lake St. Francis), SMU 11 = Ottawa River watershed population, SMU 12 = lower St. Lawrence River.

The demographic modelling indicated that, under the currently estimated suite of mortality rates and life history parameters, lake sturgeon in DU8 will require between 170 years (if populations are at 10% of the recovery target) to 300 years (if populations are at 1% of the recovery target) to reach the target of 1188 spawning females per year in each Sturgeon Management Unit (Figure 3). This recovery timeframe is sensitive to the spawning periodicity of a given population (Vélez-Espino and Koops 2008). None of the Sturgeon Management Units identified within DU8 are expected to disappear under current conditions, though the survival of individual populations within a Sturgeon Management Unit may be jeopardized.

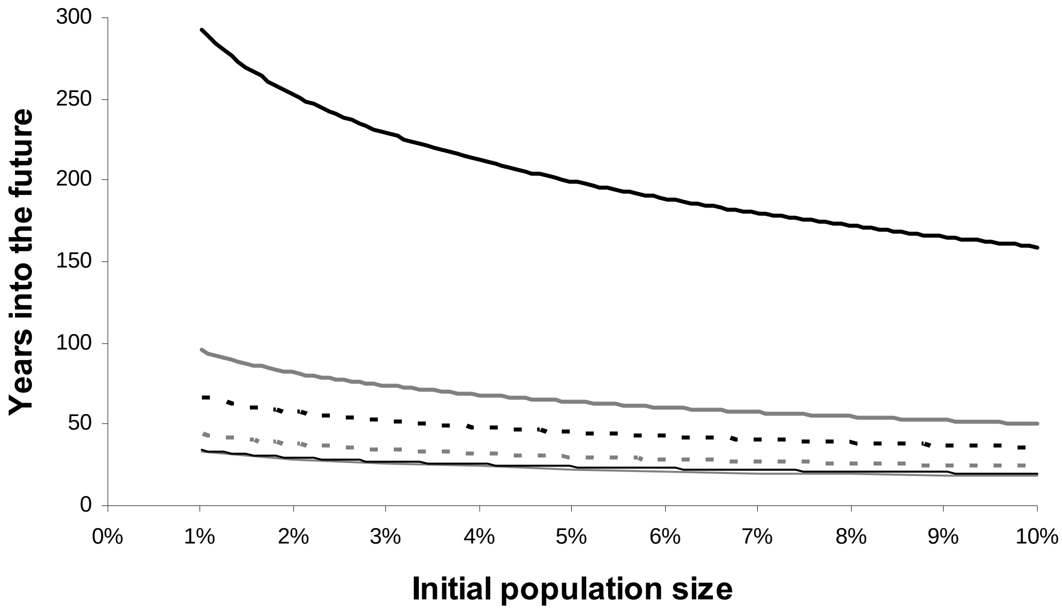

Figure 3. Stochastic projections of recovery timeframes under current conditions (solid top line) and five different recovery scenarios. Strategy 1 (solid black line) was the maximization of the survival rates of early adults, strategy 2 (solid grey line) added a 10% increase in the survival rates of late juveniles, strategy 3 (black dotted line) added a 20% increase in the survival rates of age-0 and early juveniles, strategy 4 (dotted grey line) added the maximization of the survival rate of late adults, while strategy 5 (black dashed line) added a 20% increase in fertility. Initial population size is expressed as a percentage of the recovery target.

Phase 2: Scope for Management to Facilitate Recovery

Identification of Key Recovery Parameters

Sensitivity to harm (elasticities computed from mean matrices) clearly pointed to the survival of early adults as the vital rate most sensitive to perturbations in all lake sturgeon DUs, including the three DU8 sub-units. (Figure 4a), though important variability was present among DUs (elasticity range: 0.33-0.50). The older juvenile and adult life stages were the next most sensitive, while age-0 and early juvenile life stages exhibited low sensitivity to perturbation. Fecundity rates of both adult stages were highly insensitive to perturbation (elasticity range: 0.02-0.07). These outcomes identify the importance of reducing mortality on older lake sturgeon as the key to recovering lake sturgeon populations, and suggest that any recovery alternatives that maximize survival of these stages will increase the likelihood of or shorten the time to recovery. Although lake sturgeon populations are highly sensitive (high elasticity) to early adult survival, the potential to increase the survival of older lake sturgeon limits the scope for management to improve population growth rates by increasing these vital rates. In spite of the relatively low sensitivity (elasticities) of lake sturgeon populations to changes in YOY and early juvenile survival, their high potential for improvement increases their effects on population growth (Figure 4b).

Identification and Assessment of Mortality Risks

It was not possible to quantify the magnitude of any of the major potential sources of lake sturgeon mortality. Instead, identified threats were ranked to provide at least a relative measure of their importance by determining the most important threats from the individual lake sturgeon populations (Pratt 2008). The threat data was summarized by identifying anthropogenic activities that resulted in the specific threats that were assessed, and identifying which lake sturgeon life stages those activities and outcomes were likely to differentially affect.

Two main anthropogenic activities, the presence of dams and exploitation, were the most important threats across all the Sturgeon Management Units. Dams result in habitat fragmentation, flow manipulation, and limit access to spawning habitat, which can result in habitat loss, the loss of genetic diversity and direct mortality on egg and age-0 life stages. Exploitation, including First Nation harvest, poaching, and commercial harvest, remove the sub-adult and adult life stages that are most crucial for lake sturgeon recovery (Vélez-Espino and Koops 2008). Activities including agricultural activities, urbanization and invasive species were considered to result in outcomes that provided moderate threats, though these threats were considered to be the most important for a few individual populations. All remaining activities were considered to be a low threat on the whole, but again these activities have the potential to negatively affect particular populations (Pratt 2008).

Quantification of Habitat Need and Supply

The area needed for spawning was estimated as the product of area per individual female spawner and the recovery target of 1188 spawning female sturgeon per year. Given that 13 to 48m^2 of spawning habitat per female is needed to maximize the egg to fry survival rate, the estimate of required spawning habitat ranged between 15,444m^2 (1.54ha) to 57,024m^2 (5.70ha) in each sturgeon management unit (Randall 2008).

Determining the area of lake or river habitat needed for adult sturgeon for growth and survival needed the additional step of estimating the total number of adults in a recovered population, based on the recovery target of 1188 spawning female sturgeon per year. If the population had a 1:1 sex ratio and five year spawning periodicity (Vélez-Espino and Koops 2008), a population at the recovery target would have approximately 11,880 adults. Given a range in length-at-maturity from 100-144cm, the total required area for riverine populations ranged from 582ha (adult size of 100 cm) to 1806ha (adult size of 144cm) (Randall 2008). For populations inhabiting lakes, the corresponding area requirements for 11,880 adults ranged from 1794ha to 5595ha. Lake sturgeon in lakes require more area because lakes are inherently less productive.

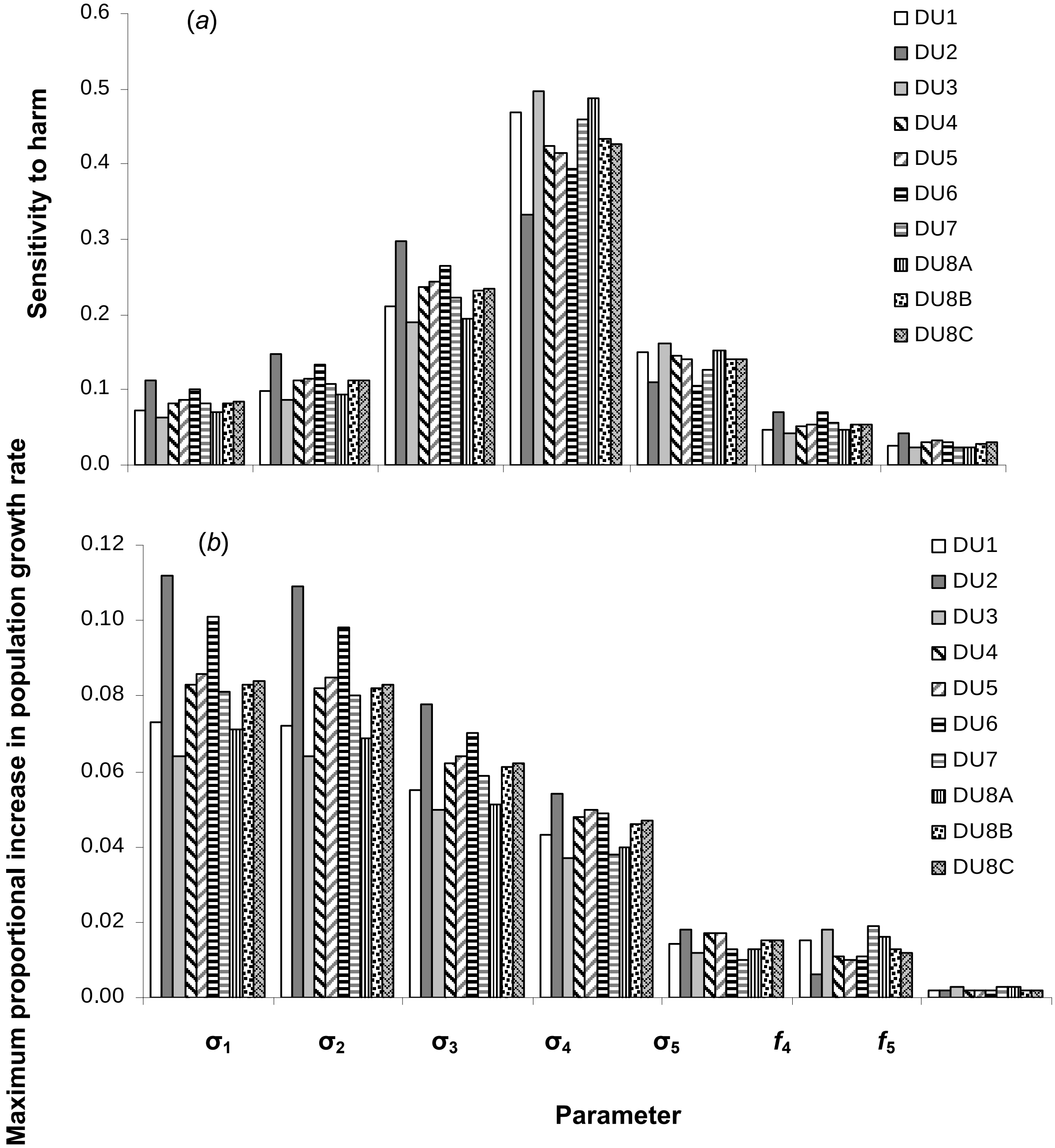

Figure 4. a) . Sensitivity to harm (elasticities) of each vital rate for lake sturgeon by Designatable Unit (DU) computed from mean matrices, and b) maximum proportional increases in population growth (Δλ/λ) computed with deterministic elasticities. σ_j is the annual survival rate of an individual in stage j. f_j is the fertility of stage j. Parameter definitions: σ_1 = age-0, σ2 = young juvenile, σ3 = older juvenile, σ4 = young adult, σ5 = older adult, f4 = young adult fecundity, f5 = older adult fecundity. See Vélez-Espino and Koops (2008) for full details. DU8 is subdivided into DU8A (Lake Erie – Lake Huron), DU8B (North Lake Superior) and DU8C (St Lawrence).

With only limited quantification of spawning habitat for a few populations (e.g. St Lawrence River) and no assessment of adult habitat available, no formal assessment of the likelihood that the current quantity and quality of habitat were limiting lake sturgeon recovery is possible. There was consensus that adult habitat was not likely limiting recovery for lake sturgeon populations that spawn in streams but reside in the Great Lakes proper, but there was less certainty about whether the same was true for riverine populations. The quantity and quality of spawning habitat was considered to be a threat to recovery for a number of individual populations, and it was therefore considered likely that spawning habitat was limiting recovery for those Sturgeon Management Units that were composed of only a few populations with few known spawning locations (e.g. SMU’s 1, 2 6, 9 and 10) (Pratt 2008).

Assessment of Habitat Threats

While it is not possible to completely assess the magnitude by which current habitat threats are limiting lake sturgeon recovery, it is possible to assess the ranked threats for each population and summarize by Sturgeon Management Unit to determine if the main threats for each unit are related to habitat quantity or quality. Threats to habitat quantity were identified as being high or moderate in all Sturgeon Management Units with the exception of the Georgian Bay area of Lake Huron. Habitat loss and fragmentation due to dams was prevalent throughout the Sturgeon Management Units. Habitat quantity was generally considered to be a higher threat than habitat quality, which was only considered to be a high threat for Lake Nipissing and Georgian Bay Lake Huron. It is obvious that within a SMU the relative importance of habitat quantity and quality threats depend on individual lake sturgeon populations, and any generalizations for a given unit do not necessarily reflect individual populations. In general, habitat threats are important for most populations and SMUs.

Phase 3: Scenarios for Mitigation and Alternatives to Activities

Inventory of Feasible Mitigation Measures and Alternative Activities

Participants were solicited for input on potential mitigation measures or alternatives to the activities for the threats to individual lake sturgeon populations that were identified prior to the assessment, and the suggested mitigation and activities were reviewed at the assessment. Mitigations and alternative activities were identified for most threats (Table 1). As threats differentially affect lake sturgeon life stages, the various suggested mitigations and alternatives can also differentially affect the survival or productivity of certain life stages. For example, reducing exploitation would enhance survival of larger lake sturgeon, while moving towards a natural flow regime would enhance the survival of age-0 lake sturgeon (Table 1) (Pratt 2008).

Recovery Scenarios

Vélez-Espino and Koops (2008) modelled recovery efforts combined with recovery targets to project recovery timeframes as a stochastic process under a number of management scenarios targeting different combinations of lake sturgeon vital rates. In particular, five hypothetical recovery scenarios, representing positive and increasing impacts on the vital rates derived from habitat rehabilitation, stocking, fishing regulations, and improved fish passage at barriers were examined (Vélez-Espino and Koops 2008). Strategy 1 maximizes the survival of early adults (e.g., through total closure of the fishery for early adults), which was the vital rate with the highest contribution to population growth rates. Strategy 2 adds a 10% increase in the survival of late juveniles (e.g., by increasing minimum legal size limits). This vital rate was the second in rank contribution to population growth rates with a maximum proportional increase less than 26% (Vélez-Espino and Koops 2008). Strategy 3 adds a 20% increase in the survival of age-0 and early juveniles (e.g., through habitat rehabilitation and stocking of age-0 and early juveniles). This is a conservative increase in these vital rates given their maximum proportional increase (73-100%). Strategy 4 maximizes the survival of late adults (in addition to the actions included in the other strategies). Lastly, Strategy 5 adds a 20% increase in fertility (e.g., through passage of spawners at barriers or dam removal). Fertility rates had the lowest contributions to population growth rates with maximum proportional increases ranging 4-20%. Complete details are available in Vélez-Espino and Koops (2008).

Table 1. Suggested mitigations and alternatives to activities for population-level threats identified for Designatable Unit 8 lake sturgeon.

Threat	Suggested Mitigation / Alternative	Life stage enhanced
Exploitation	enact zero harvest regulation	late juvenile, early and late adult
	enhance law enforcement	late juvenile, early and late adult
	improve public and First Nation education	late juvenile, early and late adult
Urbanization	increase protection during work permit reviews	all
	enforce discharge limits	all
	improve effluent from water treatment plants	all
Agricultural activities	advocate proper drainage	all
	reduce contaminant loads in run-off	all
	control erosion	all
Industrial activities	minimize point source pollution	age-0, eggs
Habitat loss due to dams	enact minimum flow requirements	age-0, eggs
	provision fish passage	all
	habitat improvement work	age-0, eggs
	prevent any additional fragmentation	all
Changes in flow regimes	amend water management plan	all
	follow natural flow regimes	age-0, eggs
Parasite infestations	monitor aquatic invasive species	all
Predation by fishes	routinely examine for sea lamprey wounds	late juvenile, early and late adult
Introduction of exotics	monitor aquatic invasive species	all
	ban use of live bait	all
	Strengthen interlake ballast water regulations	all
Genetic contamination due to stocking	develop a stocking policy	all
Diseases from aquaculture	monitor for bacteria and viruses	all
Lampricide treatments	schedule treatments according to spawning times and age-0 growth	age-0

Maximizing the survival of young adults (Strategy 1) is projected to produce recovery timeframes ranging from 50 years with an initial population vector (*IPV*) equivalent to 10% of the recovery target to 95 years with an *IPV* equivalent to 1% of the recovery target (Figure 3). By simultaneously increasing the survival rates of late juveniles by 10% (Strategy 2), recovery time frames are projected to be reduced to 36 years when *IPV* = 0.1 the annual number of spawning females and to 67 years when *IPV* = 0.01. The implementation of Strategy 3, is projected to produce recovery timeframes ranging from 24 years when *IPV* = 0.1 to 44 years when *IPV* = 0.01. The simultaneous maximization of the survival rates of late adults (Strategy 4) is projected to produce recovery timeframes ranging from 19 years when *IPV* = 0.1 to 33 years when *IPV* = 0.01. Lastly, the implementation of Strategy 5, which adds to Strategy 4 a 20% increase in fertility, had a small effect on recovery timeframes, which ranged from 18 years when *IPV* = 0.1 to 33 years when *IPV* = 0.01 (Figure 3).

CONCLUSIONS

Lake sturgeon remain widespread throughout the Great Lakes and St. Lawrence River basin (Designatable Unit 8), but serious declines in the number and size of populations have occurred. Lake sturgeon require spatially extensive habitat, and their life history traits, including large size, delayed maturation and slow growth, make then susceptible to over-exploitation and in turn are disadvantageous in the face of human-induced mortality and habitat change. Two main anthropogenic activities, the presence of dams and exploitation (commercial exploitation, First Nation harvest and poaching), were the most important lake sturgeon threats in Designatable Unit 8. While adult habitat is not believed to be limiting, there is much uncertainty around whether spawning habitat is limiting in some of the Sturgeon Management Units.

A recovery target of 1188 spawning females per year was developed for 12 Sturgeon Management Units around the basin that were either genetically distinct or geographically isolated. Model projections suggest that recovery without intervention is possible over 170 - 300 years under the currently estimated suite of mortality rates and life history parameters. Lake sturgeon populations are most sensitive to changes in early adult survival. However, maximum proportional increases in population growth rates can be achieved by focusing recovery efforts on age-0 and juvenile survival. Based on the recovery target and assuming that current abundances are 10% of this target, the time to 95% probability of recovery range from 20 years to over 100 years (1-3 generations), depending on the recovery actions implemented.

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