Ontario Ministry of Natural Resources/COA - Jason Mortlock

American Eel

(Anguilla rostrata) in Ontario

Ontario Recovery Strategy Series

Draft

Natural. Valued. Protected.

Ministry of Natural Resources

Ontario

About the Ontario Recovery Strategy Series

This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the Endangered Species Act, 2007 (ESA, 2007) and the Accord for the Protection of Species at Risk in Canada.

What is recovery?

Recovery of species at risk is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

Under the ESA, 2007, a recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Sections 11 to 15 of the ESA, 2007 outline the required content and timelines for developing recovery strategies published in this series.

Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. There is a transition period of five years (until June 30, 2013) to develop recovery strategies for those species listed as endangered or threatened in the schedules of the ESA, 2007. Recovery strategies are required to be prepared for extirpated species only if reintroduction is considered feasible.

What's next?

Nine months after the completion of a recovery strategy a government response statement will be published which summarizes the actions that the Government of Ontario intends to take in response to the strategy. The implementation of recovery strategies depends on the continued cooperation and actions of government agencies, individuals, communities, land users, and conservationists.

For more information

To learn more about species at risk recovery in Ontario, please visit the Ministry of Natural Resources Species at Risk webpage at: **www.ontario.ca/speciesatrisk**

RECOMMENDED CITATION

MacGregor, R., J. Casselman, L. Greig, W. A. Allen, L. McDermott, and T. Haxton. 2010. DRAFT Recovery Strategy for the American Eel (*Anguilla rostrata*) in Ontario. Ontario Recovery Strategy Series. Prepared for Ontario Ministry of Natural Resources, Peterborough, Ontario. vii+ 78 pp.

Cover illustration: Ontario Ministry of Natural Resources/COA – Jason Mortlock

Cette publication hautement spécialisée Recovery strategies prepared under the *Endangered Species Act, 2007*, *n'est disponible qu'en Anglais en vertu du Règlement 411/97 qui en exempte l'application de la* <u>*Loi sur les services en français*</u>*. Pour obtenir de l'aide en français, veuillez communiquer avec Pamela Wesley au ministère des Richesses naturelles au 705-755-5217.*

AUTHORS

Rob MacGregor	(Former) Ontario Ministry of Natural Resources, Great Lakes Branch Peterborough, Ontario
John Casselman	Queen's University, Kingston, Ontario
Lorne Greig	ESSA Technologies Ltd., Richmond Hill, Ontario
W.A. (Bill) Allen	Heritage One, Burk's Falls, Ontario
Larry McDermott	Plenty Canada, Lanark, Ontario
Tim Haxton	Ontario Ministry of Natural Resources, Aquatic Science Unit – Southern Science, Peterborough, Ontario

ACKNOWLEDGMENTS

We express our sincere thanks to Elder Dr. William Commanda O.C. (Officer, Order of Canada and Founder of Circle of All Nations), Elder Albert Marshall (Eskasoni Mi'Kmaw First Nation), Elder Murray Whetung (Curve Lake First Nation), and Henry Lickers (Director of the Department of Environment for the Mohawk Council of Akwesasne), for their dedication and tireless efforts to work toward harmony with the environment. We thank them for their wisdom and for granting permission to share their insights in the recovery strategy. We give particular thanks to Elder Commanda for informing the Governor General and the Queen that "the ancient American Eel, which was once so plentiful in the Ottawa River Watershed, has been placed on the Endangered Species List in Ontario" (Commanda 2009). Thanks to Dr. Cheryl Bartlett for permission to include the Two-Eyed Seeing logo developed by Integrative Science at Cape Breton University, and to David Oliver of Skylark Information Systems for assistance with preparation of maps to support our work.

The partnering efforts by Aboriginal and non-Aboriginal people in writing this recovery strategy, and the likelihood of continuing long-term work together, has strengthened our relationships with one another and with American Eel. Collective efforts among government, stakeholders and Aboriginal people to recover this species will not only aid in the restoration of lost ecological services, and restore biodiversity, cultural and natural heritage values, but will be a significant milestone in recovering and strengthening relationships among our cultures.

DECLARATION

The Ontario Ministry of Natural Resources has led the development of this recovery strategy for the American Eel in accordance with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery strategy has been prepared as advice to the Government of Ontario, other responsible jurisdictions and the many different constituencies that may be involved in recovering the species.

The recovery strategy does not necessarily represent the views of all of the individuals who provided advice or contributed to its preparation or the official positions of the organizations with which the individuals are associated.

The goals, objectives and recovery approaches identified in the strategy are based on the best available knowledge and are subject to revision as new information becomes available. Implementation of this strategy is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy.

RESPONSIBLE JURISDICTIONS

Ontario Ministry of Natural Resources
Fisheries and Oceans Canada

EXECUTIVE SUMMARY

The American Eel (*Anguilla rostrata*) is the only member of the genus *Anguilla* found in North America. In Ontario, it is near the northern extremity of its range, which spans fresh and coastal Atlantic Ocean waters of North, Central (Mexico) and northern South America. Aboriginal traditional knowledge, anecdotal (local knowledge from the public), archaeological information, historical documents and old fisheries records tell us that American Eels were once extremely abundant throughout all tributaries to Lake Ontario and the St. Lawrence River. Declining abundance in most watersheds appears to have been underway by the turn of the twentieth century. More recently, the American Eel has been apparently extirpated from many parts of its Ontario range and is in serious decline where it still exists, leading to its listing as endangered under Ontario's *Endangered Species Act, 2007* (ESA).

Present science considers the American Eel to consist of a single breeding population in which all individuals travel to the Sargasso Sea in the Atlantic Ocean to spawn. From there, young eels drift with ocean currents and most eventually migrate inland into streams, rivers and lakes. Ontario's eels, being virtually all female and the most fecund within the species' range, are an especially critical segment of the global population.

In Ontario, the American Eel is a highly valued fish for Aboriginal peoples, and was also highly valued by European settlers. It thus forms a strong component of Ontario's cultural and natural heritage. The cumulative effects of eel mortality during downstream migration due to hydroelectric turbines, reduced access to habitat imposed by man-made barriers to upstream migration, commercial harvesting in jurisdictions other than Ontario, and habitat destruction, alteration and disruption are among the most significant threats to the survival and recovery of the American Eel in Ontario.

Recovery of American Eels in Ontario is a long-term prospect, likely to take many eel generation times to complete in its fullest sense (one generation = approximately 20 years). The goal of the recovery strategy is to re-establish the American Eel throughout its native Ontario range, at population levels that: (1) restore the full cultural relationship with eels in Aboriginal communities and for Ontario residents; (2) are consistent with ecosystems of high integrity and function; (3) strengthen the biodiversity of the province's watersheds; and (4) provide valued ecological services. Although full recovery of historic abundance may not be feasible, recovery to beneficial levels (abundance sufficient to sustain sustenance and ceremonial fishing, and perhaps limited commercial fishing) should be possible, and much progress can be made within one generation time. Now that anthropogenic mortality due to fishing in Ontario has been addressed, it is recommended that a particular emphasis of eel recovery be placed on strategic provision of enhanced, adequate and safe upstream and downstream passage. The recovery goal, described in Section 2.1, will be achieved through the following recovery objectives.

1. Restore access to habitat within the historic range of American Eel.
    - By 2150, restore resilience of American Eel to anthropogenic stress in Ontario by diversifying habitats available to American Eel within the province, and by

protecting/restoring access to and use of both upper St. Lawrence River/Lake Ontario and the inland watersheds formerly used by American Eel in Ontario.
- By 2050, increase production of American Eels by restoring access to all immediate tributaries of the Ottawa River, Lake Ontario and the upper St. Lawrence River.
- Beginning immediately, consistent with the National Management Plan for American Eel, increase American Eel access to habitat by 10 percent every five years (DFO 2007a).

2. Increase escapement of silver and large yellow eels from watersheds in their historic range within Ontario.
   - By 2050, reduce cumulative mortality rates by 50 percent at the watershed level (consistent with DFO 2007a) in order to increase the escapement of large, mature female eels from provincial waters to levels targeted in implementation plans for particular watersheds. This goal is intended to support increased recruitment of eels. As there is no fishing in Ontario, the focus will need to be on cumulative mortalities due to turbines. Measured at the Moses-Saunders ladders, the intent is to achieve recruitment of eels ascending the ladders consistent with the returns observed during the late 1970s and early 1980s.
   - By 2070, increase the number of American Eels annually out-migrating from Ontario to the ocean to levels consistent with those observed in the early 1980s.
   - By June 2011 undertake negotiations with power companies, stakeholders, Aboriginal representatives and government to develop plans to reduce mortality of American Eels by hydroelectric facilities.
3. Reduce anthropogenic mortality of eels in boundary waters managed jointly with other jurisdictions.
4. Locate, protect, restore and enhance habitats upon which eels depend.
5. Reduce other sources of stress on American Eel (e.g., contaminants, disease, harmful destruction, alteration or disruption of habitat).
6. Ensure an appropriately coordinated and strategic watershed-based approach to eel recovery across its historic range in Ontario.
7. Strengthen the engagement of Aboriginal peoples, stakeholders and other partners in the development and implementation of recovery actions for American Eel.
8. Maintain strong Ontario participation and leadership in the development and implementation of coordinated inter-jurisdictional protection, management and recovery of American Eel and its habitats at national and bi-national levels.
9. Ensure ongoing understanding of the current status of American Eel and the efficacy of recovery strategy actions.
10. Evaluate potential short-term methods of supporting eel abundance in identified watersheds.
11. Address knowledge gaps to enable and enhance protection, conservation and recovery efforts.

American Eel recovery should occur through coordination and integration in science, management and conservation across the numerous jurisdictions and among the agencies and organizations responsible for eel management in North America. It is important that Ontario continue its strong efforts to encourage the participation of others to reverse American Eel declines. It also should include a commitment to integrate western science with Aboriginal Traditional Knowledge and community knowledge.

All historic migratory corridors for American Eel should be contained in the habitat regulation. In general, this will include all waters tributary to Ontario's portions of Lake Ontario, the St. Lawrence River and the Ottawa River.

It is recommended that the habitat regulation prescribe that the primary habitat in both lentic and lotic waters be protected, including all waters extending from the high-water mark (including a 30 m riparian buffer) down to a depth of 10 m for all reaches currently or formerly occupied or used as migratory corridors by American Eel. This includes all rivers, streams and rivulets, both permanent and ephemeral, with the same 30 m buffer. It should be noted that potential habitat can be much broader depending on the water body, and can extend from the high water mark (including a 30 m riparian buffer) to any depth. Local knowledge should be used to determine if refinements in particular water courses or reaches are necessary. Otherwise, protecting the primary habitat to a depth of 10 m should be sufficient.

Finally, it is recommended that all migratory corridors (historic and current) be prescribed as habitat to allow for unobstructed up and downstream movement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 BACKGROUND

Knowledge Integration

The American Eel Recovery Team developed this recovery strategy to guide the recovery and facilitate the long-term sustainability of American Eel throughout its historic range in Ontario. The strategy adheres to a number of important principles documented in MacGregor et al. (in prep.), which is a background document that contains important technical and other information that was used in developing the recovery strategy. The recovery strategy recommends strategic approaches to recovery focussed on reversibility of: (a) the substantial provincial declines in abundance; and (b) the ongoing extensive range contractions. Taken as a whole, the recovery strategy considers uncertainty, favours diversity, reversibility and adaptability over time, and expects positive steps towards sustainability (adapted from Gibson 2005). The recovery strategy was produced by bringing together and integrating the thoughts of a large team of experts in the science, management, use and Aboriginal Traditional Knowledge (ATK) of the species in the province.

The first purpose of the *Ontario Endangered Species Act, 2007* (ESA) is to "identify species at risk based on the best available scientific information, including information obtained from community knowledge and Aboriginal Traditional Knowledge (ATK)". Cultural differences in how knowledge is obtained, viewed, and communicated make integration of ATK with western science a significant challenge – one that is important to surmount, and can be met with ongoing dialogue among those who have a commitment to the guiding principle of Two-Eyed Seeing (Allen 2008a; Allen et al. 2008).

The principle of Two-Eyed Seeing was developed by Elder Albert Marshall of Eskasoni First Nation, who described it as the respectful joint integration of ATK and empirical science. The American Eel Recovery Team adopted and embedded this principle in the process of developing the Recovery Strategy for American Eel in Ontario.

Two-Eyed Seeing

Logo by Integrative Science at Cape Breton University.

The American Eel Recovery Team views Aboriginal Traditional Knowledge as an integrative 'way of knowing' gained through deep spiritual, physical, emotional and intellectual ties with nature. It reflects intimate, holistic observation of the environment. Aboriginal Traditional Knowledge in this recovery strategy is not considered to be analogous to data that can be collected; however, it is considered to reflect the insight and understanding that arises from analysis in western science. While ATK rests on the foundation of generations of oral knowledge sharing, it is not static and thus not solely traditional. Aboriginal Traditional Knowledge is unique to specific local environments and, as with the continuing refinements of western science, it grows with each generation, providing insight into current conditions.

The joint efforts of Aboriginal and non-Aboriginal members of the recovery team to integrate knowledge from ecology and fisheries science with ATK and community knowledge in developing this recovery strategy has provided a much richer understanding than could have been gained with an ATK or western scientific perspective alone.

Aboriginal Traditional Knowledge, anecdotal information from an earlier time, and early eyewitness accounts provide valuable insight into the past distribution, abundance, and importance of American Eel (Pauly 1995; Pinnegar and Englehard 2008). This knowledge has been and continues to be critically important to piecing together the former status and distribution of eels in Ontario.

Elder William Commanda, founder of a Circle of All Nations, talks in terms of the joint need for very long range perspectives and vision, saying that we need to "come together in love, peace, reconciliation and unity" (Thumbadoo 2005), and work with "one heart, one mind, one love, and one determination" (Circle of All Nations, undated). He states that, "Today, the plight of the Eel must awaken us to the crucial need to transform our relationship with Mother Earth and All Our Relations, and to awaken us to the pivotal role of Indigenous Peoples in this process" (Commanda 2008). The successful restoration of eels to their native habitat across the historic range in Ontario will be consistent with the principle of regional fairness (Supreme Court of Canada 1999), and will also be consistent with Canada’s commitment to Aboriginal peoples in the UN Convention on Biodiversity (CBD 2000).

Elder Commanda’s perspective has been a hallmark of the development of this recovery strategy. It has been an exercise of strong, unified thinking and consensus among the scientists, resource managers and Aboriginal people representatives on the recovery team (see Appendix 1).

Aboriginal people participating in development of the Recovery Strategy for American Eel in Ontario see the process as one of both healing the damage done to the eel and strengthening the relationship among all involved in the recovery effort. Knowing that American Eel has long been integral to their cultural identity, practices and customs, Aboriginal peoples have resolved to support Ontario and Canadian efforts for recovery of the species (see Appendix 2).

1.1 Species Assessment and Classification

COMMON NAME: American Eel			
SCIENTIFIC NAME: *Anguilla rostrata*			
SARO List Classification: Endangered			
SARO List History: Endangered (2008)			
COSEWIC Assessment History: Special Concern (2006)			
SARA Schedule 1: No Schedule			
RANKINGS	G-Rank: G4	N-Rank: N4	S-Rank: S1?

The Glossary provides definitions for the acronyms used in the table.

1.2 Species Description and Biology

Species Description

The American Eel is variously known as the Atlantic Eel, Freshwater Eel, Common Eel, Silver Eel, Yellow Eel, Bronze Eel, Easgann, and Anguille d'Ameriqué, among other names. The Mi'kmaq people called eels *Kat* (Prosper and Paulette 2002). Eels were called *pimizi* by the Algonquins (McGregor 1994), *bimizi* by the Ojibwe (Baraga 1878), and *goda:noh* by the Seneca (Bardeau 2002).

Juvenile and adult American Eels are yellowish-green or brownish, elongate, serpent-like fish with very small, deeply embedded scales. In Ontario, eels are generally larger (maximum length of about 1.3 m), the abundance less dense, slower growing and older (up to 42 years; J. Casselman, unpub. data) than individuals found in the southern part of the range. Casselman (2003, 2008) provides detailed information on the size, age and growth of American Eels.

Eel Genetics and Population Structure

Two species of Anguillid eels spawn in the Sargasso Sea (American Eel and European Eel, *Anguilla Anguilla)*. Morphological and genetic methods have established that American and European eel are two distinct species, yet capable of hybridizing (Albert et al. 2006; van Ginneken and Maes 2005). Molecular genetics data provide evidence both supporting and rejecting the hypothesis that American Eel is composed of a single, randomly mating (panmictic) population (reviewed in Maes and Volckaert 2007). Regional differences in patterns of recruitment suggest the possibility of at least partial demographic independence among distinct American Eel stocks. Additionally, female silver American Eels from the St. Lawrence River appear phenotypically distinct from other females throughout the species range (i.e., large body size and fast growth rate)

(Verreault et al. 2003; COSEWIC 2006; Tremblay 2009; Verreault et al. 2009). Diverse studies and personal observations provide evidence that this phenotypic differentiation has a genetic basis (Vladykov and Liew 1982; Côté et al. 2009; T. Pratt, pers. comm. 2010; Côté et al. in prep.[a;] Côté et al. in prep.[b]; Gagnaire et al. in prep.).

Yet, a very thorough and recent population genetic analysis based on the genotyping of 18 "neutral" microsatellite markers on over 2,500 individuals from 34 locations and nine year classes revealed absolutely no genetic difference across the species range (Côté et al. in prep.[c]). This suggests quantitative (functional) genetic differences between eels from different locations, within a context of panmixia (e.g., a combined effect of non-random dispersal and differential mortality occurring at young life history stages). Thus, although panmictic, individuals that are members of the same population are not individually the same genetically and therefore may not have the same propensity for dispersal according to their genotype. Similarly, individuals with different genetic makeup may have differential survival to environmental conditions encountered. Therefore, young eels that settle and survive in at a given location may genetically differ from those of other locations (L. Bernatchez, pers. comm. 2010).

In summary, because eels from the upper St. Lawrence River/Lake Ontario system are phenotypically unique in many regards, and because there is increasing evidence that there is some genetic basis underlying those phenotypic traits, a precautionary approach should be taken in order to ensure that the genetic basis underlying these unique phenotypes is not lost. There are reasonable doubts that the phenotype will be replaceable; it may not be possible to rescue the phenotype from other sources (L. Benatchez, pers. comm. 2010).

Species Biology

Life Cycle

The American Eel has a complex life history (Figure 1) with stages occurring in oceanic, coastal, estuarine and freshwater environments. American Eels begin life in the Sargasso Sea and return to the Sargasso Sea to spawn, the only location where they do so. Spawning, which has never been observed, has been inferred from sampling of young in the Sargasso Sea. Spawning emigration begins in May from the Richelieu River (Québec). Emigration peaks between July and September in Lake Ontario and the St. Lawrence River waters and may continue into November.

Eggs hatch into larvae that are called leptocephali because of their transparent and willow-leaf-like form. The larvae drift in the Gulf Stream system for seven to 12 months and transform into glass eels once they reach 55 to 65 mm in length. Glass eels have the typical elongate and serpentine form of the species and become progressively pigmented as they move across continental shelves to the shoreline. Once pigmented, they are considered elvers. The elver stage lasts from three to 12 months, during which time some migrate upstream into fresh water. In Atlantic Canada, timing of elver migration varies geographically. On the north shore of the Gulf of St. Lawrence, arrival occurs in July when elvers reach 60 to 70 mm in length. As elvers grow, they become known as yellow eels and, after a number of years, they mature into silver eels.

Additional information on the complicated life cycle of the American Eel is available in Tesch (1977) and COSEWIC (2006).

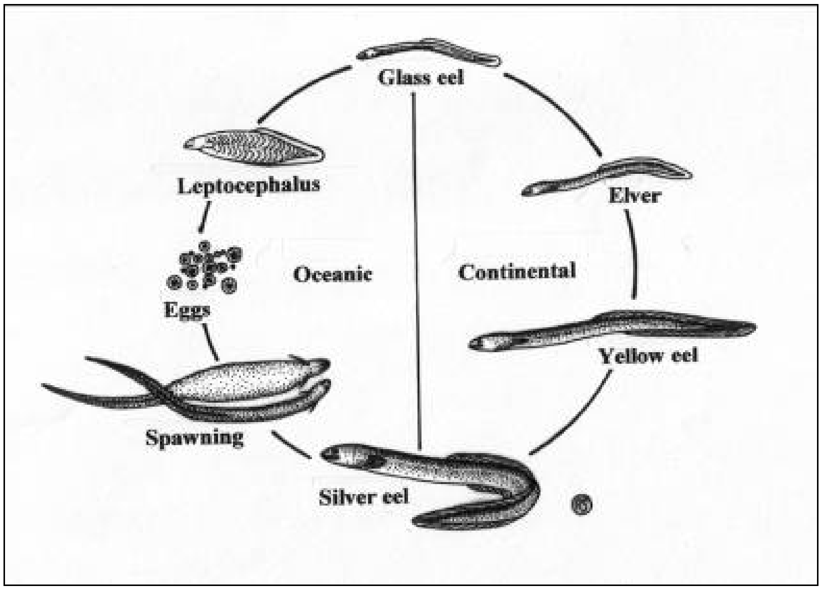

Figure 1. Life cycle of the American Eel (OMNR 2007).

Dispersal of eels into fresh water can be heavily influenced by density-dependent effects (Feunteun et al. 2003), i.e., the higher the density, the stronger the push to continue to move upstream); it can also be somewhat random, equivalent to random dispersion of particles (Ibbotson et al. 2002; Edeline et al. 2007). Juvenile eels moving into the upper St. Lawrence River and Lake Ontario system are driven by both of these forces, and tend to be very slow to mature (Jessop 2010).

The yellow eel stage is most commonly observed in fresh water, and is the principal stage in the life cycle that is observed in Ontario. Yellow eels are characterized by thick, tough skin, yellow-green to olive-brown colouration on the belly and darker colouration on the back. Sexual differentiation occurs during the yellow eel stage, the principal growth stage. Yellow eels may continue to travel upstream for many years, with seasonal peaks, usually between June and August in the upper St. Lawrence River. In Canada, eels typically hibernate in mud during winter, entering torpor at temperatures below 5°C, although there are records of eels remaining active during winter. Eel "balling" in the mud in winter has been well documented by Aboriginal people and commercial fish harvesters who speared large numbers through the ice (Prosper and Paullette 2002). This practise continues in the Maritimes.

The true silver phase is rarely seen in Ontario waters, although a greying intermediate phase occurs in some of the largest, oldest individuals. Silver eels, the mature freshwater phase, are greyish to white ventrally and develop a number of morphological and physiological adaptations for the long migration back to the spawning grounds. These include an enlarged pectoral fin, enlarged eye, modified retinal pigments, and increased body fat. Mature eels are considered to spawn (in the Sargasso Sea) between February (peak) and April. Across the range, emigration of silver eels appears to be timed to allow adults to arrive at the spawning grounds at the appropriate time.

While eels are typically catadromous, this life history strategy is not always adopted (i.e., it is facultative), as some eels appear to complete their entire life cycle in marine environments (Lamson et al. 2006). For eels and other fish species, segments of the population that exhibit different life cycle strategies are called "contingents" (Secor 1999; Jessop et al. 2002). In the American Eel, at least two contingents are recognized: (1) eels that complete their life cycle exclusively in marine environments; and (2) eels that migrate into and use freshwater environments to grow and mature. Many diadromous fish populations use multiple modes of migration and multiple habitats (McDowall 1996). Multiple life cycles can induce a dampening effect on overall variance of population responses to environmental change, thus increasing stability and resilience (MacGregor et al. 2009). Diversity of life history tactics in fish populations is increasingly recognized as having the effect of offsetting environmental stochasticity and contributing to long-term persistence (Secor 2007). For American Eel, diversity in life cycle strategies has been a hallmark of the species success and formerly wide distribution. MacGregor et al. (2009) discuss the importance of life cycle diversity to American Eel resilience, conservation and recovery.

Different life cycle contingents can be differentially vulnerable to exploitation, habitat degradation, and climate change (Secor 1999, 2007). For this reason, constituent patterns of life cycle diversity within populations should be regarded as a “portfolio,” or a collection of life cycles, which hedges against future environmental uncertainty through mechanisms that permit life cycle diversity to persist generation after generation (Secor and Kerr 2009). While both the marine and freshwater contingents are important to the conservation of the species, especially severe anthropogenic challenges faced by the species occur principally in freshwater habitats. Some may argue that marine-resident eels are sufficient to prevent the extinction of the species. Such speculation would be hazardous and risk-prone (McCleave and Edeline 2009). Further losses of freshwater eels may have serious demographic impacts because freshwater eels, by silvering at a larger size than sea eels, have higher fecundity (McCleave and Edeline 2009). Additionally, relatively low densities in the upper St. Lawrence/Lake Ontario system promote the development of juvenile eels as females (Jessop 2010). In Ontario waters, all eels produced typically are large, highly fecund females – the largest in the species range.

Ecological Role

The loss of migratory fish species such as American Eel has eroded connections among terrestrial, river, estuary and marine ecosystems. In fact, the Maryland Department of Natural Resources (MdDNR 1999) suggested that, until their decline, eels in the Susquehanna River played an important role in removing excess nutrients from the watershed by using them in growth and production, and then delivering them to the ocean (during migration to the Sargasso Sea where they spawn and die). Nutrients are tied up in the eels' flesh until they die and decompose. Once the carcasses have decomposed, the nutrients are released into the ocean where they can be efficiently used, while not leading to unwanted eutrophication effects (e.g., overproduction of algae) often observed in developed freshwater systems when nutrient levels are excessive. At one time, eels were so abundant in Ontario waters that they represented half the inshore fish biomass and no doubt played a dominant role in the fish community (Casselman 2003). Eels in Ontario also stored considerable nutrients for subsequent release in marine or estuarine systems when they were either eaten, or died and decomposed during spawning migration. Because eels are top predators, comprised of many immigrating cohorts, and resident in Ontario for long periods of time (10 to 20 years) before they emigrate back to sea, they added important stability to the nearshore fish communities of Ontario.

Eels are important competitors and predators. Small yellow eels feed extensively on invertebrates and, as their size increases, they feed more intensively on small fish (Ogden 1970). Large yellow eels in the Ottawa River often feed extensively on crayfish and other invertebrates, and are frequently caught by anglers using worms as bait (K. Punt, pers. comm. 2009). Rapidly maturing eels in Lake Ontario and the upper St. Lawrence River feed heavily on pelagic Alewife (*Alosa pseudoharengus*) and, to a much lesser extent, Rainbow Smelt (*Osmerus mordax*), just prior to emigration. Their ability to occupy interstitial spaces in the rock suggests that if abundant, they could be significant predators on the young of invasive species such as Round Goby (*Neogobius melanostomus*) and Rock Bass (*Amblopites rupestris*) (J. Casselman, unpub. data). When fish prey are not abundant, large eels feed extensively on crayfish (*Orconectes* spp.). Eels are ferocious predators, often attacking food items that are larger than they can handle, and spinning violently to dismember whatever is in their grasp (J. Casselman, pers. comm. 2009).

Large eels compete directly with other piscivores, such as bass (*Micropterus* spp.), Northern Pike (*Esox lucius*), and Walleye (*Sander vitreus*) that feed on similar prey items. However, this association needs to be quantified. Angling surveys and fish community monitoring on the Bay of Quinte, St. Lawrence River and Lake St. Francis revealed very little impact on the sport fishery when eel populations declined. Along with being predators and competitors, American Eels are an important prey species for Beluga Whales (*Delphinapterus leucas*) (MacGregor et al. 2009).

There is no doubt that eels function as an integral component in the nearshore fish communities of Ontario. It is unlikely, however, that they alone would greatly alter community structure or negatively affect abundance of other species. Above all, eels are an important indicator of diversity, adding stability and resilience to the fish community.

1.3 Distribution, Abundance and Population Trends

American Eel are known to have an exceptional ability to colonize a variety of habitats (Helfman et al. 1987; Moriarty 1987; Wiley et al. 2004). Historically (prior to 1980), the American Eel exhibited the largest range of any freshwater fish species in the western hemisphere, and held a dominant position in the fish communities by numbers and biomass in many habitats (Smith and Saunders 1955; Ogden 1970). The historic range included all accessible freshwater, estuarine and coastal marine waters of the western North Atlantic from Venezuela in the south through the Gulf of Mexico to Labrador in the north and as far inland as the headwaters of the Mississippi River (U.S.) and, in Ontario, near the extremity of their range, inland as far as Niagara Falls and the headwaters of the Ottawa River (Figure 2).

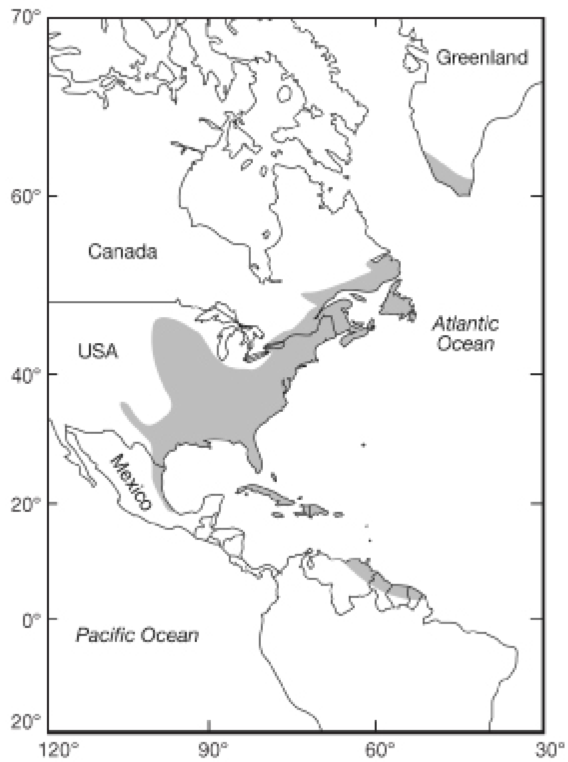

Figure 2. Geographic distribution of American eels (modified from Tesch 1977; DFO 2010).

In many freshwater systems, eels accounted for more than 50 percent of the total fish biomass (Smith and Saunders 1955; Ogden 1970; Lary et al. 1998) including the nearshore waters of Lake Ontario and the upper St. Lawrence River (Casselman 2003).

Baselines and perceptions of former abundance and distribution in Ontario have shifted over time (MacGregor et al. 2008, 2009), and the following comments of Heidenreich (1971) regarding the natural environment of Huronia are equally applicable within the historic range of eels in Ontario:

> "Relicts of the original forest in Huronia are rare and tell us almost nothing of the species distribution. The same is true of drainage conditions before and after European settlement. Some of the creeks and springs present in the 17th and 18th century are gone today as well as at least four small lakes. In some cases

> old drainage channels have been obliterated, in other cases water has been diverted, and throughout the area swamps have been drained and the water table has dropped."

Consequently, the examination and integration of ATK, archaeological information, historical records and local community knowledge has been especially important in reconstructing the historical distribution and abundance of eels in the province for the development of this strategy.

Although eels are at the extremity of the species' range in Ontario, they were once widely distributed, abundant and important in the province (MacGregor et al. 2009). Archaeological records show eel remains extending throughout the Lake Ontario, St. Lawrence River and Ottawa River watersheds. Fish bones in archaeological contexts are preserved in the alkaline soils found in southern Ontario, but not in the acidic soils of the Canadian Shield further north. Figure 3 shows archaeological sites in the southern part of the historic eel range where eel bones have been identified in faunal analyses. Since most archaeological sites in Ontario are not subject to faunal analyses, only a fraction of the known sites provide data on the presence of eels. The site shown on the Ottawa River is within Quebec, but close to the provincial border. Some circles represent two sites in close proximity. Most sites have fewer than five eels, often only one eel.

Eel bones have been found at some sites that may be outside historic American Eel range, as in the Lake Simcoe watershed, where the eel may have been transported to the site by human agency. Sites on the St. Lawrence River and Ottawa River have evidence of being used as eel harvesting and/or processing sites for the transport of eels elsewhere. (Data for site locations was provided by W. A. Allen, Heritage One based on the Ontario Ministry of Culture database.)

Two archaeological sites more than 4,000 years old at the base of an Ottawa River rapids yielded substantial eel remains (Clermont and Chapdelaine 1998; Clermont et al. 2003). A complex of stone weirs and pools was documented in 2007 in the rapids just upstream from these sites (W. A. Allen, unpub. data). At this stone weir complex a ground slate tool of a style dating to at least 4,000 years of age also was recovered (W. A. Allen, unpub. data). An association between the harvesting weirs and the nearby archaeological sites is likely.

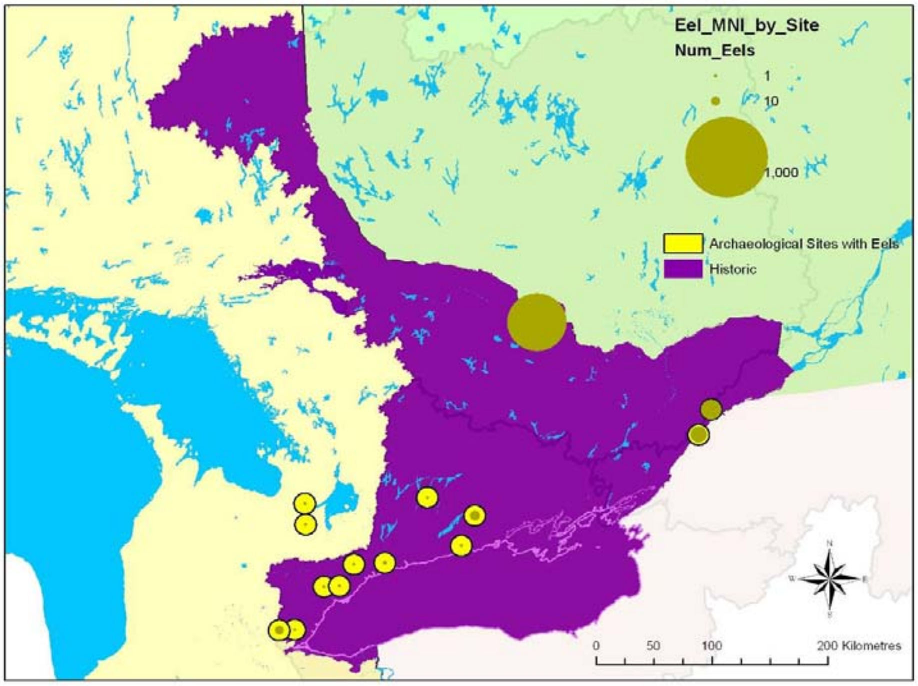

Figure 3. Distribution of archaeological sites in Ontario with known eel remains. Green circles show the Minimum Number of Individual eels (MNI) at each site. Yellow circles indicate location of sites. Green circles at sites which have extensive eel remains completely fill the yellow circle or extend beyond the circle. Eel range in New York is shown in pale pink. Eel range in Québec is shown in green.

There are numerous accounts of waters of the St. Lawrence, Ottawa, Mississippi, Clyde and Mattawa Rivers shimmering in the moonlight with young eels during their upstream migration (L. McDermott, pers. comm. 2009; H. Lickers, pers. comm. 2009). These observations reflect high recruitment events into Ontario waters. Early records and ATK reveal high abundance of eels in inland watersheds of Ontario sufficient to support local commercial fisheries (MacGregor et al. 2009). For instance, Quebec commercial eel harvests from the Ottawa River ranged from 3.4 to 15.0 metric tonnes annually between 1930 and 1937 (Dymond 1939). Commercial harvest records for the North Bay District waters of the Ottawa River show thousands of pounds of eels harvested during the period 1924 to 1938, peaking at 4,027 kg in 1932 (OMNR 1984). While waterpower development in tributary watersheds began about 1907 at stations such as Galetta on the Mississippi watershed, the development of waterpower facilities spanning the entire mainstem of the Ottawa River began in the middle reach in 1932, with the commissioning of Chats Falls Generating Station. By the late 1940s, commercial harvests of eels in North Bay area waters of the Ottawa River had declined to less than 200 kg annually.

Figure 4 depicts the strong contraction in the range of American Eel in Ontario, which appears to be continuing into the 2000s. American Eels once were abundant in all accessible tributaries of Lake Ontario and the St. Lawrence and Ottawa River systems, providing sustenance, material, medicinal and spiritual uses to Aboriginal peoples for thousands of years (MacGregor et al. 2008, 2009). Where eels continue to persist in inland rivers and lakes, their abundance is now very low, and eels are approaching extirpation from all inland watersheds in Ontario. Abundance of large eels in Lake Ontario has also collapsed; eel abundance here is now at extremely low levels and the fishery has been closed for conservation reasons. The collapse of eels in Ontario is due largely to 99 percent reduction in recruitment (Casselman 2003; Casselman and Marcogliese 2007; MacGregor et al. 2008, 2009).

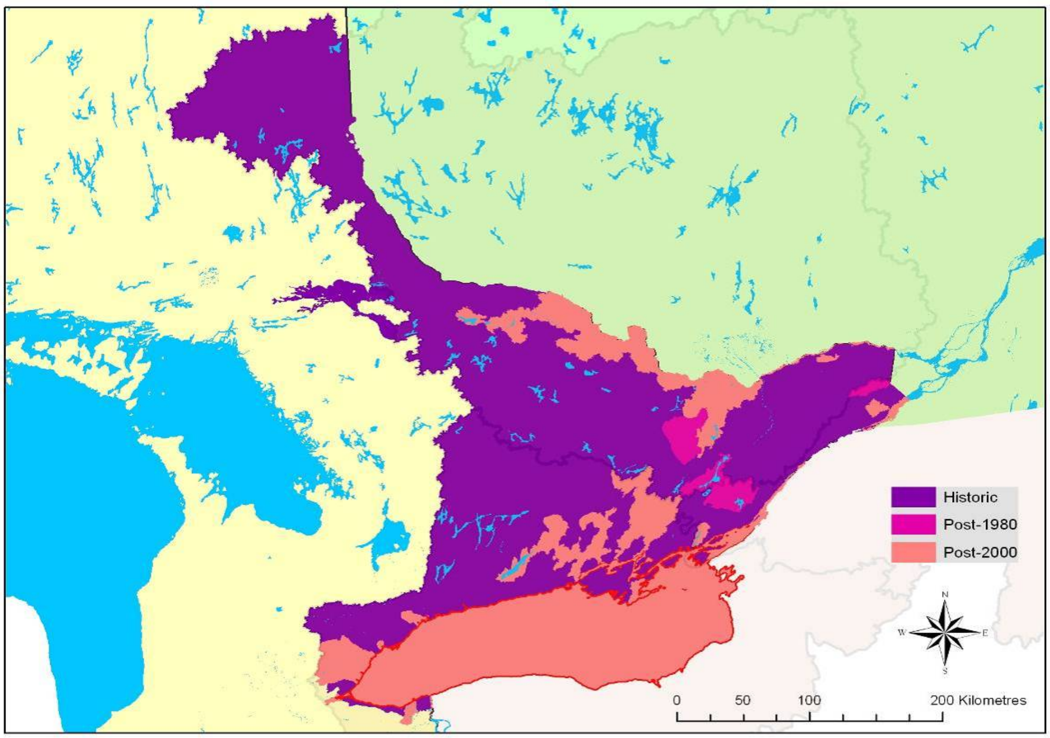

Figure 4. Contraction of the distribution of American Eel in Ontario. Information used to depict the distribution of American Eel in Ontario was compiled from Aboriginal traditional knowledge, local community knowledge, archaeological data and recorded captures via netting.

<u>Ottawa River Watershed</u>

Reviews of historic records, as well as anecdotal, ATK and archaeological information, enabled us to piece together the historic distribution of eels in the Ottawa River watershed. This information clearly shows that eels once penetrated as far north in Ontario as Lake Timiskaming (some 580 km from the confluence of the Ottawa River with the St. Lawrence River), and its tributaries, such as the Blanche River (Purvis 1887; Reading Eagle 1902). Here eels could be very large (Reading Eagle 1902) and appeared to be most prevalent in these waters prior to the construction of large hydroelectric dams on the mainstem of the Ottawa River. Additionally, near the turn of the 20th century, eels still existed in tributaries of the Montreal River (a large northern tributary of the Ottawa River) as revealed when lakes such as Kerr Lake were drained as a consequence of mining activities in Cobalt, Ontario; many eels were observed on the mud bottom after the lake was drained (Dumaresq 2006). Further evidence of widespread distribution in the upper Ottawa River comes from numerous reports of eels actually traversing the height of land connecting the Ottawa and French River watersheds using damp grassy or marshland areas. By these means, eels appeared to disperse and enter Lake Nipissing (MacGregor et al. in prep.) when they were abundant in the Ottawa River.

Eels once penetrated deeply into several Algonquin Park lakes associated with the Petawawa, Madawaska and Opeongo Rivers (tributaries to the Ottawa River system) (Mandrak and Crossman 2003). The last documented eel caught in the Park was in 1936 (Mandrak and Crossman 2003); however, a few eels have been reported caught by anglers in the Petawawa River near the boundaries of Algonquin Park as recently as 2002 (K. Punt, pers. comm. 2009). Aboriginal traditional knowledge reports several generations of a Bancroft Algonquin family harvesting large and abundant eels in Salmon Trout Lake in the Madawaska watershed. Eels were also once abundant in the Muskrat River and Bonnechere Rivers.

A few eels are still caught incidentally by anglers in Lac Des Chats on the mainstem of the Ottawa River near Arnprior, Ontario (three dams up from the confluence of the Ottawa River with the St. Lawrence River), but long-time anglers from the area report very strong declines in catches (K. Punt, pers. comm. 2009). Drastic decline, and in many instances extirpation, of eels has occurred throughout tributaries of the middle and upper reaches of the Ottawa River, coinciding with the construction of large hydroelectric dams. For instance, eels have not been observed in the mainstem of the Ottawa River watershed above Des Joachims hydroelectric facility at Rolphton for many years (OMNR 2008a; K. Punt, pers. comm. 2009). They also haven’t been seen in Calabogie Lake since the late 1970s when the development of waterpower production in Arnprior intensified (K. Punt, pers. comm. 2009), and now are considered extirpated from Round Lake, Golden Lake and above Renfrew Power Generation (at Renfrew) on the Bonnechere River (OMNR 2008a; K. Punt, pers. comm. 2009). Community knowledge and ATK corroborates this information.

Declines have been observed in the Madawaska and Bonnechere watersheds which supported large numbers of eels prior to the development of major hydroelectric facilities. Although good habitat for eels remains within Pembroke District systems, access has been severely limited as a consequence of the large number of hydroelectric facilities constructed in the early to mid-twentieth century. While young eels have been observed attempting to traverse many of the obstructions at barriers near Pembroke via old log chutes and sluices (K. Punt, pers. comm. 2009), eels are now at extremely low abundance or extirpated in most waters upstream of hydroelectric facilities. Similar ATK reports are common throughout the Ottawa River Basin.

Eels were once numerous in the lower Ottawa River at places such as Chaudier Falls (Reading Eagle 1902), especially during migratory periods, and still persist in these waters albeit at very low densities (MacGregor et al. 2009).

Mississippi River Subwatershed

The Mississippi River is a large subwatershed of the Ottawa River. Once highly abundant and heavily used by Aboriginal peoples and early European settlers, eel distribution in the Mississippi River has contracted to the lower reaches of this watershed (MacGregor et al. 2009; Casselman and Marcogliese 2010). There they have declined to very low densities, primarily because of reduced recruitment and the construction of numerous hydroelectric facilities (MacGregor et al. 2009; Casselman and Marcogliese 2010).

Aboriginal traditional knowledge supports this observation. For example, in the Mississippi River watershed, ATK confirms the presence, abundance and use of American Eels above High Falls in the headwaters (Mazinaw and Crotch Lakes) up to the mid-20th century. American Eels were described as being present in Gull Lake (well upstream of High Falls) in the 1920s (OMNR 1971), and the presence of eels in waters upstream of High Falls is further confirmed by observations that eels were harvested in the early 1900s from Ragged Chute on the Mississippi River (well upstream of High Falls) and shipped via the old K and P railway line to the Kingston fish market (Bennett and McCuaig 1981). Aboriginal traditional knowledge confirms that eels disappeared from these waters in the 1940s, some 20 years after construction of a large downstream hydroelectric facility at High Falls in 1920 (L. McDermott, pers. comm. 2009). Aboriginal traditional knowledge shared so far further indicates that no eels have been observed above the High Falls facility since the early 1950s. Similarly, no eels have been recorded in government netting programs above High Falls since the 1950s, when Ontario began recording fisheries information in these waters. Eels continue to decline in reaches of the Mississippi River downstream of High Falls (T. Haxton, pers. comm. 2009). Extrapolation of declining trap-net catches over the past three decades in five lakes throughout the Mississippi River watershed suggests that eels have now probably disappeared from the upper half of the watershed (J. Casselman, unpub. data).

Currently, eel dispersal and recruitment in the Ottawa River continues to be severely restricted by a series of hydroelectric facilities. Extrapolation of quantitative density estimates projected 45,118 eels (19,540 – 70,730; 95% confidence limit) in the Ottawa River system. Almost half of the projected numbers of eels came from below the first (most downstream) dam in the system, the Carillon dam, which has no facilitated eel passage (Casselman and Marcogliese 2010). As eel density became progressively less in the upper reaches of the Ottawa River, eel size increased, indicating the lack of recruitment to these reaches. In 2009, eel densities in the Ottawa and Mississippi rivers were significantly lower than in the St. Lawrence River (P=0.0005), but all three river systems showed similarities in that most eels occurred in the lower reaches. Based on the present survey, past reports, local observations, and historical abundance, eel abundance in the lower Ottawa and Mississippi rivers has followed the dramatic and predictable declining trend reported for the upper St. Lawrence River/Lake Ontario system(Casselman and Marcogliese 2010).

St. Lawrence River and Lake Ontario Watersheds

It has been recognized for many centuries that the important eel fisheries in the lower St. Lawrence River benefited, to a great degree, from eels migrating from what today would be called Ontario waters. For instance, in a 1634 Jesuit Relation (Thwaites 1896 – 1901:311, 314), the following was written regarding the eel fisheries in the St. Lawrence River in Quebéc and their source from more distant northern waters:

"*It is wonderful how many of these fish are found in this great river, in the months of September and October, and this immediately in front of the settlement of our French…"*

"It is thought that this great abundance is supplied by some lakes in the country farther north, which, discharging their waters here, makes us a present of this manna that nourishes us …"

Accounts from the mid-1600s record an Onondaga fisherman of the St. Lawrence Iroquois spearing as many as 1,000 eels in a single night (Thwaites 1896 – 1901), and there are many historical and archaeological references to the large abundance of eels in the St. Lawrence River and its tributaries. In more recent times, Elder Commanda noted that his ancestors and others have talked about eels "*creating great silver pathways in the rivers during migration times*" (Commanda 2008). Indeed, prior to the turn of the century, the St. Lawrence River watershed was considered to support the most productive eel fisheries in the world (The New York Times 1880). As late as the mid-1980s, eels from Ontario were still estimated to contribute 67% of the eels to the important commercial eel fisheries in Quebec (Verreault and Dumont 2003). Millions of silver eels were harvested by the St. Lawrence River annually in Quebec's long-standing tidal weir fisheries (average of 431 tons annually between 1970 and 1989; COSEWIC 2006).

The importance of the St. Lawrence River eels to species-level fecundity has been estimated (COSEWIC 2006) and noted to be substantial (ranging between 26.5% and 67% depending on the method of estimation). The facts seem clear: Ontario eels comprised more than half of Quebec's large eel fisheries as late as the mid-1980s, and are all female, the largest and most fecund in the species' range (Casselman 2003). Given the former abundance of eels in Ontario, the large size of exclusively females grown in the province, and the projected impact on species-level fecundity by eels from the St. Lawrence River/Lake Ontario, the weight of evidence indicates that Ontario holds a special segment of the global population that once contributed strongly to spawner biomass and species-level fecundity. Despite market prices well above the long-term mean in the 1970s to 2000s, eels have declined to mere remnants of their former abundance (Casselman 2003; MacGregor et al. 2009) and the once highly important and productive silver eel fisheries in Quebec waters of the St. Lawrence River have declined substantially (MacGregor et al. 2008, 2009; de Lafontaine et al. 2009).

The contribution of eels from the Ontario watersheds to the spawning stock has likely changed significantly as a consequence of their collapse provincially.

Tributaries of the upper St. Lawrence River and Lake Ontario including the Gananoque (including Charleston Lake), Cataraqui (including Big Clear and Cranberry Lakes), Napanee (including Thirteen Island Lake), Salmon (including Beaver, Bull, Buck, and Kennebec Lakes), Moira (including Moira and Stoco Lakes) and the Trent-Otonabee (including Kawartha Lakes) once supported an abundance of eels (e.g., 2.1 – 11.4 tons annually between 1885 and 1900) (MacGregor et al. 2009). Now eels are rarely found in any of these waters. Eels appear to have been relatively rare in the upper Trent and Otanabee Rivers/Kawartha Lakes waters since the early 1900s, coinciding with the construction of numerous dams and hydroelectric facilities (for instance, Sills Island, Sidney and Frankford Generating Stations) (MacGregor et al. 2009). The last few eels reported in Kawartha Lakes occurred in the mid-1980s. Elder Murray Whetung of Curve Lake First Nation, a carrier of ATK dating back to the 1920s in the Kawartha Lakes, agrees with this assessment of past and present eel status in these waters (M. Whetung, pers. comm. 2009). However, eels apparently persisted for a much longer duration in other waters closer to Lake Ontario. For instance, in 1980 anglers mentioned that many people were catching large eels in Round Lake on the Crowe River watershed (which flows into the lower Trent River) (C. McCauley, unpub. data) and eels continued to occur in the Moira, Salmon, and Napanee Rivers until the 1970s. Moreover, annual commercial harvests of eels continued in the Cataraqui River until all commercial eel fisheries were closed in 2004. The protracted persistence of eels in the aforementioned watersheds is likely attributable to the low number of hydroelectric facilities on some of these systems (C. McCauley, pers. comm. 2009).

The total annual number of eels migrating up the ladder at Moses-Saunders Dam on the St. Lawrence River represents the longest-term data set on American Eel recruitment (Castonguay et al. 1994; Casselman et al. 1997; Casselman 2003). After a peak in 1982 to 1983, ladder counts dropped sharply and fell to record low levels in the late 1990s (Figure 5). The few eels that ascended the ladder in the 1990s were much larger and older than typical recruits before the decline (Casselman 2003). Although recruitment has increased slightly in recent years, it still remains at minimal levels (J. Casselman, pers. comm. 2009).

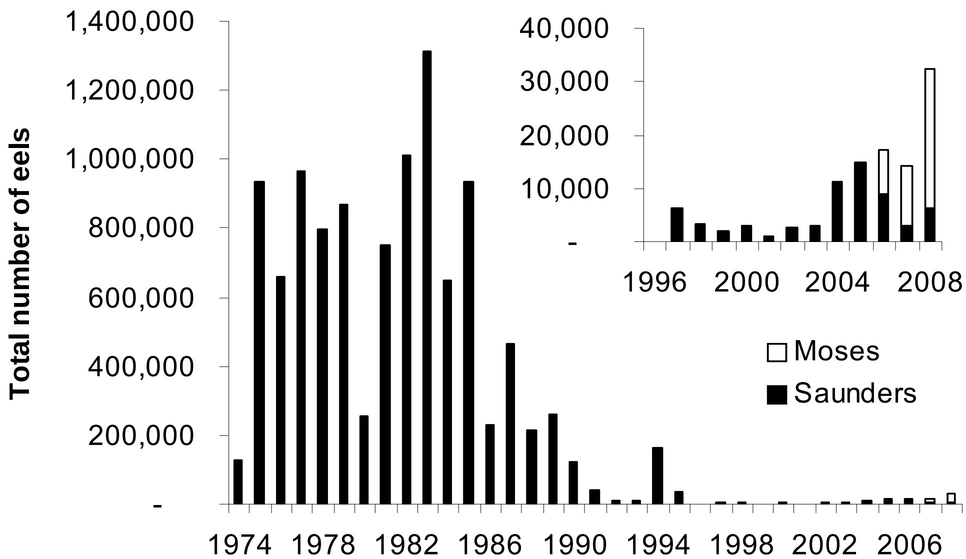

Figure 5. Total number of eels ascending the eel ladder(s) at the Moses-Saunders Dam, Cornwall, Ontario for 1974 – 2008. No counts are available for 1996 (A. Mathers, pers. comm. 2009). Moses is on the New York side of the St. Lawrence River, and Saunders is on the Ontario side.

In 2002, two eel ladders became operational at Hydro Quebec's Beauharnois Generating Station on the St. Lawrence River, some 80 km downstream of the Moses-Saunders facility. The number of eels ascending these ladders has increased steadily in recent years, reaching a peak of almost 88,000 at the western ladder in 2008 (Figure 6). Once eels have traversed the ladders at Beauharnois many enter Lake St. Francis (immediately downstream of the Moses-Saunders Generating Station). Lake St. Francis appears to be the only remaining area in Ontario where eels maintain a reasonable level of abundance. The fact that the number of eels ascending both Beauharnois and Moses-Saunders ladders has been increasing recently (albeit still at extremely low numbers relative to the early 1980s; Figure 5) after early management actions were introduced is cause for some optimism for the success of future recovery efforts.

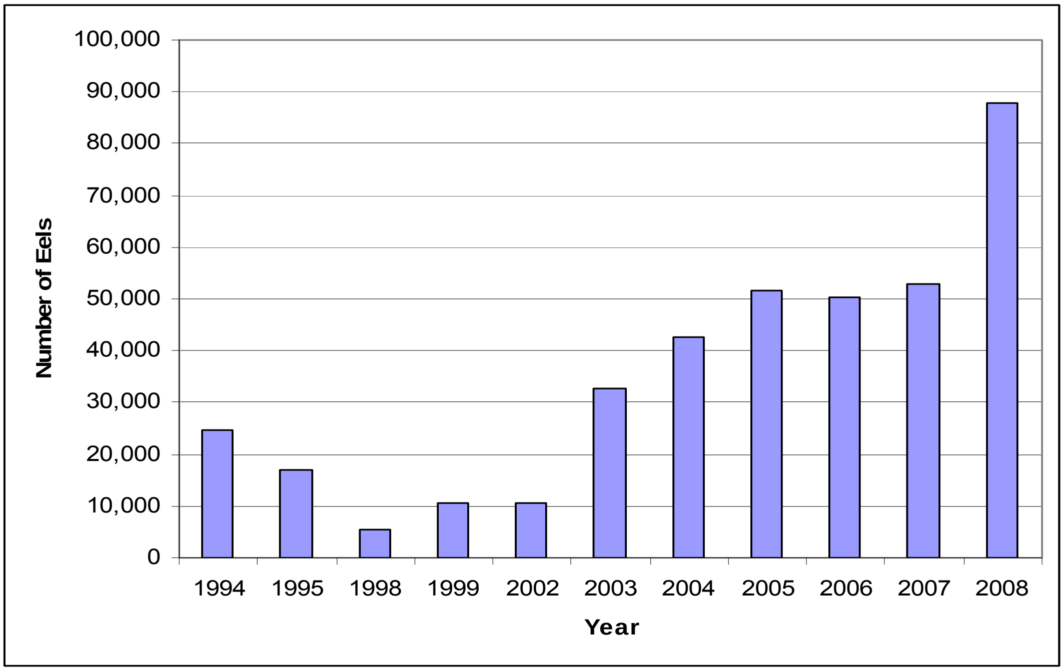

Figure 6. Total number of eels ascending the western eel ladder on Beauharnois Generating Station, St. Lawrence River, Province of Quebec (1994 – 2008). Note: counts from 1994 – 2002 represent the number of eels climbing an incomplete ladder, then captured in nets and transported above Beauharnois (data provided by Quebec, MNRF 2009).

Niagara Watersheds

At the westernmost extremity of American Eel range within Ontario (Niagara Area) eels were once abundant along the Lake Ontario shoreline and within the lower Niagara River. Bartram (1751:92) observed that “Below the Falls in the holes of the rocks, are a great plenty of Eels, which the Indians and French catch with their hands without other means”. Gill (1908:121) noted that “at the proper season you will find them [eels] by the cartloads, by millions upon millions”, and Goode (1881:83) observed that “the visitor who enters under the sheet of water at the foot of the falls will be astonished at the enormous number of young eels crawling over the slippery rocks and squirming in the seething whirlpools”, indicating that they were clearly impeded by the falls. Eels were also plentiful within Martindale Pond and Jordan Harbour, and were found in many inland watersheds of the Niagara Peninsula. While eels are now rare in these areas, the occasional eel has been captured over the last two decades in Twelve Mile Creek (MacGregor et al. in prep.; A. Yagi, pers. comm. 2009).

Introductions

Niagara Falls apparently is the natural limit of American Eel distribution in the Great Lakes, and the species was considered absent from Lake Erie waters prior to the opening of the Welland Canal in 1829 (Trautman 1981). Eels probably gained access to Lakes Erie, Huron and Superior through the Welland Canal (Scott and Crossman 1973), but have never been very abundant in these waters. While there are reports of some commercial harvests of eel in the upper Great Lakes as early as 1907, and Lakes

Erie and St. Clair as early as 1914 (D. Coulson, pers. comm. 2010; K. Punt, pers. comm. 2010), it is unlikely that Lake Erie and the upper Great Lakes formed part of the historic range, given the formidable obstacle posed by Niagara Falls. These harvest reports could be as a result of the following.

- Eelpouts (*Lota lota*) or Sea Lamprey (*Petromyzon marinus*) misreported in commercial catches as American Eel.
- Stocking eels in Lake Erie by Ohio. Trautman (1981) gives accounts of the Michigan Fish Commission stocking eels from the Hudson River into southern Michigan waters as early as 1878, and of the Ohio Fish Commission stocking eels from the Hudson River beginning in 1882. For more than a decade thereafter eels were liberated into Ohio waters. In 1887, the annual Ohio Fish Commission began to mention the capture of eels in many Ohio localities, especially in the Lake Erie drainage where the species had been formerly rare (Trautman 1981). Anecdotal information reported abundant catches in Maumee Bay and Sandusky River below dams at Fremont. These catches were reported from 1895 and 1910 (Trautman 1981).
- Access provided by the opening of the Erie and Welland canals.

Occurrences of American Eel in the Great Lakes above Niagara Falls (Lakes Erie, Huron and Superior) apparently are the result of stocking and/or dispersal through the Erie and Welland canals and for now should be considered as introductions outside the historic range (Scott and Crossman 1973; Trautman 1981; COSEWIC 2006). Nevertheless, given their propensity to use damp substrates to surmount obstacles, the possibility that eels found access somewhere over the Niagara Escarpment to Lake Erie and were historically native to the Upper Great Lakes warrants further investigation. Access by possible routes identified in (MacGregor et al. in prep.) from the Ottawa River to Lake Nipissing and then via the French River to Lake Huron should also be investigated (see p. 10).

While eels were caught in Lake Simcoe from time to time in the mid-late 1900s, they generally were not considered native to the lake. Rather, their presence in the lake was considered to have been facilitated by the development of the Trent-Severn waterway. However, recent field checks in the Balsam Lake area, ATK and archaeological evidence suggest that eels may well have been native to Lake Simcoe (MacGregor et al. in prep.). It appears that there were at least two low-lying marshy areas bordering the Talbot River tributary to Lake Simcoe where eels could easily have crossed watershed boundaries (namely at Corson Marsh and Grass Creek Marsh). Balsam Lake is mentioned in an ATK story published in 1914 (George 1914). There are several pre-contact archaeological villages in the Balsam Lake area but potential associations with eels have not been studied. Eel remains have been found in small numbers in an archaeological context at Lake Simcoe.

Summary

Although eels have virtually disappeared from many inland waters of Ontario, they are still present provincially, primarily in the downstream reaches of some watersheds (lower Ottawa River and its tributaries, lower Trent River, the upper St. Lawrence River, and in Lake Ontario); in all instances, densities are very low (MacGregor et al. 2008, 2009). Lake Ontario and the upper St. Lawrence River remained into the 1980s as the last provincial stronghold for American Eel, and the steep decline of the species in these waters since the mid-1980s has been well documented and publicized (GLFC 2002; Casselman 2003; Dekker et al. 2003; Hoag 2007; Lees 2008; MacGregor et al. 2008).

The precipitous decline of American Eel in Ontario waters is likely a significant threat to the status and recovery of the global population. Ontario's eels, being virtually all female and the most fecund within the species range (COSEWIC 2006) have formed an especially critical segment of the global population. Additionally, because the dispersal of young eels from the Sargasso Sea is driven by large pulses of young eels (Casselman 2003), recovery of abundance and distribution within the distant waters of Ontario will depend significantly on improved production and enhanced density-dependent dispersal of recruits from the Sargasso Sea. This in turn is thought to be driven to a great extent by the numbers of mature eels that return safely to the Sargasso Sea to spawn successfully.

Detailed mapping of American Eel occurrence in Ontario is available at the Ontario Ministry of Natural Resources District level in MacGregor et al. (in prep.).

1.4 Habitat Needs

Eels spawn in the Sargasso Sea (Schmidt 1922), east of the Bahamas and southwest of Bermuda (25°N; 60°W; McCleave et al. 1987), but habitat requirements for spawning and incubating are poorly understood. Kleckner and McCleave (1988) related the northern limit of spawning by Atlantic eels (*Anguilla* spp.) in the Sargasso Sea to thermal fronts and surface water masses, with spawning taking place south of east-west thermal fronts that separate southern Sargasso Sea surface water from mixed Subtropical Convergence Zone water to the north.

American Eels use a broad diversity of habitats during their growth period (Helfman et al. 1987). American Eels occur naturally in perhaps the broadest diversity of habitats of any fish species in the world (Helfman et al. 1987; Moriarty 1987). However, cumulative anthropogenic impacts in fresh water have severely impacted their historic freshwater abundance and distribution in North America (MacGregor et al. 2009). During their oceanic migrations, eels occupy salt water, and in their continental phase, they use all salinity zones. In their continental growth phase, marine habitat use appears limited to shallow, protected waters. Survival is affected by environmental conditions in any habitat (oceanic, estuarine, freshwater) occupied during any life cycle phase. Growing eels are primarily benthic, utilizing substrate (rock, sand, and mud), bottom and woody debris, and submerged vegetation for protection and cover (Scott and Crossman 1973;

Tesch 1977). Vegetation (e.g., eel grass) and interstitial spaces comprised of rock piles, logs, and other complex structures are important to American Eel as cover, particularly during daylight hours, and should be protected as habitat. Given the high abundance of eels often observed in tributaries, these waters seem to comprise a very important component of eel habitat (Machut et al. 2007). Habitat in tributaries is often of high quality and less disturbed than other areas (Machut et al. 2007).

The construction of dams and hydroelectric facilities in fresh water has grown significantly in Ontario over the past century (MacGregor et al. 2009). These barriers occur throughout eel habitat in Ontario and pose obstacles to their migrations and dispersal. The ability of eels to overcome obstacles is size-dependent. Small eels (<10 cm long) can creep up damp vertical barriers (Legault 1988), but larger eels generally cannot bypass dams or large waterfalls (McCleave 1980; Barbin and Krueger 1994). Hence, larger eels attempting to move upstream require unobstructed passage or eel ladders (Moriarty 1987). Connectivity among important inland habitats is important to ensure eels are able to disperse effectively and take advantage of the diverse growth and maturing aquatic habitats in the province, and enabling resilience in the stock. Additionally, safe and adequate passage to and from the oceanic spawning grounds is required to complete their life cycle.

Precise information concerning habitat use by eels is lacking. In freshwater streams, eels generally do not show consistent preferences for habitat type, cover, substrate, water temperature, or density of predators (Hawkins 1995; Smogor et al. 1995), but eel densities are influenced by water depth and velocity (Wiley et al. 2004).

In fresh water, eels are predominantly sedentary (Feunteun et al. 2003). Otoliths, or ear stones, can provide a chemical environmental history for eels. Casselman (1982) analyzed strontium/calcium ratios in eel otoliths to document migratory history – ocean life, immigration into the St. Lawrence River, and residency in Lake Ontario. Recent investigations using otolith microchemistry (Jessop et al. 2002; Cairns et al. 2004; Thibault et al. 2005) report three main movement patterns related to coastal waters: (1) saltwater residency; (2) freshwater residency; and (3) inter-habitat shifting. In the St. Jean River on the Gaspé Peninsula, some freshwater resident eels perform very short intrusions into brackish or salt water (Daverat et al. 2006). Otolith chemistry has shown that some eels spend their entire life cycle in the ocean, making it clear that not all eels exhibit catadromous life history strategies (Tsukamoto et al. 1998; Jessop et al. 2002; Morrison et al. 2003; Arai et al. 2004). However, the proportion of non-catadromous eels remains un-quantified.

Local seasonal movements may also involve habitat and environmental requirements affected by water temperature, oxygen concentration and water quality; winter habitat requirements are poorly understood (Tesch 1977; Feunteun et al. 2003). American Eel in small tributaries such as the Bonnechere River have been observed moving downstream in the fall from hard clay bottoms to areas in the lower reaches with mud or silt bottoms where eels are known to overwinter by burrowing into the mud (K. Punt, pers. comm. 2009).

Yellow eels tend to occupy home ranges in fresh water (Morrison and Secor 2003), and their normal scope of activity is within a relatively restricted area (LaBar and Facey 1983). However, some American Eels have been shown to make seasonal migrations in spring and fall, establishing home ranges in summer, and some may inhabit thermal refuge areas in winter (Hammond and Welsh 2009).

Finally, it is important to note that ATK, local community knowledge, archaeological information, historical records, and scientific papers all document the remarkable and regular behaviour of large and small eels to exit the water and move considerable distances along damp substrates such as moss, grass, rocks and cement. Large and small migrating eels often have been found in gardens and wriggling through wet grass alongside many migratory corridors, including the Ottawa River and St. Lawrence River (Meek 1916; Haro et al. 2000; H. Lickers, pers. comm. 2009; K. Punt, pers. comm. 2009), emphasizing the importance of riparian areas to eels. Machut (2007) also emphasized the importance of riparian areas to eels.

Although habitat use appears to be extremely diverse, there may be important requirements that have not been considered. For example, eels typically overwinter in soft substrates where they burrow into the upper layers of sediment (Jessop et al. 2009). These wintering grounds may be quite specific, and need to be located and evaluated in Ontario waters where eels are still present.

1.5 Limiting Factors

Panmixia and Global Population Changes

According to current science, the American Eel consists of a single genetic population in which all individuals of the species mate randomly at the same spawning site in the Sargasso Sea. As a result, biological and ecological factors outside the eel's range in Ontario will affect recovery within Ontario. This may be a limiting factor to recovery in Ontario, as this population structure suggests that jurisdictions outside Ontario will influence recovery within the province. Some 25 jurisdictions have management responsibilities for American Eel in North America (MacGregor et al. 2008). Hence, the conservation and management of American Eel will require bi-national and inter-jurisdictional cooperation (MacGregor et al. 2008, 2009; Velez-Espino and Koops 2009). However, as Ontario holds a very special female segment of the species, Ontario actions alone can significantly benefit the entire species, including Ontario eels. Of course, panmixia also means that Ontario eels will benefit as a result of global conservation efforts.

Eels are declining in other jurisdictions across their range (ASFMC 2000, 2006; de Lafontaine et al. 2009; MacGregor et al. 2009; Weeder and Uphoff 2009). Because eels are panmictic and dispersal of young eels to Ontario waters is somewhat density-dependent, a decline in the global population of American Eel (especially spawners) could lead to reduced density of young eels and hence reduced dispersal of young recruits to Ontario, at the extremity of the range where declining recruitment would be most noticeable (Casselman 2003).

Larval Dispersal
Leptocephali are not very mobile for a period of time and somewhat dependent at this life history stage on ocean currents for their dispersal from the Sargasso Sea to continental waters. The potential effects of ocean currents on recruitment have been described by Friedland et al. (2007), Bonhommeau et al. (2008) and Miller et al. (2009). However, other factors such as fishing mortality may disrupt the ability of spawners to reach the Sargasso Sea and must be considered as possible contributors to recruitment declines (Miller et al. 2009). Anguillid eel populations can likely survive wide ranging changes in oceanic and continental environmental conditions, considering that Atlantic eel species have survived extreme conditions such as ice ages since their evolution millions of years ago (Miller et al. 2009).

1.6 Threats to Survival and Recovery

Several threats need to be addressed to achieve recovery of eels in Ontario. The impact of each of these threats on eels has not yet been fully quantified in all watersheds. A model developed to examine the cumulative effects of anthropogenic mortality on eels found that fishing followed by turbine mortality were significant factors affecting eels, and that eels were sensitive to the effects of habitat exclusion by dams (Reid and Meisenheimer 2001).

Harvesting
Throughout its range, all continental life stages of the American Eel are harvested. To date, there has been no coordinated attempt to establish a total allowable catch for the North American “stock” as a whole that would be sustainable. Ontario established quota for eels in the 1980s, but they were never achieved largely because the stock was declining so rapidly. Aboriginal peoples have a long association with the species and have harvested eels for millennia, as exemplified by archaeological evidence from Morrison and Allumette Islands in the Ottawa River (Clermont and Chapdelaine 1998; Clermont et al. 2003). The effects of commercial fishing have been much more severe than Aboriginal fishing, globally and within the province. Commercial harvest records cover more than a century for the upper St. Lawrence River and Lake Ontario. The total North American harvest increased from an average of 1,215 tons annually between 1950 and 1955 to an unprecedented peak of 2,915 tons in 1978 (Casselman and Marcogliese 2007). By the early 1990s, North American harvests began to decline. By 2004, eel harvests fell rapidly to 840.4 tons. This decline occurred despite sustained high prices; well above the long-term mean (Casselman and Marcogliese 2007). Overall trends in Ontario commercial harvests parallel those of Canada and the United States (MacGregor et al. 2009). Between 1950 and 2003, Ontario commercial eel harvests averaged 80.1 metric tons, but rose substantially in the 1970s to an unprecedented 228.2 metric tons (Casselman and Marcogliese 2007), representing 20

percent of the total Canadian harvest. Ontario harvests plummeted thereafter. As harvests rose rapidly, concerns arose over sustainability (Kolenosky and Hendry 1982).

There is evidence that over-fishing has occurred for some time in other parts of the species' range such as Delaware and Chesapeake Bay (Clark 2009; Weeder and Uphoff 2009). In Ontario, the commercial yellow eel fishery was closed in 2004 and a small recreational fishery was closed in 2005. Although recent buy-outs of some eel fishermen may reduce the Quebec harvest, there is no quota and yellow and silver eels are still harvested in the St. Lawrence River system by Quebec commercial fishers. Glass eels are harvested by fishers in eastern Canada and the United States. The vast majority of Canadian glass eel harvest is exported, primarily to Asia (Jessop 1997). Glass eels from Canadian fisheries are the only available source of glass eels for conservation stocking efforts aimed at maintaining and/or producing yellow and silver eels.

<u>Barriers to Migration</u>
Dams can severely impede upstream dispersal of juvenile eels in freshwater if no passage way is provided (Haro et al. 2000). It has been estimated that 85 percent of freshwater habitat for migratory fish in the United States has been lost due to barriers (Lary et al. 1998). In a 1998 study, the U.S. Fish and Wildlife Service determined that eels may have been eliminated from 81 percent of their historic habitat between Connecticut and Maine due to the construction of a large number of dams (ASMFC 2000). Barriers reduced eel densities by at least a factor of 10 on the Hudson River, and eel condition was significantly poorer above barriers (Machut et al. 2007). The situation appears similar in Ontario where at least 953 dams exist within the eel’s historic range (Figure 7). Hydroelectric dams generally pose the most significant barrier to upstream migration due their height. However, with the exception of one eel ladder at the Moses-Saunders facility on the St. Lawrence River, as of 2008 no provisions for upstream fish passage for any species have been made at any of the approximately 200 hydroelectric stations in Ontario. Negotiations with a few facilities are now underway to correct this situation for upstream eel passage.

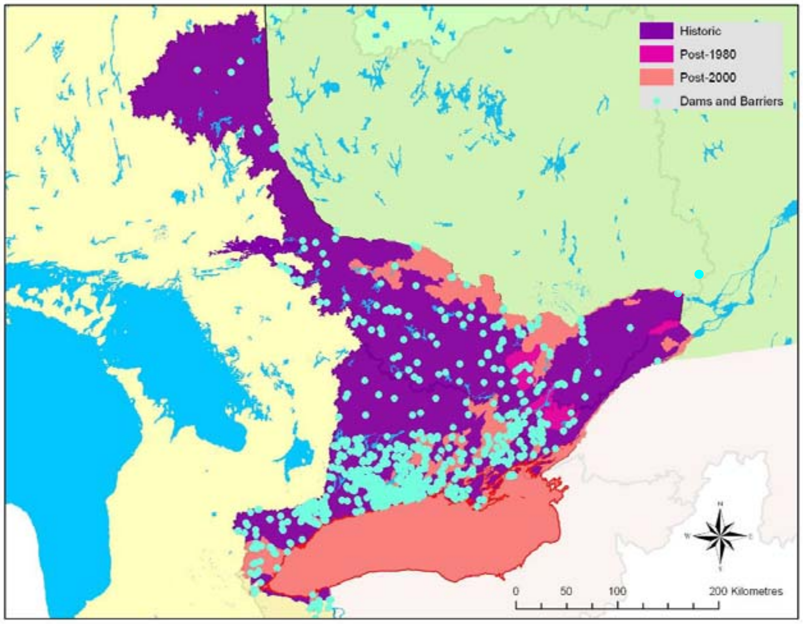

Figure 7. Location of dams, barriers, and other water control structures within the historical American Eel range in Ontario.

It is important to note that extensive quantitative electrofishing in the St. Lawrence and Ottawa Rivers in 2009 has shown that there is a disproportionate abundance of eels immediately below Moses-Saunders Generating Station on the St. Lawrence River, and immediately below Carillion and Chats Generating Stations on the Ottawa River (Casselman and Marcogiese 2010). Clearly, access by eels to formerly important eel growing habitat in Ontario continues to be challenged by the numerous barriers within the historic and current species range, and remains so even where a ladder exists at Moses-Saunders (Casselman and Marcogliese 2010).

Within the historic range of eels in Ontario, numerous barriers have led to substantial cumulative loss in access by eels to formerly productive maturing habitat, and have limited the capacity of Ontario's waters to rear large, highly fecund females. Range contraction has been clearly documented within the Ottawa River (MacGregor et al. 2009), where an estimated 3,700 km^2 of suitable habitat (Quebec and Ontario combined) was present before extensive dam construction throughout the watershed (Verreault et al. 2004). This equated to lost production of approximately 255,000 highly fecund female silver eels per year (Verreault et al. 2004). If eels were still able to access the Ottawa River in sufficient numbers as elvers, and subsequently escape the significant cumulative mortalities induced by the series of turbines on the watershed (MacGregor et al 2009), spawner biomass and population-level fecundity of eels from Ontario could improve substantially, having significant impact on subsequent recruitment (Russel and Potter 2003; Verreault et al. 2004). Barriers to upstream migration had a greater effect on European eel (*Anguilla anguilla*) densities than distance from the ocean (White and Knights1997).

While not all dams pose complete barriers to upstream migration (Haro et al. 2000), and the impact is variable depending on the nature of the barrier, numerous structures on a single watershed cumulatively impart substantial impediments in accessing available habitat in Ontario (McCleave 2001; Goode 2006).

<u>Turbines at Hydroelectric Facilities</u>

Hydroelectric facilities in Ontario pose significant challenges to eels (Larinier and Dartiguelongue 1989; Mitchell and Boubée 1992; Desroches 1995; Normandeau Associates Inc. and Skalski 1998; Haro et al. 2000; Dönni et al. 2001, in ICES 2003; McCleave 2001; Allen 2008 b, c, d), as they impart serious individual and cumulative mortalities at the watershed level to downstream migrants en route to spawn (McCleave 2001; MacGregor et al. 2009). There are 87 hydroelectric facilities within the historic range of eels in Ontario, and 30 within the post-2000 range (Figure 8). As of 2009, many of these facilities continue to cause annual eel mortalities (Community Stewardship Council of Lanark County 2010; A. Bendig, pers. comm. 2009; K. Punt, pers. comm. 2009). With the exception of recent trap and transport efforts at Moses-Saunders, mortalities due to turbines at all hydroelectric facilities in Ontario continue unmitigated on most watersheds.

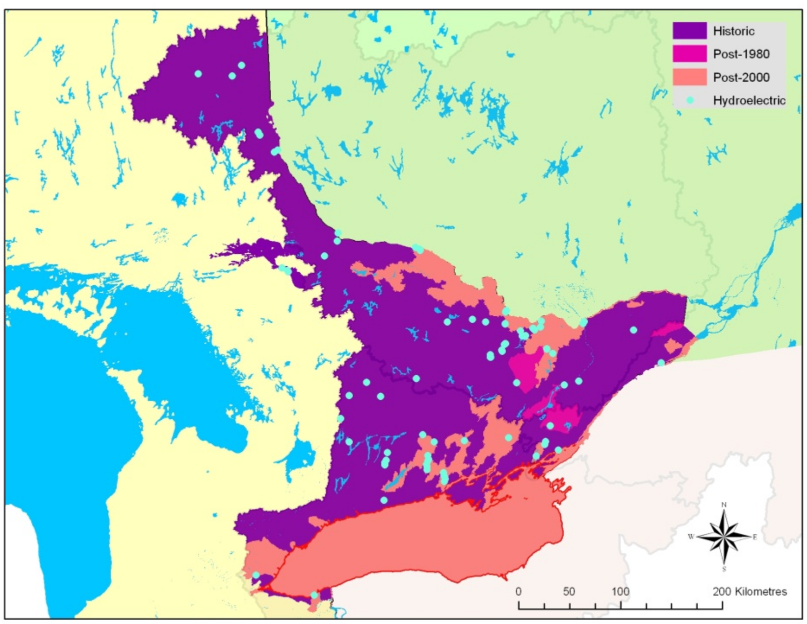

Figure 8. Hydroelectric facilities within the Ontario range of American Eel.

When eels were abundant in North American watersheds, entanglement in turbines was sufficient to cause major operational difficulties or complete shutdowns of power plants and mills, and these mortalities have been ongoing for decades at many facilities (MacGregor et al. 2009). The following quote from a 1902 newspaper article regarding a large sawmill at Chaudier Falls (a site where hydroelectric facilities now are installed to serve the City of Ottawa) paints a vivid picture of the large number of eels once passing downstream in the Ottawa River at that time:

> “Hull, Canada: A turbine mill wheel which runs a gang of saws at the Chaudier waterfall stopped suddenly. Upon shutting down the mill and unscrewing the upper cap, it was discovered that the wheel had become packed full of eels. It looked as though there must have been hundreds of thousands of them.” (Reading Eagle 1902; St. John Daily Sun 1902).

Cumulative mortalities of eels passing through a series of hydroelectric facilities on smaller watersheds can also be very high, at times approaching 100 percent. For instance, Dönni et al*. (*2001, in ICES 2003*)* estimated an average annual mortality of 92.7 percent for European Eel (*A. anguilla*) in the River Rhine for a succession of 12 hydroelectric facilities in Germany. This suggests that cumulative turbine mortalities imposed by a series of facilities on the Trent and Ottawa Rivers (MacGregor et al. 2009) could also be very high. While American Eel have declined substantially in abundance in inland watersheds of Ontario, electrofishing and tailrace surveys in 2009 and photographs submitted to the Ontario Ministry of Natural Resources in 2007/2008 have demonstrated that eels are still being killed by hydroelectric facilities in the Ottawa, lower Trent, and Mississippi Rivers (A. Bendig, pers. com. 2009; Community Stewardship Council of Lanark County 2010, MacGregor et al. in prep.). On the St. Lawrence River, cumulative turbine mortality of eels at the Beauharnois and Moses-Saunders facilities during their downstream spawning migration has been estimated to be 41 percent (Desroches 1995; Normandeau Associates Inc. and Skalski1998).

MacGregor et al. (in review) have demonstrated the significant impact of cumulative effects faced by an eel living in Mississippi Lake attempting to reach the Sargasso Sea to spawn, highlighting the need to immediately adopt cumulative effects assessment procedures in current approvals processes. Since the closure of commercial and sport fisheries in Ontario in 2004 and 2005 respectively, hydroelectric turbines are the greatest anthropogenic source of eel mortality in the province. No efforts to address downstream passage issues apparently were required nor attempted at any facility, until pilot trap and transport efforts at Moses-Saunders began in 2007 (OMNR 2008b). The duration of unmitigated impact therefore has been nearly a century at many facilities, and the impacts have accumulated. Negotiations are now underway at a couple of other facilities to mitigate turbine mortalities, but none have yet been implemented. Additionally, as of late 2009 at least 12 proposals for new facilities are known and others are likely within the historic range of eels in Ontario, highlighting the urgent need for action to avoid exacerbating the effects.

In Ontario, downstream migrants are invariably large females. These eels are very susceptible to turbine mortality as a consequence of their size, exacting a heavy mortality on sexually mature downstream migrants (Goode 2006). The overall impact of this stressor has not been measured; only direct, short-term mortality has been considered. Passage through turbines could have other major physical and physiological effects on eels that survive passage. Hence, effects that have been estimated to date (if at all) should be viewed as minimal impacts.

First Nations peoples have added their voice to this concern through Elder Commanda who indicated that hydroelectric facilities impact our watersheds (“Veins of Mother Earth”) in a variety of ways, and that we must consider their cumulative impacts. He urged caution as we proceed with more of these facilities, in order to respect the life-giving capacity of aquatic ecosystems in their entirety. Elder Commanda has expressed deep concern over the devastating impacts of dams and waterpower facilities on eel populations (W. Commanda, pers. comm. 2008).

The loss of freshwater eels is cause for concern, and provides impetus for implementing a precautionary approach to management of the species (McCleave and Edeline 2009). If the impacts of turbine mortalities are left unmitigated, hydroelectric facilities will remain as the major cumulative anthropogenic source of eel mortality in the province, jeopardizing survival and impeding recovery of the species in Ontario. Successful recovery of American Eel in Ontario will be very dependant on provision of safe upstream and downstream passage. Mitigation actions are feasible and underway in other jurisdictions to address similar impacts of hydroelectric facilities (MacGregor et al. in prep.; see also Sections 1.8 and 2.0).

<u>Habitat Alteration</u>
Portions of the remaining accessible habitat may be degraded due to poor land use practices, particularly timber harvest, farming practices and urbanization of watersheds that impair stream quality and riparian zones, imposing additional potential stressors to yellow eels (Machut et al. 2007). For instance, clearing and working land to the shoreline, with no buffer strips in particular, can result in erosion and sedimentation of watercourses, leading to infilling of interstitial spaces important to eels as habitat. Sediments arising from such practises also contain contaminants, making eel flesh less safe to eat and posing risks to reproductive success. The invasion of dreissenid mussels (e.g., Zebra Mussel; *Dreissena polymorpha*) may also have had some impact on eels in some waters (e.g., Lake Ontario), by increasing water clarity and forcing eels into deeper and thermally less preferred waters (J. Casselman, unpub. data).

Operation of water control structures can affect flow and water levels. This could impact the habitat and migration of eels. Water level fluctuations can negatively affect wetland habitat for eels and possibly eels directly during winter drawdown events. Alteration of important wintering habitat has not been assessed, including desiccation of these important habitats during winter drawdowns. Winter drawdown of reservoirs can also cause ice scouring and removal of aquatic vegetation in the littoral zone which eels use for cover and protection in other seasons. Creation of reservoirs during the construction of a new hydroelectric facility can inundate and destroy wetland complexes and wetland habitat for eels. Additionally, water management regimes can affect fish community structure (Haxton and Findlay 2009). Winter drawdowns of reservoirs can remove all available food for juveniles, thereby potentially affecting growth and survival of eels. This has been shown for other littoral zone benthivores (Haxton and Findlay 2009).

Indeed, operating regimes and discharges at reservoirs that alter or reduce summer flows can negatively affect the peak midsummer upstream migration of juvenile eels (J. Casselman, pers. comm. 2009).

Toxicity and Contaminants

Contaminants such as polychlorinated biphenyls (PCBs) may affect eel fertility, survival, and migration success. The importance of this stressor has not been quantified despite the fact that very elevated levels of contaminants are well documented in eels in the St. Lawrence River system (Reid and Meisenheimer 2001).

Productivity and Food-web Changes

Profound ecological changes have occurred in Lake Ontario since 1970 (Mills et al. 2003). Forage species are important in production, growth, and fecundity of eels, particularly in relation to maturation. Prey species important for eel production in the St. Lawrence River/Lake Ontario system (e.g., Alewife) have been in decline as a result of changes induced by phosphorus control efforts and invasive species (e.g., Zebra Mussel and Quagga Mussel (*Dreissena rostriformis bugensis*), Round Goby) (Mills et al. 2003). Changes in prey availability have the potential to affect eel growth and production.

Changing Oceanic Conditions

Climate change and other environmental shifts may alter the Gulf Stream, reducing ocean productivity and influencing the production and ability of leptocephali to drift from the Sargasso Sea to continental waters (Friedland et al. 2007; Bonhommeau et al. 2008; Miller et al. 2009).

However, past recruitment indicates that although oceanic conditions influence recruitment, changing conditions should not greatly limit recruitment or restoration. When recruitment was high prior to the mid-1970s, the effects of changing oceanic conditions were undetectable. However, since then, recruitment has declined to a point where oceanic effects are now apparent. Historic evidence suggests that if recruitment were high, changing oceanic conditions would be considerably less important (J. Casselman, pers. comm. 2009). If escapement and reproductive capacity were increased, this factor would become less important.

The concern is that the cumulative anthropogenic effects of such factors as over-fishing and turbine mortalities may have destabilized the eel population, making it more sensitive and less resilient to changes in environmental conditions and other perturbations (Bonhommeau et al. 2008; MacGregor et al. 2009). Similarly, poor conditions for survival and growth of other species such as salmon may also have become more common in the marine environment (Friedland et al. 2003; Lawson et al. 2004), thus increasing the impacts of environmental perturbations in fresh water (McCormick et al. 2009). For this reason, continued global warming is an additional concern (Miller et al. 2009).

This highlights the importance of reducing human-induced mortality, and the need to boost production and resilience of American Eel by restoring access and habitat diversity, regardless of the influence of variations in environmental conditions. While changes in ocean currents may, from time to time, change dispersal patterns of leptocephali to coastal waters, plenty of recruits were available in coastal waters during unfavourable events when spawners were abundant (J. Casselman pers. comm. 2009). Conservation of spawners is paramount, particularly when environmental conditions are less favourable.

Both Canada and the European Union have recognized that while shifts in ocean currents may influence annual recruitment to continental waters (Miller et al. 2009), recruitment will be dependent on the biomass of spawners, and there is a clear need to improve production and escapement of spawners (DFO 2004, 2007a; EU 2007; Brujis et al. 2009).

Parasites

An exotic, parasitic bladder worm, *Anguillicoloides crassus*, that may negatively affect eels has been introduced into United States waters (Fries et al. 1996). It recently has been detected in some waters within the Atlantic Provinces, but has not been observed in eels in the Ontario segment of the population. In the European Eel, the parasite is thought to negatively affect silver eels during spawning migration (Sjoberg et al. 2009 and references therein). Policies and procedures have been implemented to restrict its spread into Ontario during stocking and other transport events (Williams and Threader 2007). By enabling eel access to fresh water through such provisions as eel ladders and dam removal, stocking of parasite-free eels can have the effect of lowering infestation rates (Schmidt et al. 2009). Infestation rates are lower for inland American Eel (Machut and Lindburg 2008) probably because transmission from secondary hosts is reduced (Schmidt et al. 2009).

Cumulative Effects

Because eels migrate across an extensive geographic range and have a complex life cycle, the cumulative effects of multiple stressors accrue across the range (MacGregor et al. 2009). The cumulative effects of habitat loss and degradation must have reduced the effective population size of the species in the decades leading up to the declines (Miller et al. 2009). As eels are panmictic, the impacts of commercial fishing, turbine mortalities and lost access to habitat due to dams throughout the species' range, and the effects of those impacts (i.e., lost production due to lost habitat and mortalities due to fishing and turbines), accumulate on one common stock. These cumulative effects have been, and continue to be, substantial in Ontario and across the entire range of the species (MacGregor et al. 2009; MacGregor et al. in review).

The cumulative effects of reduced access to rearing and maturing habitat, combined with the significant anthropogenic mortalities (fishing and turbines) of Ontario's large fecund females, will depress spawner biomass, population-level fecundity and subsequent production of new juveniles. This would have the effect of reducing density-dependent dispersal back to Ontario's female rearing and maturing waters. Indeed, the evidence suggests that the decline in spawning stock size exiting the St. Lawrence River was not due to poor recruitment as a result of changes in oceanic conditions, but to large-scale cumulative mortality factors associated with high exploitation in Lake Ontario and to construction of hydroelectric facilities in the 1950s (de Lafontaine et al. 2009; MacGregor et al. 2009). As more and more of these pressures are imposed on Ontario's eels, the production and escapement of eels from Ontario will continue to decline towards extirpation unless long-overdue mitigation is implemented (MacGregor et al. in review).

Cumulative effects of dams and hydroelectric facilities on migratory fish species are exacting similar tolls in other jurisdictions. For instance, major rivers in the Gulf of Maine average five or more mainstem dams; the cumulative impacts of these dams are the major reason for the failure of most migratory fish restoration efforts (Goode 2006). Major efforts are underway to correct the situation in the Gulf and other jurisdictions in the United States.

Cumulative effects generally have not been considered in the past during approval processes in Ontario, as no formal mechanism currently exists provincially to include them in project-by-project decision making, or in site- or harvest-specific assessments. This may account, in part, for the decline of the eel despite federal and provincial legislative authorities and mandates to prevent it through provisions in both Canada's *Fisheries Act* (Canada Department of Justice 1985), and Ontario's *Lakes and Rivers Improvements Act 1990* (Ontario Government 1990). Implementation of effective conservation measures also has been inhibited by complexities associated with: (a) governance over the lifecycle of the species (life stages of American Eel span some 25 jurisdictions having management responsibility for the species (MacGregor et al. 2008)); (b) the shifting baseline[1] in perspectives of former distribution and abundance of eels (MacGregor et al. 2009); and (c) competing values of waterpower producers, commercial fisheries and biodiversity conservation (Collares-Pereira and Cowx 2004; MacGregor et al. 2008, 2009).

The split of management responsibilities between federal and provincial jurisdictions for waters within the province also complicates conservation governance with respect to American Eel, and the effective assessment of cumulative effects. In light of growing demand for renewable energy, and in view of strong human population growth projections for Ontario, continued lack of consideration/mitigation of the cumulative effects of dams, turbines and fisheries on American Eel may well be one of the largest single threats to survival and recovery of the species in the province (MacGregor et al. in review). The panmictic, highly plastic life history strategy of American Eel has enabled the species to be very successful across a wide diversity of habitats. However, panmixis may also be the species' Achilles heel, exposing it to cumulative anthropogenic effects across a wide geographic range, all of which accumulate to negatively impact the single spawning stock.

[1] See glossary for definition of shifting baseline.

1.7 Knowledge Gaps

Although it may appear that considerable knowledge about eels exists, there are many aspects of this relatively secretive animal that are very poorly understood. Given its unique life cycle of being an ocean spawner and highly migratory, the mysteries concerning the animal are considerable. Where basic biological information is known for the freshwater phase, it is usually quite limited, in both abundance and locale. The species has not been well sampled; therefore, its abundance is not well documented, particularly in Ontario waters, and distribution has changed dramatically over time. Biological data are limited; considerably more information is required to support recovery and restoration of eels in Ontario. It is difficult to list these uncertainties and gaps in priority order, but to support recovery, the following information should be acquired.

(1) Abundance and distribution in Ontario under present, as well as historic, conditions. Significant progress has been made with the assistance of ATK in this recovery strategy to acquire historic information; however, much more should be acquired. Present and future changes in abundance should be monitored in a quantitative fashion in support of the recovery strategy.

(2) Mortality rates due to different threats need to be quantified to develop a complete picture of the cumulative effects on the species. This would involve measuring downstream passage at various types of hydroelectric facilities throughout the range so that a thorough estimate can be made for each hydro facility. This goes hand in hand with the necessity to effectively reduce downstream passage mortality, particularly throughout the Ottawa River and its tributaries. Current quantitative information is available on passage mortality at the two large hydro facilities on the St. Lawrence River, but not for smaller facilities on other rivers.

(3) Upstream passage has been fairly well studied and achieved through the installation of artificial facilities. However, downstream passage options need to be studied in detail and facilitated. Providing safe downstream passage is particularly important.

(4) Downstream passage effects have been assessed only in terms of mortality. No doubt there are less obvious, but possibly equally important, physical and physiological effects on eels that survive entrainment and passage. These impacts need to be examined in detail and evaluated.

(5) Harvest mortality has been eliminated in Ontario; however, commercial harvest elsewhere could affect overall spawning and recruitment, which would affect recruitment and restoration in Ontario. Silver eel fisheries in the lower St. Lawrence River have been reduced but still exist. The importance of this exploitation needs to be evaluated in the context of recovery of the species in Ontario.

(6) Limited upstream and downstream passage at obstructions in Ontario exists at some structures, even when not facilitated. The significance of this, and details concerning influencing factors, should be studied and quantified.

(7) Eels are considered to be highly versatile in habitat association and use. But in reality, their specific habitat requirements are very poorly understood. The general perception that they are very diverse may well be related to the fact that specific studies on use and requirements have not been adequately carried out, and in particular, overwintering habitat is considered to be quite unique but is not at all well understood. This could be an important factor limiting abundance of the species.
(8) More information needs to be acquired concerning habitat impacts involving changes in behaviour, abundance, growth, survival, and production due to alterations by invasive species such as dreissenids, loss of wetlands, and drawdowns caused by water control.
(9) The importance of contaminants is poorly understood, including the sublethal effects of pollutants and parasites, on swimming performance and egg production and fertilization. A study is currently underway at Queen's University on the role of contaminants; however, additional information that would shed more light on spawning success may need to be acquired.
(10) The cumulative impact of habitat loss needs to be quantified, in particular blockage of upstream passage on abundance and freshwater production of spawning females, not only in Ontario but throughout the range of the species.
(11) .Develop a better understanding of the stock-recruitment relationships in American Eel. The role of Ontario and the St. Lawrence River eels needs to be further investigated and refined.
(12) Climate and environmental conditions are changing. Habitat availability and use under these changing conditions needs to be more thoroughly documented to support a better understanding. In addition, the potential effects of global warming on oceanic conditions and eel recruitment need further research.
(13) Eels are being stocked in Ontario. Their abundance, distribution, possible interaction with other eels, biology, and potential contribution to subsequent recruitment need to be evaluated. Biological data need to be assembled and made available to better understand these issues.

1.8 Recovery Actions Completed or Underway

In 2004 the Minister of Fisheries and Oceans announced a goal of reducing eel mortality in the upper St. Lawrence River/Lake Ontario system by 50 percent within 2 years and called on stakeholders and jurisdictions to take the necessary measures to reach this goal. Since that time, both Ontario and Quebec have announced plans to undertake mitigation or offsetting measures to reduce mortality and set the scene for recovery of American Eel.

<u>Recovery Planning</u>
The American Eel is listed under Ontario's ESA (Ontario Government 2007), and under this Act hydroelectric facilities that currently harm eels within the province have the opportunity to enter into Agreements with the province until June 2011, thereby enabling the facility to remain in compliance with the Act after that date (Ontario Government

2008). As of May 2009, Quebec, Ontario, and Fisheries and Oceans Canada (DFO) are nearing completion of the National Management Plan for the American Eel (DFO 2007a). The Plan includes a draft framework for eel recovery in the upper St. Lawrence River/Lake Ontario segment of the eel range, and a formal Memorandum of Understanding to develop coordinated management and science approaches for eel conservation across the North American range. Additionally, the Canadian Eel Steering Committee for Downstream Passage and Habitat Issues developed a "Decision Analysis" in 2005 aimed at developing mitigation measures to increase eel survival in the upper St. Lawrence/Lake Ontario system (Greig et al. 2006).

Eel Fisheries

Ontario commercial eel fisheries were closed in 2004 and the recreational fishery for eels was closed in 2005. This was one of the earliest attempts to reduce mortality and initiate eel recovery. Silver eels escaping from Ontario are still exploited in the Gulf of St. Lawrence fisheries; however, planned reductions in these fisheries now are being implemented as part of the Hydro Quebec Action Plan (MNRF 2009). Quebec has closed the historically important Richelieu River fishery and fisheries in the St. Lawrence have been reduced in recent years by licence retirement. Fisheries regulations (size limits, seasons, etc.) have also been made somewhat more restrictive in the Maritimes (COSEWIC 2006; MacGregor et al. 2008).

Upstream Migration

In Ontario, the only actions to mitigate upstream passage have been at Moses-Saunders Generating Station on the St. Lawrence River, although discussions are currently underway at several other facilities. Here, an eel ladder has been in operation since 1974, and an experimental approach involving glass eel stocking in the upper St. Lawrence River/Lake Ontario has been underway since 2006. In New York, a state of the art eel ladder was recently installed on the U.S. portion of the Moses-Saunders facility.

In the United States, there is much activity to restore passage for migratory fish species (including eels) to the inland waters of many states (GMCME 2007; MacGregor et al. in prep.). For instance, a full migratory fish passage plan has been developed and is now well into implementation for the Susquehanna River in Maryland (PFBC 2007), and planning is well underway for the Penobscot River in Maine (PRRT 2009). Upstream eel passage on the Oswego River (a New York tributary to Lake Ontario where eels once were highly abundant but disappeared due to hydroelectric installations) now has been required during a Federal Energy Regulatory Commission (FERC) re-licensing exercise for Brookfield Power at its Varik waterpower facility. Provision of one-inch trash rack overlays is required on all three Brookfield facilities in the Oswego River to deter large fish from entering turbine intakes (Elmer and Murphy 2007).

Stocking of Eels

In 2006 a pilot stocking program of eels began in the Ontario portion of the St. Lawrence River and Lake Ontario. Stocking began earlier in Quebec. Funding and support for stocking has been provided by Ontario Power Generation, Quebec Hydro, and provincial governments. Effectiveness monitoring of the stocking programs has shown that stocking has some promise as a means of maintaining the presence of eels in these waters (good survival and growth). However, disconcerting issues have recently arisen with the program in Lake Ontario that have caused widespread concern: (1) some of the stocked eels have turned out to be males; and (2) there is evidence of very early downstream migration of the stocked fish (T. Pratt, pers. comm. 2010). The occurrence of males is an undesirable outcome because recorded history shows it is unprecedented in Ontario waters, and males do not contribute nearly as much to recruitment as do females. Early maturity at a small size is also undesirable because small females contribute less to recruitment than do large females, and it is unclear if these small females have sufficient energy reserves to make the long journey to the Sargasso Sea and spawn successfully. The implications of these outcomes need to be thoroughly evaluated before stocking in waters other than the St. Lawrence River and Lake Ontario is undertaken. Additionally, stocking is not seen as a desirable long-term mitigation or recovery measure (Parnell and Greig 2005). The true contribution of the stocked fish in terms of producing subsequent natural recruitment will, because of the mysteries around spawning, be one of the major drawbacks to the ultimate assessment of their contribution.

Turbine Mortality

Negotiations with some power companies in Ontario and Québec have led to formal action plans to further address and offset turbine-related mortalities at two specific locations on the St. Lawrence River (Beauharnois and Saunders generating stations). Where effort has been applied elsewhere, some success has been achieved in reducing downstream mortality (e.g., Boubée et al 2001; Watene and Boubée 2005). One example is the installation of a grid on the water intake at a small hydro dam on the Rimouski River, Québec (G. Verreault, pers. comm. 2009). A trap and transfer program initiated by Ontario Power Generation has shown some promising results, but further evaluation is required to examine its biological effectiveness and the feasibility of full scale implementation (A. Mathers, pers. comm. 2009; T Pratt, pers. comm. 2010). A single hydroelectric facility located at Appleton on the Mississippi River was designed to enable downstream eel passage, but the passage actions were not implemented.

2.0 RECOVERY

2.1 Recovery Goal

The recovery goal for American Eel is by 2150 (7 generations) to re-establish species throughout its historic range in Ontario[2], at abundance levels that: (1) restore cultural relationships and natural heritage values; (2) are consistent with ecosystems of high integrity and function; (3) strengthen the biodiversity of the province's watersheds; and (4) provide valued ecological services.

Emphasis of the Strategy and Rationale
The recovery team recommends a phased and strategic watershed-based approach (see Section 2.3, pg. 50) to restoring American Eel throughout its historic range (as indicated by historic records, abundance and ATK) in Ontario. Recovery of American Eels in Ontario is realistic and extremely important, especially in light of the unique and significant phenotype that formerly contributed substantially to the reproductive output of the species. This phenotype may not be replaceable if lost (L. Bernatchez, pers. comm. 2010). Recovery in Ontario will be a long-term prospect, likely to take over a century to complete in its fullest sense.

While anthropogenic mortality due to fishing in Ontario has been addressed, improved production[3] and escapement of spawners from Ontario waters remains especially important. A significant proportion of the remaining eels in Ontario are still being killed by turbines during their spawning migration. American Eel is semelparous (only spawn once) and special protection should be afforded to seaward migrating eels (L. Velez-Espino, pers. comm. 2009). Therefore, it is recommended that a particular emphasis of eel recovery be placed on strategic provision of enhanced, adequate and safe upstream and downstream passage (see Section 2.3, pg. 51 and Appendix 3).

Similar efforts are underway in many other jurisdictions (Elmer and Murphy 2007; GMCME 2007; PFBC 2007; PRRT 2009; MacGregor et al. in prep.; Safe Harbor Corporation 2010). Strategic provision of adequate safe upstream passage (e.g., installation of eel ladders) is an easy, effective short-term approach to achieve improved access to habitat fairly quickly, enabling phased improvement of abundance in inland watersheds, and gradually restoring resilience, biodiversity, and ecosystem services over time. This will provide time to evaluate and implement the numerous downstream passage options. For instance, the Gulf of Maine Council on the Marine Environment states:

> "It may seem counterproductive to install elver ladders to get eels upstream, if there is not a safe way for them to get back downstream. However, after eels pass a dam they may spend 10 to 30+ years in the watershed, giving people considerable time to install downstream passage facilities. Allowing upstream

---
[2] Historic range in Ontario is depicted in Figure 3.
[3] See glossary for definition of production.

> passage now can essentially “bank” eels in the watershed with the hope that safe downstream passage will be provided by the time these fish mature and return to the sea” (GMCME 2007).

There will be many years before downstream passage mitigation needs to be installed, once upstream access is provided, affording adequate time to find interim mitigation measures. Trap and transfer programs or strategic turbine shut-downs at night during peak migration periods (once identified) should be considered in the near term to alleviate downstream passage issues, until more effective means are installed to protect migrants. Regardless, eels are currently being killed by turbines in many watersheds, and mitigation measures will need to be implemented in any event for facilities to remain in compliance with legislation. It is expected that an adaptive management approach will be required.

As in all fisheries management actions, uncertainties are inevitable and often site-specific. However, the early provision of upstream passage is a procedure widely adopted in numerous North American jurisdictions (Elmer and Murphy 2007; GMCME 2007; PFBC 2007; PRRT 2009) as it is highly feasible with numerous benefits (Briand et al. 2005; Machut et al. 2007). Leaving eels accumulated below facilities can lead to reduced growth and condition, and increased parasite loads and mortality due to competition and predation (Machut 2006; Machut et al. 2007). Increased growth and hence size of female eels is positively correlated with increased fecundity. Therefore, increasing eel condition and growth by enabling dispersal may help to stabilize decreasing American Eel populations and increase recruitment (Barbin and McCleave 1997; Machut et al. 2007). Installation of eel ladders at hydroelectric facilities is known to work well to improve upstream passage, and given propensity of the species to move and colonize new areas randomly at the yellow eel stage, large accumulations are not necessary to stimulate dispersal. Enhancing tributary habitat by improving access may increase the carrying capacity of the entire watershed (Machut et al. 2007).

Enhanced access to a diversity of lost habitats will lead to improved growth and production of Ontario’s large females from a diversity of habitats, eventually improving the reproductive capacity of the species, while restoring resilience of the species to anthropogenic stress, and yielding greater dispersal of new recruits throughout Ontario.

2.2 Protection and Recovery Objectives

Table 1. Protection and recovery objectives.

No.	Protection or Recovery Objective
1	Restore access to habitat within the historic range of American Eel. • By 2150, restore resilience of American Eel to anthropogenic stress in Ontario by diversifying habitats available to American Eel within the province, and by protecting/restoring access to and use of both upper St. Lawrence River/Lake Ontario and the inland watersheds formerly used by American Eel in Ontario. • By 2050, increase production of American Eels by restoring access to all immediate tributaries of the Ottawa River, Lake Ontario and the upper St. Lawrence River. • Beginning immediately, consistent with the National Management Plan for American Eel, increase American Eel access to habitat by 10 percent every five years (DFO 2007a).
2	Increase escapement of silver and large yellow eels from watersheds in their historic range within Ontario. • By 2050, reduce cumulative mortality rates by 50 percent at the watershed level (consistent with DFO 2007a) in order to increase the escapement of large, mature female eels from provincial waters to levels targeted in implementation plans for a given watershed. This objective is intended to support increased recruitment of eels. As there is no fishing in Ontario, the focus will need to be on cumulative mortalities due to turbines. Measured at the Moses-Saunders ladders, the intent is to achieve recruitment of eels ascending the ladders consistent with the returns observed during the late 1970s and early 1980s. • By 2070, increase the number of American Eels annually out-migrating from Ontario to the ocean to levels consistent with those observed in the early 1980. • By June 2011 undertake negotiations with power companies, stakeholders, Aboriginal representatives and government to develop plans to reduce mortality of American Eels by hydroelectric facilities.
3	Reduce anthropogenic mortality of eels in boundary waters managed jointly with other jurisdictions.
4	Locate, protect, restore and enhance habitats upon which eels depend.
5	Reduce other sources of stress on American Eel (e.g., contaminants, disease, harmful destruction, alteration or disruption of habitat).
6	Use a coordinated and strategic watershed-based approach to eel recovery across its historic range in Ontario.
7	Strengthen the engagement of Aboriginal peoples, stakeholders and other partners in the development and implementation of recovery actions for American Eel.
8	Maintain strong Ontario participation and leadership in the development and implementation of coordinated inter-jurisdictional protection, management and recovery of American Eel and its habitats at national and bi-national levels.
9	Ensure ongoing understanding of the current status of American Eel and the efficacy of recovery strategy actions.
10	Evaluate potential short-term methods of supporting eel abundance through stocking in identified watersheds.
11	Address knowledge gaps to enable and enhance protection, conservation and recovery efforts.

2.3 Approaches to Recovery

Table 2. Approaches to recovery for the American Eel.

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
1.0 Restore access to habitat within the historic range of American Eel.				
Critical	Long-term	Management and Protection	**1.1** Using a strategic and phased approach, ensure existing facilities provide upstream passage for American Eel.	• Barriers to migration • Productivity and food web changes
Critical	Short-term	Management and Protection	**1.2** Develop and implement strategic passage plans for eels on key watersheds.	• Barriers to migration • Productivity and food web changes
Critical	Ongoing	Management and Protection	**1.3** Ensure all new facilities on watersheds within the native range of eels are designed to allow upstream passage for American Eel. • Ensure existing facilities mitigate downstream passage mortalities in accordance with both strategic and opportunistic manners identified in watershed implementation plans (see 2.5) • Protect migratory corridors from further permanent blockages. • Protect migratory corridors from harmful alterations of disruptions during peak migration periods	• Barriers to migration • Productivity and food web changes
Critical	Short term	Management and Protection	**1.4** Provide policy and procedure tools to evaluate and address the cumulative impact of numerous water control structures on upstream passage.	• Barriers to migration • Productivity and food web changes
2.0 Increase escapement of eels from watersheds within their historic range within Ontario				
Critical	Long-term	Management and	**2.1** Reduce/eliminate turbine mortality due to	• Turbine mortality at

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
		Protection	hydroelectric facilities on all watersheds within historic range of American Eel in Ontario. • Ensure all new facilities on watersheds within the native range of eels are designed for and able to provide safe downstream passage for American Eel. • Beginning immediately, determine peak migration times, and routes upstream and downstream, of American Eel in priority watersheds within Ontario. • Ensure existing facilities mitigate downstream passage mortalities in accordance with both strategic and opportunistic manners identified in watershed implementation plans (see 2.5). • Conduct workshops with eel biologists, holders of ATK, and engineers experienced in fish passage techniques to develop methods suitable for safe downstream passage of eels for small and large rivers. • Establish eel transfer programs for large maturing eels currently resident above selected hydroelectric facilities (short-term). • Evaluate and address the cumulative impact of water control structures on downstream passage. • Seek alternate, techniques/alternatives to hydroelectric dams to meet energy requirement needs and remove reliance on flowing waters.	hydroelectric facilities
3.0 Reduce anthropogenic mortality of eels in boundary waters managed jointly with other jurisdictions				
Critical	Short-term	Management and Protection	**3.1** Encourage other jurisdictions to reduce commercial harvests of yellow and silver eel.	• Harvesting

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
			3.2 Encourage other jurisdictions to mitigate turbine mortalities of downstream migrants.	• Turbine mortality at hydroelectric facilities
4.0 Locate, protect, restore and enhance habitat on which eels depend.				
Critical	Ongoing	Management and Protection	**4.1** Ensure no net loss of habitat from development and new structures.	• Habitat alteration
Critical	Ongoing	Management and Protection	**4.2** Ensure wetland protection and restoration.	• Habitat alteration
Critical	Ongoing	Management and Protection	**4.3** Work in cooperation with water control boards to identify water management strategies that meet needs for flood control while not detrimentally affecting eels or their habitat.	• Habitat alteration
Critical	Short-term	Management and Protection; Research	**4.4** Consider how flows and water levels can be managed to improve habitat for eels. Factors to address include: • water level fluctuations (winter drawdowns could kill eels overwintering in wetlands; devoid nursery areas of pertinent forage); • ponding practices could inundate and destroy wetlands; and • increased or reduced flows as well as timing of flows could impede eel migration upstream or downstream.	• Habitat alteration
Critical	Short-term	Research and Monitoring	**4.5** Locate and quantify areas of residual eel abundance. Identify habitat parameters associated with eel abundance.	• Habitat alteration
Critical	Short-term	Management and Protection	**4.6** Identify additional measures, if any, needed to protect these habitats.	• Habitat alteration
5.0 Reduce other sources of stress on American Eel (e.g., contaminants, disease, harmful destruction, alteration or disruption of habitat).				

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Important	Ongoing	Management and Protection	**5.1** Support actions to reduce contaminant and pollution loadings in eel habitats (e.g., Remedial Action Plans, Lakewide Management Plans, Toxics Management Plans etc).	• Toxicity and contaminants
Important	Short-term	Management and Protection Research; Monitoring and Assessment	**5.2** Evaluate the impact of contaminants on eels.	• Toxicity and contaminants
6.0 Use a coordinated and strategic watershed-based approach to eel recovery across its historic range in Ontario.				
Critical	Short-term	Management and Protection	**6.1** Develop upstream and downstream passage strategies and implementation plans for American Eel on all key watersheds in Ontario. Begin implementation at downstream facilities and work progressively upstream.	• Cumulative effects in Ontario
Critical	Ongoing	Management and Protection	**6.2** Incorporate cumulative effects analysis in the review of all water power projects and other developments that may impact eels within their historic range in Ontario	• Cumulative effects in Ontario
Critical	Ongoing	Management and Protection	**6.3** Employ decision analysis that builds on existing research to determine priority actions that address the specific threats operating in different parts of the range.	• Cumulative effects in Ontario
Critical	Short-term	Management and Protection	**6.4** Develop a decision support tool to identify and prioritise mitigation actions at hydroelectric installations and other barriers.	• Cumulative effects in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Critical	Short-term	Management and Protection	**6.5** Establish watershed-level escapement targets for silver eels that address cumulative mortalities on each watershed. • Generally begin strategic approach for mitigating downstream passage issues within the lower areas of the watersheds first. • Consistent with the specific approaches under Objectives 1.0 and 2.0, it is recommended that an opportunistic approach be adopted within the approvals process to ensure passage wherever warranted by the watershed implementation plans. • Develop watershed based implementation plans (refer to Appendix 3, Watershed-based Implementation Plans) and begin implementation of a phased and strategic approach to re-establish American Eels in key watersheds	• Cumulative effects in Ontario
Critical	Ongoing	Management and Protection	**6.6** In view of the joint federal and provincial interests in the resources of the Trent River and other water bodies under federal jurisdiction, work in close cooperation with the federal government, especially Fisheries and Oceans Canada, to ensure effective implementation of the strategy.	• Cumulative effects in Ontario
Critical	Ongoing	Management and Protection	**6.7** Where appropriate, and consistent with the strategic approach of the recovery strategy, use existing regulatory tools (Ontario's ESA, the *Fisheries Act* and the *Lakes and Rivers Improvement Act*) to mandate upstream and downstream passage at existing facilities.	• Cumulative effects in Ontario
Critical	Short-term	Management and Protection	**6.8** Assess and address cumulative mortalities of eels in Ontario	• Cumulative effects in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed

Critical	Ongoing	Monitoring and Assessment	**6.9** Develop and regularly monitor the following:
			• Develop and implement an on-going monitoring program to assess abundance, recruitment and silver eel escapement on priority watersheds:
			  ◦ regularly monitor and report on mortality at hydroelectric generating stations;
			  ◦ regularly monitor recruitment of eels at the watershed level on priority watersheds; and
			  ◦ conduct a recurring assessment of eel recruitment, abundance and silver eel escapement on priority watersheds.
			• Establish benchmarks for success and thresholds at the watershed level for additional conservation actions:
			  ◦ establish lower threshold levels of abundance, recruitment and silver eel escapement below which recovery and sustainable management would be compromised
				• Cumulative effects in Ontario

Critical	Ongoing	Monitoring and Assessment	**6.10** Every 10 years, update / revise the watershed implementation plans as new scientific information regarding the biology and status of American Eel becomes available.	• Present and future changes in abundance
7.0 Strengthen engagement of Aboriginals, stakeholders and other partners in development and implementation of recovery actions for American Eel.				
Critical	Ongoing	Education and Outreach	**7.1** Share and collaborate effectively with Aboriginal communities to integrate ATK into recovery planning and implementation.	• Historic conditions • Present and future changes in abundance

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Critical	Ongoing	Education and Outreach	**7.2** Include Aboriginal representation in the design and implementation processes of education/outreach and recovery planning.	• Historic conditions • Present and future changes in abundance
Critical	Ongoing	Education and Outreach	**7.3** Develop strong and lasting partnerships with Aboriginal communities, industry, other stakeholders and local communities in implementation of the watershed-based recovery strategy	• Cumulative effects • Upstream and downstream passage
Critical	Ongoing	Education and Outreach	**7.4** Provide support to enable full participation of Aboriginal communities in the development and implementation of all aspects of the recovery strategy.	• Cumulative effects • Upstream and downstream passage • Present and future changes in abundance
Critical	Long-term	Education and Outreach	**7.5** Develop education, science-transfer and public-awareness programs: • focus on local communities and schools; • develop partnerships in implementation of recovery strategy; and • stress ecological value in environment to reduce eel mortality by humans. These programs should place special emphasis on youth and attempt to partner with the Ontario Stewardship program.	• Cumulative effects • Upstream and downstream passage • Present and future changes in abundance • Climate change and environmental change
8.0 Maintain strong Ontario participation and leadership in the development and implementation of coordinated inter-jurisdictional protection, management and recovery of American Eel and its habitats at national and bi-national levels				
Critical	Short-term	Education and Outreach	**8.1** Engage other jurisdictions in developing and implementing inter-jurisdictional conservation, recovery and management strategies for American Eel in bi-national and inter-provincial boundary waters that address provincial issues.	• Inter-jurisdictional • Cumulative effects

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Critical	Ongoing	Education and Outreach	**8.2** Continue to direct Ontario resources and expertise towards the development and implementation of coordinated inter-jurisdictional science, management, conservation and protection efforts for American Eel and its habitat	• Inter-jurisdictional • Cumulative effects
Critical	Short-term	Management and Protection	**8.3**. Provide support to enable full participation of Aboriginal communities in the development and implementation of all aspects recovery.	• Inter-jurisdictional • Cumulative effects
Critical	Ongoing	Management and Protection	**8.4** For watersheds managed by other agencies, work in cooperation with the management agencies to protect and improve the status of eels and their habitat.	• Inter-jurisdictional • Cumulative effects • Upstream and downstream passage
9.0 Ensure ongoing understanding of current status of the American Eel and the efficacy of the recovery strategy actions				
Important	Short-term	Inventory, Monitoring and Assessment	**9.1** Design and implement a monitoring program to provide the necessary information on trends in abundance across the identified key watersheds. Include information from Aboriginal and community knowledge in this assessment, and ensure representation of Aboriginal peoples on monitoring teams. For example, assess recruitment of juvenile eel to the lower Ottawa River downstream of the first barrier.	• Barriers • Turbine Mortality • Quantify mortality
Important	Short-term	Inventory, Monitoring and Assessment	**9.2** Integrate and coordinate research among jurisdictions. Support research and assessment that improves understanding of eel population trends and effectiveness of mitigation options.	• Inter-jurisdictional • Abundance and distribution
Critical	Ongoing	Inventory, Monitoring and Assessment	**9.3** Identify recovery opportunities and methods.	• Upstream and downstream passage • Turbine mortalities

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
10.0 Evaluate potential short-term methods of supporting eel production in identified watersheds based on a phased and strategic approach				
Critical	Short-term	Research	**10.1** Evaluate the effectiveness (survival, growth, production of females, etc.) of current stocking efforts in Lake Champlain and the upper St. Lawrence River/Lake Ontario.	• Strategic stocking
Critical	Short-term	Research	**10.2** Locate sources of glass eels for stocking, primarily from the St. Lawrence River system or if necessary from elsewhere (areas that produce primarily female silver eels).	• Strategic stocking
Critical	Short-term	Research	**10.3** Work with DFO to ensure the development of a regulation to set aside a portion of the glass eel/elver quota for conservation. This regulation would be analogous to that already developed by the European Union to support Eel conservation in Europe.	• Strategic stocking
Critical	Short-term	Research	**10.4** Evaluate success of stocking programs (survival, growth, production of females etc.).	• Strategic stocking
Critical	Short-term	Research	**10.5** Explore/evaluate other methods to improve short-term production, e.g., upstream transfer of young eels.	• Upstream passage
11.0 Address knowledge gaps to enable and enhance protection, conservation and recovery efforts.				
Important Critical	Short-term Short-term	Research Research	**11.1** Work to gain more insights from ATK, and further integrate ATK with western scientific knowledge of eel ecology. **11.2** Quantify cumulative mortality estimates for each watershed.	• Historic conditions • Present and future changes in abundance • Cumulative mortality

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Important	Short-term	Research	**11.3** Develop a population model allowing assessment of the impact of mortality at specific points in the life history on overall abundance, escapement, and subsequent recruitment. Use this model to support management decision making.	• Cumulative mortality
Important	Short-term	Research	**11.4** Determine the impact of contaminant loadings and toxicity on the survival and recruitment of eels within a watershed.	• Impact of contaminants
Critical	Short-term	Research	**11.5** Begin immediately to identify migratory routes and timing of migration for recruits and silver eels at existing hydroelectric facilities. Determine how flows and other environmental variables affect movements of eels upstream and downstream.	• Turbines at hydroelectric facilities
Important	Short-term	Research	**11.6** Strengthen the understanding of historical distribution of eels, by regularly updating the documentation based on historical records, new archaeological finds, and ATK.	• Historical distribution
Critical	Short-term	Research	**11.7** Assess ecological role and potential ecological impact of reintroducing eels into former habitat.	• Effects of restoration on fish communities
Important	Short-term	Research	**11.8** Identify important wetlands for over wintering eels and evaluate the impact of winter drawdowns.	• Habitat
Important	Short-term	Research	**11.9** Encourage and support the evaluation of Gulf Stream effects, considering significance of slight increases in recruitment, including the role of regulatory changes on recent slight increases in abundance (e.g., eel ladder numbers).	• Ocean effects • Climate change

Supporting Narrative

There is some limited evidence that some eels in the upper St. Lawrence and Lake Ontario may now be maturing and leaving the river system relatively quickly; some have been found to leave in seven to eight years (T. Pratt, pers. comm. 2010; A. Mathers, pers. comm. 2010), whereas the average residency is 12 years before they migrate (J. Casselman, pers. comm. 2010). This may be due to a density-dependent growth/maturation response in the remaining eels, now that the population has collapsed to very low abundance (J. Casselman, pers. comm. 2010). Regardless, there will still be many years before downstream passage mitigation needs to be installed, once upstream access is provided. Trap and transfer programs or strategic turbine shut-downs at night during peak migration periods (once identified) should be considered in the near term to alleviate downstream passage issues, until more effective means are installed to protect migrants.

Some have suggested concentrating all provincial rehabilitation efforts at Saunders Generating Station at the outlet from Lake Ontario. Not only would this run counter to the foregoing, it is fraught with uncertainties and risk. The densest human population in Canada surrounds Lake Ontario; urbanization is intense and future growth projections are enormous. Contaminants are still problematic throughout the lake; the lake is plagued by profound, ongoing ecosystem change due to the effects of invasive species. While considerable habitat is available in Lake Ontario, uncertainties remain regarding the present and future quality of habitat. Also, mitigating the effects of Saunders is especially difficult given the problems associated with the magnitude of the St. Lawrence River and Moses-Saunders facility. Given the historic abundance of eels in the lake, recovery efforts at Saunders-Lake Ontario are strongly encouraged to continue while uncertainties are investigated, but concentrating recovery efforts only at Saunders-Lake Ontario is not recommended. It is strongly recommended that recovery efforts be broadened to include additional waters, to increase available habitat and build resilience in the stock. Increasing available habitat for eels is a worthy goal given the drastic decline in eels (Machut et al. 2007), and there is considerably more quality habitat in other Ontario watersheds if access were available.

Safe downstream passage can be provided over time to ensure these benefits will accrue to the species and the province on a sustained basis. Enhanced downstream passage can be quite site-specific, often beginning with trapping migrating eels and transporting them around facilities; this can be quite effective (McCarthy et al. 2008) while longer term solutions are developed. Regardless, given that turbine mortalities still exist in Ontario waters, progress (often through adaptive management approaches) in mitigating downstream passage issues will assist waterpower facilities currently harming eels to remain in compliance with the ESA after June 30, 2011. The current exemption for waterpower will expire for those facilities where eels are known to exist and are harmed, unless agreements under the Regulation are entered into prior to that date.

Watershed Implementation Plans (Objective 6)

The recommended approach is to adopt strategic watershed approaches in which implementation of the strategy will be guided by watershed specific implementation plans. This is consistent with watershed (catchment) based approaches and watershed restoration efforts in other jurisdictions (Collares-Pereira and Cowx 2004; MacGregor et al. in prep.). The primary thrust of the strategy is the restoration of upstream and downstream passage at man-made structures, especially at hydroelectric facilities. Restoration should begin at the lower end of a watershed and work progressively upstream as American Eels regain access to the upper portions of the watershed. This approach should occur at a provincial scale, where the Ottawa River and St. Lawrence River would receive priority in terms of effort as they are the two most downstream systems. Two exceptions to this sequencing are recommended.

1. Long time periods normally pass before upgrades/modifications are proposed at a facility (often 30 – 50 years). Therefore, it will often be important to ensure passage during the approvals process for new or existing facilities, regardless of location within a watershed, and particularly for the first three barriers upstream of the last barrier where eels currently occur. The permitting process often can be the best time to consider eel passage because engineering and other construction works will be underway at the same time. Eel passage should be considered at a facility even when there are no such passageways further downstream or upstream.
2. In heavily developed watersheds, passage should be provided at potentially impeding structures in the lower or middle reaches, regardless of documented current presence of eels. This will be important to enable eels to reach more pristine, often protected waters that are not heavily impacted by urbanization and other anthropogenic impacts on water quality, habitat and eels (Machut et al. 2007).

Given the lengthy approvals processes, implementation of items 1 and 2 above will be critical to take advantage of future recruitment pulses when they occur. Failure to proactively install enhanced passage will lead to significant missed opportunities to take advantage of unpredictable strong recruitment events.

2.5 Area for Consideration in Developing a Habitat Regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of Natural Resources on the area that should be considered in developing a habitat regulation. A habitat regulation is a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the recovery team will be one of many sources considered by the Minister when developing the habitat regulation for this species.

It is recommended that all reaches (Aquatic Resource Areas[4] as defined by the Ontario Ministry of Natural Resources) currently or formerly occupied, or used as migratory

[4] Aquatic Resource Areas are aggregations of stream segments with similar physical and biological characteristics.

corridors by American Eel, be prescribed as habitat in a habitat regulation for American Eel. Including formerly occupied reaches is consistent with the recovery strategy goal that recommends re-establishing American Eel throughout its historic range.

It is recommended that within these reaches the prescribed area include primary habitat in both lentic and lotic waters, including all waters extending from the high-water mark[5] (including a 30 m riparian buffer (Environment Canada 2005) immediately adjacent to the high-water mark (DFO 2007b)) down to a depth of 10 m (Verreault et al 2004). The 30 m buffer should also be applied to all permanent and ephemeral rivers, streams and rivulets. It should be noted that primary habitat can be much broader depending on the water body, and can extend from the high water mark (including a 30 m riparian buffer) to any depth (e.g., Lac des Chats where primary habitat appears to extend to a depth of 15 m; K. Punt, pers. comm. 2009). Local knowledge should determine if refinements in a given reach are required.

In general, currently or formerly occupied habitat is found in all waters tributary to Ontario's portions of Lake Ontario, the St. Lawrence River, and the Ottawa River. Migratory corridors include (but may not be limited to) all water bodies within the following key watersheds (this includes all associated lakes, rivers, streams, rivulets and waterways, permanent or ephemeral):

- upper St. Lawrence River/Lake Ontario;
- Ottawa River;
- Mississippi River;
- Bonnechere River;
- Kawartha Lakes;
- Salmon River;
- Moira River;
- Napanee River;
- Credit River;
- Humber River;
- Duffins Creek;
- Bronte Creek;
- Don River;
- Hamilton Harbour and Cootes Paradise;
- Petawawa River;
- Madawaska River;
- Mattawa River;
- Lake Timiskaming (including the Montreal and Blanche Rivers);
- Muskrat Rive;
- Rideau River;
- Rideau Canal;
- Raisin River;
- South Nation River;
- Gananoque River;
- Trent/Otonabee River;

[5] See glossary for definition of high-water mark.

- Twelve Mile Creek/Martindale Pond;
- Jordan Harbour; and
- Niagara River.

GLOSSARY

Anthropogenic: Caused by humans.

ATK: Aboriginal Traditional Knowledge.

Benthivore: Feeding on bottom-dwelling organisms.

Catadromous: Going down rivers to the sea to spawn as does the American Eel (Scott and Crossman 1973).

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The committee responsible for assessing and classifying species at risk in Canada.

Committee on the Status of Species at Risk in Ontario (COSSARO): The committee established under section 3 of the *Endangered Species Act, 2007* that is responsible for assessing and classifying species at risk in Ontario.

Conservation status rank: A rank assigned to a species or ecological community that primarily conveys the degree of rarity of the species or community at the global (G), national (N) or sub-national (S) level. These ranks, termed G-Rank, N-Rank and S-Rank, are not legal designations. The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:

1 = critically imperilled
2 = imperilled
3 = vulnerable
4 = apparently secure
5 = secure

Density-dependence: Describes a factor that influences individuals in a population to a degree that varies in response to how crowded (dense) the population is.

Diadromous: Involves migrations between freshwater and marine biomes (McDowall 2009).

Dreissenid: Small bivalves (clam-like) of the family Dreissenidae. Two species have invaded the Great Lakes (zebra and quagga mussels; *Dreissena polymorpha* and *Dreissena bugensis* respectively.

Ephemeral stream: A watercourse generally without a well-defined channel which flows only in response to rainfall or snowmelt. Ephemeral streams flow for less than 20% of the year during normal rainfall conditions. Includes ephemeral watercourses in urban and agricultural settings

Endangered Species Act, 2007 (ESA): The provincial legislation that provides protection to species at risk in Ontario.

Escapement: That portion of an diadromous fish population that escapes the anthropogenic mortality and reaches the freshwater spawning grounds. The number of eels which have escaped the fisheries and turbines and are available for spawning.

Eutrophication: Excessive nutrients in a lake or other body of water, usually caused by runoff of nutrients (animal waste, fertilizers, sewage) from the land, which causes a dense growth of plant life; the decomposition of the plants depletes the supply of oxygen. Can also be used to describe the natural aging processes in lakes.

Facultative: Not compulsory, not restricting.

Fecund: Producing or capable of producing an abundance of offspring. Egg-laden.

G-Rank: Global Rank; a rarity rank based on the range-wide status of a species, subspecies or variety

High water mark: The usual or average level to which a body of water rises at its highest point and remains for sufficient time so as to change the characteristics of the land. In flowing waters (rivers, streams) this refers to the "active channel/bank-full level" which is often the 1:2 year flood flow return level. In inland lakes, wetlands or marine environments it refers to those parts of the water body bed and banks that are frequently flooded by water so as to leave a mark on the land and where the natural vegetation changes from predominately aquatic vegetation to terrestrial vegetation (excepting water tolerant species). For reservoirs this refers to normal high operating levels (Full Supply Level). For the Great Lakes this refers to the 80th percentile elevation above chart datum as described in DFO's Fish Habitat and Determining the High Water Mark on Lakes (DFO 2007b).

Lacustrine: Of a lake or relating to a lake.

Lentic: Of, relating to, or living in still waters (as lakes, ponds, or swamps).

Leptocephali: Flat and transparent larva of the eel, marine eels, and other members of the Superorder Elopomorpha. These fishes with a leptocephalus larva stage include the most familiar eels such as the conger, moray eel, and garden eel, and the freshwater eels of the family Anguillidae, plus more than 10 other families of lesser-known types of marine eels. These are all true eels of the order Anguilliformes. The fishes of the other four traditional orders of elopomorph fishes that have this type of larva are more diverse in their body forms and include the tarpon, bonefish, spiny eel, and pelican eel.

Lotic: Of or relating to or living in actively moving water.

Mitigation: Elimination or reduction of frequency, magnitude, or severity of exposure to environmental, economic, legal, or social risks, or minimization of the potential impact of a threat.

N-Rank: National Rank; refers to the national conservation status rank of an element.

Panmictic: Describing a population in which mating is entirely random and any two (male and female) individuals are equally likely to mate. Random mating (or *panmixis*) is one of the assumptions of the Hardy-Weinberg equilibrium. Random mating within an interbreeding population American Eel and the Monarch Butterfly are examples of panmictic species.

Piscivore: Habitually feeding on fish.

Production: Total elaboration of new tissue in a time period of interest by a species-population. It includes the sum of growth increments for all population members alive at any time in the period (Chapman 1978). Total elaboration of new body substance in a unit of time, irrespective of whether or not it survives to the end of that time (Ricker 1975).

Recruitment: Addition of new members to the aggregate under consideration. In a fishery it is the supply of fish that becomes available at some particular stage in their life history, generally that stage at which the fish first become vulnerable to the gear used in the fishery (Everhart et al. 1975). Addition of new fish to the vulnerable population by growth from among smaller size categories (Ricker 1975).

Resilience: The magnitude of the population perturbations that the system will tolerate before collapsing into qualitatively different regime (Holling 1973; May 1976).

Semelparous: Used to describe an organism that reproduces just once during its lifetime, after which its death is inevitable.

Shifting baseline: A term used to describe the way significant changes to a system are measured against previous baselines, which themselves may represent significant changes from the original state of the system. The term was first used by the fisheries scientist Daniel Pauly (1995) in his paper "Anecdotes and the shifting baseline syndrome of fisheries". Pauly developed the term in reference to fisheries management where fisheries scientists sometimes fail to identify the correct "baseline" population size (e.g., how abundant a fish species population was *before* human exploitation) and thus work with a shifted baseline. In this way large declines in ecosystems or species over long periods of time were, and are, masked. There is a loss of perception of change that occurs when each generation redefines what is "natural". The term has become widely used to describe the shift over time in the expectation of what a healthy ecosystem baseline looks like.

Species at Risk Act (SARA): The federal legislation that provides protection to species at risk in Canada. This act establishes Schedule 1 as the legal list of wildlife species at risk to which the SARA provisions apply. Schedules 2 and 3 contain lists of species that at the time the act came into force needed to be reassessed. After species on Schedule 2 and 3 are reassessed and found to be at risk, they undergo the SARA listing process to be included in Schedule 1.

Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the *Endangered Species Act, 2007* that provides the official status classification of species at risk in Ontario. This list was first published in 2004 as a policy and became a regulation in 2008.

S-Rank: Sub-national or Provincial Rank; refers to the provincial conservation status rank of an element, and used to set protection priorities for rare species and natural communities.

Stochasticity: a) Involving or containing a random variable or variables: *stochastic calculus.*
b) Involving chance or probability: *a stochastic stimulation.*

Torpor: The dormant, inactive state of a hibernating or estivating animal.

REFERENCES

Albert, V., B. Jonsson, and L. Bernatchez. 2006. Natural hybrids in Atlantic eels (*Anguilla anguilla*, *A-rostrata*): evidence for successful reproduction and fluctuating abundance in space and time. Molecular Ecology 15:1903-1916.

Allen, W.A. 2008a. Dbaajmoowin: Dialogue with the elders, in S. Weber and D. Harmon (eds.). Protected areas in a changing world: Proceedings of the 2007 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites. The George Wright Society, Hancock, Michigan.

Allen, W.A. 2008b. American eel: Driving a Shift in Power. PowerPoint presentation. Available: www.latornell.ca/pdf/2008sessions/2008_T2F_William_A_Allen.pdf

Allen, W.A. 2008c. American eel: Driving a Shift in Power. Delivery notes and reference list. Available: www.latornell.ca/pdf/2008sessions/2008_T2F_William_A_Allen_delivery.pdf

Allen, W.A. 2008d. American eel: Driving a Shift in Power. Handout. Available: www.latornell.ca/pdf/2008sessions/2008_T2F_William_A_Allen_handout.pdf

Allen, W.A., L.M. Brady, and P. Decontie. 2008. Manaadjiyindj iyaa manidoo nayaagadjitoodj kije-asin mazinaakobiihiganan – Honouring the Spirits of Sacred Pictographs. Pp. 277-289, in C. Dignard, K. Helwig , J. Mason, K. Nanowin, and T. Stone (eds.). Preserving Aboriginal Heritage: Technical and Traditional Approaches, Proceedings of Symposium 2007. Canadian Conservation Institute, Ottawa, Canada.

Aoyama, J., M. Nishida, and K. Tsukamoto. 2001. Molecular phylogeny and evolution of the freshwater eel, genus *Anguilla*. Molecular and Phylogenetic Evolution 20:450-459.

Arai, T., A. Kotake, P.M. Lokman, M.J. Miller, and K. Tsukamoto. 2004. Evidence of different habitat use by New Zealand freshwater eels *Anguilla australis* and *A. dieffenbachia*, as revealed by otolith microchemistry. Marine Ecology Progress Series 266:213-225.

ASMFC (Atlantic States Marine Fisheries Commission). 2000. Interstate Management Plan for American Eel. Report No. 36:1-93.

ASMFC (Atlantic States Marine Fisheries Commission). 2006. Stock Assessment Report No. 06-01 of the Atlantic States Marine Fisheries Commission: Terms of References and Advisory Report to the American Eel Stock Assessment Peer Review, January 2006. Atlantic States Marine Fisheries Commission, Washington, D.C.

Avise, J.C., G.S. Helfman, N.C. Saunders, and L.A. Hales.1986. Mitochondrial DNA differentiation in North Atlantic eels: Population genetic consequences of an unusual life history pattern. Proceedings of the National Academy of Sciences of the United States of America 83:4350-4354.

Baraga, F. 1878. A dictionary of the Otchipwe language explained in English, Part 1 English-Otchipwe, Beauchemin & Valois, Montreal, Quebec.

Barbin, G.P. and J.D. McCleave. 1997. Fecundity of the American eel *Anguilla rostrata*, at 45 degrees N in Maine, USA. Journal of Fish Biology 51:840-847.

Barbin, G.P. and W.H. Krueger. 1994. Behaviour and swimming performance of elvers of the American eel, *Anguilla rostrata,* in an experimental flume. Journal of Fish Biology 45:111-121.

Bardeau, P.E.W. 2002. Onondowa'Ga:' Gawe:no, new reference edition. Seneca Nation of Indians, Salamanaca, New York

Bartram, J. 1751. Observations on the inhabitants, climate, soil, rivers, productions, animals, and other matters worthy of notice made by Mr. John Bartram, in his travels from Pennsylvania [sic] to Onondago, Oswego and the Lakes Ontario, in Canada to which annex'd a curious account of the cataracts at Niagara by Mr. Peter Kalm, a Swedish gentleman who travelled there.

Bendig, A., Ontario Ministry of Natural Resources; pers. comm. 2009

Bennett, C. and D.W. McCuaig. 1981. In search of the K & P. Juniper Books Ltd, Renfrew, Ontario.

Bernatchez, L., Université Laval; pers. comm. 2009

Bonhommeau, S., E. Chassot, B. Planque, E. Rivot, A.H. Knap, and O. Le Pape. 2008. Impact of climate change on eel populations of the Northern Hemisphere. Marine Ecology Progress Series 373:71–80.

Boubée, J.A., C.P. Mitchell, B.L. Chisnall, D.W. West, E.J. Bowman, and A. Haro. 2001. Factors regulating the downstream migration of mature eels (*Anguilla* spp) at Aniwhenua Dam, Bay of Plenty, New Zealand. New Zealand Journal of Marine and Freshwater Research 35:121-134. Available: www.royalsociety.org.nz/Site/publish/Journals/nzjmfr/2001/9.aspx

Briand, C., D. Fatin, G. Fontenelle, and E. Feunteun. 2005. Effect of re-opening of a migratory pathway for eel (*Anguilla anguilla*) at a watershed scale. Bulletin Francais de la *Peche* et de la Pisciculture 378-379:67-86. DOI: 10.1051/kmae:2005004.

Brujis, M.C.M., R.H. Hadderingh, U. Schwevers, B. Adam, U. Dumont, and H.V. Winter. 2009. Managing human impact on downstream migrating European eel in the River Meuse. Pp. 381-390, in J.M. Casselman and D.K. Cairns (eds). Eels at the edge: science, status and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Cairns, D.K., J.C. Shiao, Y. Iizuka, W.N. Tzeng, and C.D. MacPherson. 2004. Movement patterns of American eels in an impounded watercourse, as indicated by otolith microchemistry. North American Journal of Fisheries Management 24:452-458.

Canada Department of Justice. 1985. *Fisheries Act* (R.S., 1985, c. F-14). Available: http://lois.justice.gc.ca/en/ShowFullDoc/cs/F-14///en

Casselman, J., Queens University; pers. comm. 2009 and 2010

Casselman, J.M. 1982. Chemical analyses of the optically different zones in eel otoliths. Pp. 74-82, in K.H. Loftus (ed.). Proceedings of the 1980 North American Eel Conference. Ontario Fisheries Technical Report Series #4, Toronto, Ontario.

Casselman, J.M. 2003. Dynamics of resources of the American eel, *Anguilla rostrata*: declining abundance in the 1990s: Chapter 18. Pp. 255-274, in K. Aida, K. Tsukamoto, and K. Yamauchi (eds.). Eel Biology. Springer-Verlag, Tokyo.

Casselman, J.M. 2008. Otolith age interpretations of juvenile American eels ascending the R.H. Saunders Eel Ladder, Moses-Saunders Generating Station, upper St. Lawrence River, 2003-2007. Conducted by AFishESci Inc. for Ontario Power Generation through the Species at Risk Stewardship Program. 13 p. + 5 appendices.

Casselman, J.M., L.A. Marcogliese, and P.V. Hodson. 1997. Recruitment index for the upper St. Lawrence River and Lake Ontario eel stock: a re-examination of eel passage at the R.H. Saunders hydroelectric generating station at Cornwall, Ontario, 1974-1995. Pp. 161-169, in R.H. Peterson (ed.). The American eel in eastern Canada: Stock status and management strategies. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2196.

Casselman, J.M. and L.A. Marcogliese. 2007. Long-term changes in American eel (*Anguilla rostrata*) commercial harvest and price in relation to declining abundance. Completion report. 94 p. (57 pages text + 4 tables + 22 figures). Prepared for Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, and Department of Fisheries and Oceans by AFishESci Inc., Bath, Ontario K0H 1G0.

Casselman, J.M. and L.A. Marcogliese. 2010. Abundance and Distribution of American Eels (*Anguilla rostrata*) and Other Fish in the Lower Mississippi and Ottawa Rivers, 2009, as Determined by Quantitative Electrofishing. Conducted by AFishESci Inc, in cooperation with Plenty Canada and Mississippi Valley Conservation for, and with financial support provided by, Ontario Species at Risk Stewardship Fund.

Castonguay, M., P.V. Hodson, C.M. Couillard, M.J. Eckersley, J.D. Dutil, and G. Verreault. 1994. Why is recruitment of the American Eel, *Anguilla rostrata*, declining in the St. Lawrence River and Gulf? Canadian Journal of Fisheries and Aquatic Sciences 51:479-488.

CBD (Convention on Biodiversity). 2000. Sustaining Life on Earth: How the Convention on Biological Diversity Promotes Nature and Human Well-Being. Traditional Knowledge, pg. 15. Secretariat, Convention on Biodiversity, Montreal, Canada. http://www.cbd.int/doc/publications/cbd-sustain-en.pdf

Chapman, D. W. 1978. Production in fish populations. Pp. 5-25, in S. Gerking (ed.). Ecology of Freshwater Fish Production. John Wiley & Sons. New York – Toronto. 520 pp.

Clark, J.H. 2009. The American eel fishery in Delaware: recent landings, trends and characteristics of the exploited eel population. Pp. 229-239, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Circle of All Nations. Date unknown. www.angelfire.com/ns/circleofallnations/page2.html.

Clermont, N. and C. Chapdelaine. 1998. Île Morrison, Lieu sacré et atelier de l'Archaïque dans l"Outaouais, Paléo-Québec 28, Musée Canadien Des Civilisations et Recherches amérindiennes au Québec, Montréal, Quebec.

Clermont, N., C. Chapdelaine, and J. Cinq-Mars. 2003. Île aux Allumettes, L'Archaïque supérier dans L'Outaouais, Paléo-Québec 30, Musée Canadien Des Civilisations et Recherches amérindiennes au Québec, Montréal, Quebec.

Collares-Pereira, M.J. and I.G. Cowx. 2004. The role of catchment scale environmental management in freshwater fish conservation. Fisheries Management and Ecology 11:303-312.

Commanda, W., Algonquins of Ontario; pers. comm. 2009

Commanda, W. 2007. Correspondence from William Commanda, Algonquin Elder to Pooi-Leng Wong, Fisheries and Oceans Canada, March 31, 2007. www.icenetwork.ca/about_us/gwcvictoria%20island/othergwcdomtar08 (February 2009).

Commanda, W. 2008. Manoshkadosh the American eel. Written statement by Elder W. Commanda concerning the American eel on file with the Ontario Ministry of Natural Resources and Plenty Canada.

Commanda, W. 2009. William Commanda's Reflections in correspondence to the Governor General and to the Queen regarding his appointment to Officer of the Order of Canada and his work. Correspondence on file with the Ontario Ministry of Natural Resources and Plenty Canada.

Community Stewardship Council of Lanark County. 2010. American Eel-Hydro dam tailwaters monitoring project: assessment of mortalities on the Ottawa and Mississippi Rivers.

COSEWIC 2006. COSEWIC assessment and status report on the American eel *Anguilla rostrata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 71 pp. Available: http://dsp-psd.pwgsc.gc.ca/Collection/CW69-14-458-2006E.pdf

Cote, C.L., M. Castonguay, G. Verreault, and L. Bernatchez. 2009. Differential effects of origin and salinity rearing conditions on growth of glass eels of the American eel *Anguilla rostrata*: implications for stocking programmes. Journal of Fish Biology 74:1934-1948.

Côté, C.L., M. Castonguay, and L. Bernatchez (in prep.[a]). Contrasted patterns of phenotypic differentiation in controlled conditions; evidence for quantitative genetic differences between American eel from different origins.

Côté, C.L., S. Kalujnaia, G. Cramb, M. Castonguay, and L. Bernatchez (in prep.[b]) Differential transcriptomic profiles between American eel from different origins.

Côté, C.L., P.A. Gagnaire, M. Castonguay, L. Bernatchez (in prep.[c]). Fst = 0 in space and time confirms panmixia at the species range in the American eel (Anguilla rostrata).

Coulson, D., Ontario Ministry of Natural Resources; pers. comm. 2010

Daemen, E., T. Cross, F. Ollevier and F.A.M. Volckaert . 2001. Analysis of the genetic structure of European eel (*Anguilla anguilla*) using microsatellite DNA and mtDNA markers. Marine Biology 139:755-764.

Dannewitz, J., G.E. Maes, L. Johansson, H. Wickstrom, F.A.M. Volckaert and T. Jarvi. 2005. Panmixia in the European eel: a matter of time. Proceedings of the Royal Society B-Biological Sciences 272:1129-1137.

Daverat, F., K.E. Limburg, I. Thibault, J.C. Shiao, J.J. Dodson, F. Caron, W.N. Tzeng, Y. Iizuka, and H. Wickström. 2006. Phenotypic plasticity of habitat use by three temperate eel species, *Anguilla anguilla*, *A. japonica* and *A. rostrata*. Marine Ecology Progress Series 308:231-241.

Dekker W., J.M. Casselman, D.K. Cairns, K. Tsukamoto, D. Jellyman, and H. Lickers. 2003. Worldwide decline of eel resources necessitates immediate action: Québec declaration of concern. Fisheries 28:28-30.

de Lafontaine, Y., P. Gagnon, and B. Côté. 2009. Abundance and individual size of American Eel (*Anguilla rostrata*) in the St. Lawrence River over the past four decades. Hydrobiologia 647:185-198. DOI 10.1007/s10750-009-9850-5. 14 pp.

Desroches, D. 1995. Suivi de la migration de l'anguille d'Amerique (*Anguilla rostrata*) au complexe Beauharnois, 1994. Rapport prepare par Milieu & Associes inc. Pour la vice-presidence Environnement, Hydro-Québec, Montréal, Quebec.

DFO (Fisheries and Oceans Canada). 2004. Fisheries and Oceans Canada news release September 17, 2004, DFO and provinces release American eel management strategy. Available: www.dfo-mpo.gc.ca/media/npress-communique/2004/hq-ac79-eng.htm. (July 2008)

DFO (Fisheries and Oceans Canada). 2007a. American eel management plan. Available: www.dfo-mpo.gc.ca/communic/fish_man/consultations/eel-anguille_e.htm. (July 2008)

DFO (Fisheries and Oceans Canada). 2007b. Isolated or dry open-cut stream crossings. Available: http://www.dfo-mpo.gc.ca/habitat/what-quoi/os-eo/qc/pdf/stream-eng.pdf

DFO (Fisheries and Oceans Canada). 2010. Underwater world. American Eel. Available: http://www.dfo-mpo.gc.ca/science/publications/uww-msm/articles/eel-anguille-eng.htm

Dönni, W., K-J. Maier, and H. Vicentini. 2001. Bestandsentwicklung des Aals (*Anguilla anguilla*) im Hochrhein. Mitteilung Zur Fischeri, BUWAL, Bern, Germany. du Creux, F. 1664.

Dumaresq, C. 2006. Cobalt mining legacy. Available: http://cobaltmininglegacy.ca/mininghistory.php

Dymond, J.R. 1939. The fishes of the Ottawa region. Contributions of the Royal Ontario Museum of Zoology15, Toronto, Ontario.

Edeline, E., L. Beaulaton, R. le Barb, and P. Elie. 2007. Dispersal in metamorphosing juvenile eel *Anguilla anguilla*. Marine Ecology Progress Series 344:213-217.

Elmer, J.D. and S.P. Murphy. 2007. Improving fish habitat in the Oswego River. Hydro Review, September 2007:16-21.

Environment Canada. 2005. How much habitat is enough? Available: http://www.on.ec.gc.ca/wildlife/factsheets/fs_habitat-e.html

EU (European Union). 2007. Council Regulation (EC) No. 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Official Journal of the European Union, 22.9.2007, L 248/17. Available: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2007/l_248/l_24820070922en00170023.pdf. (July 2008)

Everhart, W.H., A.W. Eipper, and W.D. Youngs. 1975. Principles of Fishery Science. Cornell University Press. Ithaca and London. 288 pp.

Feunteun, E, P. Laffaille, T. Robinet, C. Briand, A. Baisez, J.M. Olivier, and A. Acou. 2003. A Review of upstream migration and movements in inland waters by anguillid eels: toward a general theory. Pp. 191-213, in K. Aida, K. Tsukamoto, and K. Yamauchi (eds.). Eel biology. Springer Verlag, Tokyo.

Friedland, K.D., D.J. Reddin, J.R. McMenemy, and K.F. Drinkwater. 2003. Multidecadal trends in North American Atlantic salmon (*Salmo salar*) stocks and climate change trends relevant to juvenile survival. Canadian Journal of Fisheries and Aquatic Sciences 60(5):563-583.

Friedland, K.D., M.J. Miller, and B. Knights. 2007. Oceanic changes in the Sargasso Sea and declines in recruitment of the European eel. ICES Journal of Marine Science 64:519-530.

Fries, L.T., J.T. Williams, and S.K. Johnson.1996. Occurrence of *Anguillicola crassus*, an exotic parasitic swim bladder nematode of eels, in the southeastern United States. Transactions of the American Fisheries Society 125:704-797.

Gagnaire, P.A., C.L. Côté, M. Hansen, M. Castonguay, and L. Bernatchez (in prep.). Functional genetic structure imposed by spatially varying selection in the American eel.

George, J. (Washaghezik). 1914. Monsters. Certain Ojibwa Myths by Col. Geo. E. Laidlaw, in 26th Annual Archaeological Report Ontario Being an Appendix to the Report of the Minister of Education Ontario. King’s Printer. Printed by Order of the Legislative Assembly, Toronto, Ontario.

Gibson, R.B. 2005. Sustainability Assessment Criteria and Processes. Earthscan, London, U.K.

Gill, T. 1908. Life history of the common eel. Transactions of the American Fisheries Society 37(1):115-121.

GMCME (Gulf of Maine Council on the Marine Environment). 2007. American Eels: restoring a vanishing resource in the Gulf of Maine. Available: http://www.wildlife.state.nh.us/marine/marine_PDFs/American_Eels_GulfOfMaine.pdf 12 pp.

Goode, A. 2006. The plight and outlook for migratory fish in the Gulf of Maine. Journal of Contemporary Water Research and Education 14:23-28. Available: http://www.ucowr.siu.edu/updates/134/5.pdf

Goode, G.B. 1881. The eel question. Transactions of the American Fisheries Society 10(1):81-124.

GLFC (Great Lakes Fishery Commission). 2002. Position statement on American eel. Available: www.glfc.org/lakecom/loc/eelposition.htm (March 2007)

Greig, L., I.J. Parnell, and D.R. Marmorek. 2006. Developing an action plan for American eels in the St. Lawrence River – Lake Ontario Region: Decision analysis. Prepared by ESSA Technologies Ltd., Richmond Hill, Ontario, for Hydro-Québec, Fisheries and Oceans Canada, Ontario Ministry of Natural Resources, Ontario Power Generation, and the U.S. Fish & Wildlife Service, on behalf of the Passage and Associated Habitat Subcommittee of the Canadian Eel Working Group. 155 pp.

Hammond, S.D. and S.A. Welsh. 2009. Seasonal movements of large yellow American Eels downstream of a hydroelectric dam, Shenandoah river, West Virginia. Pp. 309-323, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status, and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Haro, A.J., W. Richkus, K. Whalen, A. Hoar, W.D. Busch, S. Lary, T. Bush, and D. Dixon. 2000. Population decline of the American eel: implications for research and management. Fisheries 25(9):7-16.

Hawkins, C.M. 1995. Environmental habitat quality requirements/guidelines for American eel *Anguilla rostrata*. Document prepared for Habitat Management Division, Department of Fisheries and Oceans, Maritimes Region, Dartmouth, Nova Scotia.

Haxton, T., Ontario Ministry of Natural Resources; pers. comm. 2009

Haxton, T.J. and C.S. Findlay 2009. Variation in large-bodied fish community structure and abundance in relation to water management regime in a large regulated river. Journal of Fish Biology 74:2216-2238.

Heidenreich, C.E. 1971. The natural environment of Huronia and Huron seasonal activities. Marburger Geographische Schriften. Helft 50. Marburg/Lahn 1971.

Helfman, G.S., D.E. Facey, L.S. Hales, Jr., and E.L Bozeman, Jr. 1987. Reproductive ecology of the American Eel. Pp. 42-56, in M.J. Dadswell, R.L. Klauda, C.M. Moffitt, R.L. Saunders, R.A. Rulifson, and J.E. Cooper (eds.). Common strategies of anadromous and catadromous fishes. American Fisheries Society Symposium 1, Bethesda, Maryland.

Hoag, H. 2007. A slippery slope. The Globe and Mail, March 31:2007

Holling, C.S. 1973. Resilience and stability of ecological systems. A. Rev. Ecol. Syst. 4:1-24.

Ibbotson, A., J. Smith, P. Scarlett, and P. Aprahamian. 2002. Colonization of freshwater habitats by the European eel *Anguilla anguilla.* Freshwater Biology 47:1696-1706.

ICES (International Council for Exploration of the Sea). 2003. Report of the ICES/EIFAC Working Group on Eels. International Council for Exploration of the Sea, ICES CM 2003/ACFM:06, Copenhagen, Denmark.

Jessop, B.M. 1997. American eel elvers and their fishery in the Scotia-Fundy area of Atlantic Canada: an overview. Pp. 134-143, in R.H Petersen (ed.). The American eel in eastern Canada: stock status and management strategies, Canadian Technical Report of Fisheries and Aquatic Sciences 2196, Quebec City.

Jessop, B.M. 2010. Geographic effects on American eel (*Anguilla rostrata*) life history characteristics and strategies. Canadian Journal of Fisheries and Aquatic Sciences 67: 326-346.

Jessop, B.M., J.C. Shiao, Y. Iizuka, and W.N. Tzeng. 2002. Migratory behaviour and habitat use by American eels *Anguilla rostrata* as revealed by otolith microchemistry. Marine Ecology Progress Series 233:217-229.

Jessop. B.M., J.C. Shiao, and Y. Iizuka. 2009. Life history of American Eels from Western Newfoundland. American Fisheries Society 138:861-871.

Kleckner, R.C. and J.D. McCleave. 1988. The northern limit of spawning by Atlantic eels (*Anguilla* spp.) in the Sargasso Sea in relation to thermal fronts and surface water masses. Journal of Marine Research 46:647-667.

Kolenosky, D.P. and M.J. Hendry. 1982. The Canadian Lake Ontario fishery for American eel (*Anguilla rostrata*). Pp. 8-16, in K.H. Loftus (ed.). Proceedings of the 1980 North American Eel Conference. Ontario Ministry of Natural Resources, Fisheries Branch, Ontario Fish Technical Series No. 4, Toronto.

LaBar, G.W. and D.F. Facey. 1983. Local movements and Inshore population sizes of American Eels in Lake Champlain, Vermont. Transactions of the American Fisheries Society 112:111-115.

Lamson, H.M., J.-C. Shiao, Y. Iizuka, W.-N. Tzeng, and D.K. Cairns. 2006. Movement patterns of American eels (*Anguilla rostrata*) between salt- and freshwater in a coastal watershed, based on otolith microchemistry. Marine Biology 149:1567-1576.

Larinier, M. and J. Dartiguelongue. 1989. La circulation des poissons migrateurs : le transit à travers les turbines des installations hydroélectriques. Bulletin Français de la pêche et de la Pisciculture:312-313.

Lary, S.J., W.-D. Busch, C.M. Castigione, and R. MacDonald. 1998. Distribution and availability of Atlantic Coast freshwater habitats for American eel (*Anguilla rostrata*). U.S. Fish and Wildlife Service, Draft Administrative Report: 98-02.

Lawson, P.W., E.A. Logerwell, N.J. Mantua, R.C. Francis, and V.N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 61(3):360-373.

Lees, D. 2008. Eels on wheels. The Walrus. December 2008:42-57.

Legault, A. 1988. Le franchissement des barrages par l'escalade de l'anguille: étude en Sèvre Niortaise. Bulletin Français de la Pêche et de la Pisciculture 308:1-10.

Lickers, H., Akwesasne First Nations; pers. comm. 2009

Logan Journal. 1845. September 22, 1845.

MacGregor, R.B., A. Mathers, P. Thompson, J.M. Casselman, J.M. Dettmers, S. LaPan, T.C. Pratt, and W.A. Allen. 2008. Declines of American eel in North America: Complexities associated with bi-national management. Pp. 357-381, in M.G. Schechter, W.W. Taylor, and N.J. Leonard (eds.). International governance of fisheries ecosystems: learning from the past, finding solutions for the future. American Fisheries Society, Bethesda, Maryland.

MacGregor, R.B., J.M. Casselman, W.A. Allen, T. Haxton, J.M. Dettmers, A. Mathers, S. LaPan, T.C. Pratt, P. Thompson, M. Stanfield, L. Marcogliese, and J.-D. Dutil. 2009. Natural heritage, anthropogenic impacts and bio-political issues related to the status and sustainable management of American eel: A retrospective analysis and management perspective at the population level. Pp. 713-739, in Haro, A.J., K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R.A. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds.). 2009. Challenges for Diadromous Fishes in a Dynamic Global Environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

MacGregor, R.B., L. Greig, W. Allen, T. Haxton, J.M. Casselman, L. McDermott, and J.M Dettmers (in prep.). American eel in Ontario: Background, Principles, Biological Feasibility and Importance of Recovery. Great Lakes Fishery Commission.

MacGregor, R.B., T. Haxton, J. Casselman, L. Greig, W.A. Allen, and L. McDermott (in review). The Demise of American eel in Ontario and New York: Species-level Implications of Regional Cumulative Effects. American Fisheries Society Special Symposium.

Machut, L.S. 2006. Population dynamics, *Anguillicola crassus* infection, and feeding selectivity of American Eel *(Anguilla rostrata*) in tributaries of the Hudson River, New York. M.Sc. Thesis. State University of New York, College of Environmental Science and Forestry. Syracuse, NY. 177 pp.

Machut, L., K.E. Limburg, R.E. Schmidt, and D. Dittman. 2007. Anthropogenic impacts on American Eel demographics in Hudson River tributaries, New York.

Machut, L.S. and K.E. Lindburg. 2008. *Anglocolla crassus* infection in *Anguilla rostrata* from small tributaries of the Hudson River, New York, USA. Diseases of Aquatic Organisms 79:37-45.

Maes, G.E. and F.A.M. Volckaert. 2002. Clinal genetic variation and isolation by distance in the European eel *Anguilla anguilla* (L.). Biological Journal of the Linnean Society 77: 509-521.

Maes, G.E, J. M. Pujolar, B. Hellemans, and F.A.M. Volckaert. 2006. Evidence for isolation by time in the European eel (*Anguilla anguilla* L.). Molecular Ecology 15: 2095-2107.

Maes G.E. and F.A.M. Volckaert. 2007. Challenges for genetic research in European eel management. Ices Journal of Marine Science 64: 1463-1471

Mandrak, N.E. and E.J. Crossman. 2003. Fishes of Algonquin Provincial Park, Friends of Algonquin Park, Whitney, Ontario.

Mathers, A., Ontario Ministry of Natural Resources; pers. comm. 2009 and 2010

May, R.H. 1976. Models for two interacting populations. Pp. 49-70, in R.H. May (ed.). Theoretical Ecology: Principles and Applications. W.B. Saunders Company. Philadelphia – Toronto. 317 pp.

McCarthy, T.K., P. Frankiewicz, P. Cullen, M. Blaskowski, W. O'Connor, and D. Doherty. 2008. Long-term effects of hydropower installations and associated river regulation on River Shannon populations: mitigation and management. Hydrobiolgia 609:109-124. DOI 10.1007/s10750-008-9395-z

McCauley, C., Ontario Ministry of Natural Resources; pers. comm. 2009

McCleave, J.D. 1980. Swimming performance of European eel (*Anguilla anguilla* (L.)) elvers. Journal of Fish Biology 16:445-452.

McCleave, J.D., R.C. Kleckner, and M. Castonguay. 1987. Reproductive sympatry of American and European eels and implications for migration and taxonomy. Pp. 186-297, in M.J. Dadswell, R.L. Klauda, C.M. Moffitt, R.L. Saunders, R.A. Rulifson, and J.E. Cooper (eds.). Common strategies of anadromous and catadromous fishes. American Fisheries Society, Symposium 1, Bethesda, Maryland.

McCleave, J.D. 2001. Simulation of the impact of dams fishing weirs on the reproductive potential of silver-phase American eels in the Kennebec River basin. North American Journal of Fisheries Management 21:592-605.

McCleave, J.D. and E. Edeline. 2009. Diadromy as a conditional strategy: patterns and drivers of eel movements in continental habitats. 2009. Pp. 97-119, in A.J. Haro, K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds.). Challenges for diadromous fishes in a dynamic global environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

McCormick, S.D. , D.T. Lerner, M.Y. Monette, K. Nieves-Puigdoller, J.T. Kelly, and B.T. Bjornosson. 2009. Taking it with you when you go: How perturbations to the freshwater environment, including temperature, dams and contaminants, affect marine survival of salmon. Pp. 195-214, in A.J. Haro, K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds.). Challenges for diadromous fishes in a dynamic global environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

McDowall, R.M. 1996. Diadromy and the assembly and restoration of riverine fish communities: a downstream view. Canadian Journal of Fisheries and Aquatic Sciences 53(Supplement 1):213-236.

McDowall, R.M. 2009. Making the best of two worlds: diadromy in the evolution, ecology and conservation of aquatic organisms. Pp. 1-22, in A.J. Haro, K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R.A. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds.). Challenges for diadromous fishes in a dynamic global environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

McDermott, L., Algonquins of Ontario; pers. comm. 2009

McGregor, E. 1994. *Algonquin Lexicon*, Kitigan Zibi Education Council, Maniwaki, Québec. 407 pp.

MdDNR (Maryland Department of Natural Resources). 1999. Maryland Waters: An evaluation of stream health. Available: http://www.dnt.state.md.us/streams/news/march99/index.html

Meek, A. 1916. The Migrations of Fish. London, Edward Arnold.

MNRF (Ministère des Ressources naturelles et de la Faune). 2009. Une nouvelle mesure pour assurer le renouvellement de l'anguille d'Amerique. Communique de press, le 17 mars 2009. Cabinet du ministre delegue aux Ressources naturelles et a la Faune.

Mitchell, C.P. and J.A.T. Boubée. 1992. Impacts of turbine passage on downstream migrating eels. New Zealand Freshwater Fisheries Miscellaneous Report No.112. Fisheries Research Centre, Rotorura.

Miller, M.J., S. Kamura, K.D. Friedland, B. Knights, H. Kim, D.J. Jellyman, and K. Tsukamoto. 2009. Review of ocean-atmosphere factors in the Atlantic and Pacific oceans influencing spawning and recruitment of Anguillid eels. Pp. 231-249, in Haro, A.J., K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R.A. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds.). Challenges for Diadromous Fishes in a Dynamic Global Environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

Mills, E.L., J.M. Casselman, R. Dermott, J.D. Fitzsimmons, G. Gal, K.T. Holek. 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. Rudstram, T. Schaner, and T.J. Stewart. 2003. Lake Ontario: food web dynamics in a changing ecosystem (1970-2000). Canadian Journal of Fisheries and Aquatic Sciences 60:471-490.

Moriarty, C. 1987. Factors influencing recruitment of the Atlantic species of Anguillid Eels. pp. 483-491, in M.J. Dadswell, C.M. Moffit, R.L. Saunders, R.A. Rulifson, and J.E. Cooper (eds.). Common strategies of anadromous and catadromous fishes, American Fisheries Society Symposium 1, Maryland.

Morrison, W.E. and D.H. Secor. 2003. Demographic attributes of yellow-phase American eels (*Anguilla rostrata*) in the Hudson River. Canadian Journal of Fisheries and Aquatic Sciences. 60:1487-1503.

Morrison, W.E., D.H. Secor, and P.M. Piccoli. 2003. Estuarine habitat use by Hudson River American Eels as determined by otolith strontium: calcium ratios. Pp. 87-99, in D.A. Dixon (ed.). Biology, Management, and Protection of Catadromous Eels. American Fisheries Society Symposium 33, Missouri.

New York Times, The. 1880. Catching Canadian eel: the fisheries of the St. Lawrence River. The New York Times, October 18.

Normandeau Associates Inc. and J.R. Skalski. 1998. Draft final report. Estimation of survival of American eel after passage through a turbine at the St. Lawrence-FDR power project. Prepared for New York Power Authority, White Plains, New York.

Ogden, J.C. 1970. Relative abundance, food habits, and age of the American eel, *Anguilla rostrata* (LeSueur), in certain New Jersey streams. Transactions of the American Fisheries Society 99:54-59.

OMNR (Ontario Ministry of Natural Resources). 1971. Bancroft District Records, Big Gull Lake Files.

OMNR (Ontario Ministry of Natural Resources). 1984. Commercial fish production historic records, Northern Inland Waters 1924-1982. Written correspondence from K.J. Chambers to the Regional Directors North Central Region, Northern Region and Northeastern Region, Ontario Ministry of Natural Resources.

OMNR (Ontario Ministry of Natural Resources). 2007. American eel in Ontario, Status of Resource Report, Ontario Ministry of Natural Resources. Available: http://www.mnr.gov.on.ca/STEL02_166010.pdf

OMNR (Ontario Ministry of Natural Resources). 2008a. Fisheries Management in Renfrew County: A State of the Resource Report and a Focussed Review of Fisheries Issues. January 2008. 100 pp.

OMNR (Ontario Ministry of Natural Resources). 2008b. PARTNERS SUPPORT ACTION PLAN TO BRING BACK AMERICAN EEL: Native Species Important Part Of Great Lakes Ecosystem. News release June 20, 2008. Available: http://www.mnr.gov.on.ca/en/Newsroom/LatestNews/246778.html

Ontario Government. 1990. *Lakes and Rivers Improvement Act*. Available: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90l03_e.htm

Ontario Government. 2007. *Endangered Species Act*, 2007. Ontario Government, Toronto. http://www.ontla.on.ca/web/bills/bills_detail.do?locale=en&BillID=1498&detailPage=bills_detail_the_bill

Ontario Government. 2008. O. Reg. 242/08. To establish new regulatory provisions under the *Endangered Species Act*, 2007 to allow certain activities to continue. Available: http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_080242_e.htm

Parnell, I.J. and L. Greig. 2005. Developing an Action Plan for American eels in the St. Lawrence River – Lake Ontario Region: Decision Analysis – Trade-offs. Prepared by ESSA Technologies Ltd., Richmond Hill, ON, for the Passage and Associated Habitat Subcommittee of the Canadian Eel Working Group. 102 pp.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome in fisheries. Trends Ecology and Evolution 10:420.

PFBC (Pennsylvania Fish and Boat Commission). 2007. Migratory fish restoration and passage on the Susquehanna River. Available: http://www.fish.state.pa.us/pafish/shad/migratory_fish.pdf

PRRT (Penobscot River Restoration Trust). 2009. Project details. Available: http://www.penobscotriver.org/

Pinnegar, J.K. and G.H. Engelhard. 2008. The 'shifting baseline' phenomenon: a global perspective. Reviews in Fish Biology and Fisheries 18:1-16.

Pratt, T., Fisheries and Oceans Canada; pers. comm. 2010

Prosper, K. and M.J. Paulette. 2002. The Mi'kmaq Relationship With Kat (American Eel) Scientific Name: *Anguilla rostrata*, Paqtnkek Fish and Wildlife Commission, Afton First Nation, Antigonish, Nova Scotia.

Punt, K., Ontario Ministry of Natural Resources; pers. comm. 2009 and 2010

Purvis, F. 1887. Field Notes of Subdivision Survey of the Township of Hilliard. Field Note Book 1300. Available: Crown Surveys Office, Ontario Ministry of Natural Resources, Peterborough.

Reading Eagle. 1902. Mysteries About Eels: enormous numbers in a turbine wheel-sudden disappearance. July 19:4.

Reid, K.B. and P. Meisenheimer. 2001. The decline of American eel (*Anguilla rostrata*) in the Lake Ontario/St. Lawrence Ecosystem: A modelling approach to identification of data gaps and research priorities. Report Prepared for lake Ontario Technical Committee by Beak International Incorporated, ref.: 21852.10. Available: http://www.glfc.org/lakecom/loc/eel.pdf

Russell, I.C. and E.C.E. Potter. 2003. Implications of the precautionary approach for the management of the European eel, *Anguilla anguilla*. Fisheries Management and Ecology. 10 :395-401.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191.

Safe Harbor Corporation. 2010. How Fish Lifts Work. Available: http://www.shwpc.com/fishlift.html#migratory

SCC (Supreme Court of Canada). 1999. R. v. Marshall. Docket Number 26014. Supreme Court of Canada. Available: http://csc.lexum.umontreal.ca/en/1999/1999scr3-533/1999scr3-533.html

Schmidt, J. 1922. The breeding places of the eel. Philosophical Transactions of the Royal Society. London B. Biological Sciences 211:179-208.

Schmidt, R.E, C.M. O'Reilly, and D. Miller. 2009. Observations of American Eels using an upland passage facility and effects of passage on the population structure. N. American Journal of Fisheries Management 29:715-720.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184, Fisheries Research Board of Canada, Ottawa, Canada.

Secor, D.H. 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries Research 43:13-34.

Secor, D.H. 2007. The year-class phenomenon and the storage effect in marine fishes. Journal of Sea Research 57:91-103.

Secor, D. H. and L. A. Kerr. 2009. Lexicon of life cycle diversity in diadromous and other fishes. Pp. 537-556, in A.J. Haro, K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R.A. Cunjak, J.E. Cooper, K.L. Beal, and T.S. Avery (eds). Challenges for diadromous fishes in a dynamic global environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

Sjoberg, N.B., E. Petersson, H. Wickstrom, and S. Hansson. 2009. Effects of the swimbladder parasite *Anguillicola crassus* on the migration of European silver eels *Anguilla anguilla* in the Baltic sea. Journal of Fish Biology 74:2158-2170.

Smith, M.W. and J.W. Saunders. 1955. The American eel in certain fresh waters of the Maritime provinces of Canada. Journal of the Fisheries Research Board of Canada 12(2):238-269.

Smogor, R.A., P.L. Angermeier, and C.K. Gaylord. 1995. Distribution and abundance of American eels in Virginia streams: Tests of null models across spatial scales. Transactions of the American Fisheries Society 124:789-803.

Swain, S.P, A.F. Sinclair, and J.M. Hanson. 2007. Evolutionary response to size-selective mortality in an exploited fish population. Proc. R. Soc. B (2007) 274, 1015-1022, doi:10.1098/rspb.2006.0275. Available: http://rspb.royalsocietypublishing.org/content/274/1613/1015.full.pdf

St. John Daily Sun.1902. Mysteries About Eels: Enormous numbers in a turbine wheel – a sudden disappearance.

Tesch, F.W. 1977. The eel: biology and management of anguillid eels. Chapman and Hall, London.

Thibault, I., J. Dodson, F. Caron, J.C. Shiao, Y. Iizuka, and W.N. Tzeng. 2005. Alternative migratory behavior of the American eel (*Anguilla rostrata*) in the Saint-Jean River, Gaspé (Quebec). Fish and Diadromy in Europe: Ecology, Management and Conservation Symposium, held March 29 - April 1, Bordeaux, France. Preliminary results.

Thumbadoo, R.V. 2005. LEARNING from a kindergarten dropout – William Commanda – Ojigkwanong Cultural Sharings and Reflections. Circle of All Nations. Kanata, ON. 192 pp.

Thwaites, R.G. 1896 – 1901. The Jesuit Relations and Allied Documents. 73 Volumes. Burrows Bros., Cleveland, Ohio.

Trautman, M.B. 1981. The Fishes of Ohio. Ohio State University Press. 782 pp.

Tremblay, V. 2009. Reproductive strategy of female American Eels among five subpopulations in the St. Lawrence River watershed. Pp. 85-102, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Tsukamoto, K., I. Nakai, and W.V. Tesch. 1998. Do all freshwater eels migrate? Nature 396(6712):635-636.

van Ginneken, V.J. and G.E. Maes. 2005. The European eel (*Anguilla anguilla*, Linnaeus), its lifecycle, evolution and reproduction: a literature review. Reviews in Fish Biology and Fisheries 15:367-398.

Velez-Espino, L., Fisheries and Oceans Canada; pers. comm. 2009

Velez-Espino, L.A. and M.A. Koops. 2009. A synthesis of the ecological processes influencing variation in life history and movement patterns of American Eel. Towards a global assessment. Rev. Fish. Biol. Fisheries. DOI 10.1007/s11160- 009-9127-0.

Verreault, G., Québec Ministère des Ressources naturelles et de la Faune; pers. comm. 2009

Verreault, G. and P. Dumont. 2003. An estimation of American eel escapement from the upper St. Lawrence River and Lake Ontario in 1996 and 1997. Pp. 243-251, in D. A. Dixon (ed.). Biology, management and protection of catadromous eels. American Fisheries Society, Symposium 33, Bethesda, Maryland.

Verreault, G., P. Pettigrew, R. Tardif, and G. Pouliot. 2003. The exploitation of the Migrating Silver American Eel in the St. Lawrence River Estuary, Québec, Canada.

Pp. 225-234, in D.A. Dixon (ed.). Biology, management, and protection of catadromous eels. American Fisheries Society, Symposium 33, Bethesda, Maryland.

Verreault, G., P. Dumont, and Y. Mailhot. 2004. Habitat losses and anthropogenic barriers as a cause of population decline for American eel (*Anguilla rostrata*) in the St. Lawrence watershed, Canada. International Council for the Exploration of the Sea. CM Document 2004/S:04, Copenhagen, Denmark. Available: www.ices.dk/products/CMdocs/2004/S/S0404.pdf

Verreault G, W. Dargere, and R. Tardif. 2009. American eel (*Anguilla rostrata*) movements, growth and sex ratio following translocation. Pp. 129-136, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Watene, E.M. and J.A.T. Boubée. 2005. Selective opening of hydroelectric dam spillway gates for downstream migrant eels in New Zealand. Fisheries Management and Ecology 12(1):69-75.

Weeder, J.A. and J.H. Uphoff Jr. 2009. Are American Eel Harvests in Maryland's Chesapeake Bay Sustainable? Pp. 347-358, in J.M. Casselman and D.K. Cairns (eds.). Eels at the edge: science, status and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Whetung, M., Curve Lake First Nation; pers. comm. 2009

White, E.M. and B. Knights. 1997. Dynamics of upstream migration of the European eel *Anguilla anguilla* (L.), in the rivers of Severn and Avon, England, with special reference to the effects of man-made barriers. Fisheries Management Ecology 4:311-324.

Wiley, D.J., R.P. Morgan II, R.H. Hilderbrand, R.L. Raesly, and D.L. Shumway. 2004. Relations between physical habitat and American eel abundance in five river basins in Maryland. Transactions of the American Fisheries Society 133: 515-526.

Williams, B. and R. Threader. 2007. A review of the proceedings and outcomes of the workshop on the American eel, *Anguilla rostrata*, stocking in Canadian waters. Montreal, Canada, March 27-28, 2007. Report developed for Ontario Power Generation, Renfrew, Ontario.

Wirth T. and L. Bernatchez. 2001. Genetic evidence against panmixia in the European eel. Nature 409:1037-1040.

Wirth, T. and L. Bernatchez. 2003. Decline of North Atlantic eels: a fatal synergy? Proceedings of the Royal Society of London, Series B, Biological Sciences 270:681-688.

Vladykov, V.D. and P.K.L. Liew. 1982. Sex of Adult American Eels (*Anguilla rostrata*) Collected as Elvers in Two Different Streams Along the Eastern Shore of Canada, and Raised in the Same Freshwater Pond in Ontario. Proceedings of the 1980 North American eel Conference; Ontario Fisheries Technical Report Series 4:6.

Yagi, A., Ontario Ministry of Natural Resources; pers. comm. 2009

RECOVERY STRATEGY DEVELOPMENT TEAM MEMBERS

Table 2. Recovery strategy development team members.

NAME	AFFILIATION and LOCATION
Rob MacGregor (chair)	OMNR
Alastair Mathers	OMNR
Amy Boyko	DFO
Anne Bendig	OMNR
Anne Yagi	OMNR
William Allen	Heritage One, Burk's Falls
Brad Steinberg	OMNR
Cam Mccauley	OMNR
Jeff Beaver	Plenty Canada, Lanark
John Casselman	Queens University, Kingston
Rebecca Geauvreau	OMNR
Kevin Reid	Ontario Commercial Fisheries Association
Kirby Punt	OMNR
Larry McDermott	Shabot Obaadjiwan First Nation; Plenty Canada, Lanark
Lorne Greig	ESSA Technologies Ltd., Richmond Hill
Marie-Andree Carriere	OMNR
Sarah Nugent	OMNR
Stuart Niven	DFO
Thomas Hoggarth	DFO
Tim Haxton	OMNR
Tom Pratt	DFO
John Dettmers	GLFC
Jason Borwick	OMNR
Krista Coppaway	Curve Lake First Nation and Plenty Canada
Henry Lickers	Akwesasne First Nation

Appendix 1. Strengthening Our Relationship

The collaborative effort to develop this strategy through integration of our shared knowledge is a strong example of current efforts to work together to ensure sustainable use of shared resources.

Elder William Commanda carries a Wampum Belt[6] known as the Welcoming Belt, dating from 1701. This belt is the Aboriginal record of the Agreement with the French and English newcomers. The Agreement enshrined respect for one another's culture, and carried the shared obligation to protect and nourish Mother Earth's life giving capacity, including the conservation of all species. This was an early record of the principles of sharing ATK, and is one of the founding steps in the development of Canada as a nation.

The recovery team adhered to the agreement recorded in the Welcoming Belt throughout the preparation of this recovery strategy. This strengthening of our relationship is a process that Aboriginal people have anticipated for many generations as foretold in the Sacred Seven Fire Prophecy Wampum Belt, which dates from the late 1400s and which Elder William Commanda also carries for the people.

> "The seventh prophet talked about a time of choice-making for all – for continued exploitation of land and peoples, or for a renewed respect for Mother Earth and reconciliation between indigenous peoples and the newcomers. The double diamond at the centre of this eight-diamond belt reflects the hope for unity to emerge out of the duality." (Thumbadoo 2005).

Elder William Commanda writes that "the prophesy tells us that humanity is now at a cross roads, and that we urgently need to evaluate and transform our relationship with Mother Earth and each other" (Commanda 2007). The emergence of concern for the status of endangered species such as American Eel is understood to reflect the unfolding of the seventh prophesy.

[6] Wampum belts created from quahog shell beads document agreements, stories and prophesies. The belts serve both as a living record of a commitment, and also as a means to recall the detailed messages embedded in the design (Thumbadoo 2005).

Appendix 2. Aboriginal Peoples' American Eel Resolution

The following resolution was created and endorsed during a November 2008 workshop with Aboriginal peoples convened by Fisheries and Oceans Canada and the Ontario Ministry of Natural Resources. The purpose of the meeting was to discuss the listing of American Eels in Ontario as endangered under Ontario's ESA, the participation of Aboriginal peoples in the development of a Recovery Strategy for American Eel in Ontario as required by legislation, and to seek input on the federal government's draft National Management Plan and proposed listing of American Eel as special concern under the federal *Species at Risk Act*. The workshop was attended and endorsed by representatives of the Algonquin and Mi'kmaq First Nations as well as some from Curve Lake Reserve on the Kawartha Lakes. The following is the resolution written and signed by all First Nations in attendance:

We, the Aboriginal people who have attended the Eastern Ontario - Western Quebec workshop November 22-24, 2008 appreciate the guidance of our Elders who directed us on the way to address the decline of the American Eel, support the National Management plan guiding principles as amended during this workshop.

We wish to communicate the following, to ensure this ancient fish remains in the full historic range of its habitat and returns to waters from which it has been extirpated.

It was the unanimous decision that the status of the American Eel must be listed nationally as THREATENED under the SARA.

Our collective Aboriginal responsibilities with the American Eel remain vitally important to us even though our relationship with the eel has been put into jeopardy.

We also reaffirm our responsibilities to our Aboriginal brothers and sisters whose strong relationship with the American Eel is impacted by decisions made in our respective territories.

All development and fisheries management decisions must be guided by the precautionary principle and cumulative impacts must be assessed both on a watershed basis and on the basis that the American Eel, *Anguilla rostrata*, comes from one genetic stock.

Recognizing that if the American Eel is to recover, both habitat and recruitment issues must be addressed. Therefore, ambitious plans must be implemented immediately to enhance fish passage, reduce harvest and increase recruitment.

The Glass eel fishery for export must be closed, in order to achieve the objective for increased recruitment. Glass eels must be made available for conservation stocking, but only as a temporary measure until long term solutions are achieved to address declining abundance and recruitment.

Aboriginal peoples' ways of knowing and western science must be integrated equally in a full and respectful way in the decision making and implementation of the management plan.

Appendix 3. Considerations for Watershed-Based Implementation Plans

Watershed-based implementation plans for American Eel should include but not be limited to the following considerations.

- Use a GIS-based decision support tool and a decision analysis process in determining the best options for mitigation and recovery on each key watershed.

- Establish watershed-specific performance measures in the Watershed Implementation Plan for the following metrics:
    - Mortalities at hydroelectric facilities;
    - Recruitment; and
    - Escapement.

- As fish passage provisions are key to the success of mitigating threats and setting the scene for recovery, the implementation plans must consider the following.
    - Adhere to goals and objectives of this strategy.
    - Undertake assessment to confirm residual or relict presence/absence and abundance of eels within the historic range.
    - Identify existing means of passage where passage enhancements may be most efficiently and effectively implemented.
    - Identify strategic sites for mitigation of passage issues on a watershed basis:
    - develop a phased, strategic approach and timelines for implementation.
    - Ensure integration of implementation plans with the waterpower agreements described under the ESA (Ontario Government 2007), Ontario Regulation 242/08 (Ontario Government 2008).
    - Adopt an adaptive management approach where uncertainties are high.
    - Identify the need/opportunities to accommodate passage for other fish species at the same time (e.g., American Shad *Alosa sapidissima*).
    - If there are concerns over invasive species entering a watershed upon provision of passage, it should be noted that an eel ladder is a very specialized device and that typically no other species use it but eels. Therefore, the risk of invasive species entering after an eel ladder is installed typically should be minimal. Concerns over sea lamprey using the ladders also appear to be minimal as lamprey migration periods in March to early April occur at a time when American Eel ladders would not be operational.
    - Understand that mitigation options for passage will often be quite site-specific.
    - Consider the cumulative effects of a series of dams and hydroelectric facilities within a watershed on eels when issuing instruments for these facilities.

- Develop thresholds and benchmarks for success (e.g., escapement and recruitment targets).
- Ensure adequate effectiveness monitoring when issuing legal instruments for undertakings with the potential to have adverse effects on eels.
- Learn from the numerous experiences of other jurisdictions implementing fish passage initiatives at the watershed scale.
- Integrate the needs for power production, navigation and flood control into fish passage designs.