American Eel
Management Plan

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Canadian Eel Working Group

Fisheries and Oceans Canada
Ontario Ministry of Natural Resources
Ministère des Ressources naturelles et de la Faune du Québec

Preface

This draft Management Plan was developed by the Canadian Eel Working Group (CEWG) to coordinate management action among Canadian jurisdictions with responsibilities for conservation and management of American eel. Much of the content (long-term objectives, shorter-term objectives and management actions, implementation strategies) is based on a CEWG Workshop October 5-6, 2006. The draft Management Plan was reviewed by responsible Agencies and by interested parties prior to being finalized in its current form.

This draft Management Plan is part of an ongoing process to strengthen management of American eel, to halt abundance declines and foster conditions for rebuilding the population. A final version of this Management Plan will be completed based on input received from stakeholders. A more detailed implementation plan will also be developed based on the principles and objectives identified in the Management Plan once it is completed. The Management Plan is intended to meet the requirements for a species listed as "Special Concern" under the Species at Risk Act although at the time of writing, no decision has been made on whether or not to list American eel under the Species at Risk Act.

CEWG expresses its thanks to all those who contributed to this draft Management Plan through participation in workshops and meetings, and by commenting on drafts. CEWG would also like to thank Bob Beecher for facilitation of the October 2006 workshop and Howard Powles for assistance with drafting the Management Plan.

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Biological overview[1]

Description

The American eel (*Anguilla rostrata*) is the only member of the genus *Anguilla* found in North America. *Anguilla* eels are termed "freshwater eels" although part of their life cycle occurs in the sea and some individuals complete the life cycle in salt water. Juvenile and adult American eels are elongate, snake-like fish with rudimentary, deeply-embedded scales. The species has historically been common or abundant throughout its range.

Distribution

The American eel is widely distributed in fresh waters, estuaries and coastal marine waters of the western north Atlantic from Venezuela in the south to Greenland and Iceland in the north. Adults are found in oceanic waters of the Sargasso Sea where spawning occurs, and larvae are distributed in the western Atlantic Ocean as they move toward coastal and estuarine waters. In Canada the historic range includes all accessible freshwater, estuarine and coastal areas connected to the Atlantic Ocean, as far north as the mid-Labrador coast and as far inland as Niagara Falls in the Great Lakes. Continental shelf areas are also used by juvenile eels arriving from the oceanic spawning grounds and by adult silver eels returning to the spawning grounds. Recent occurrences in the Great Lakes above Niagara Falls (Lakes Erie, Huron and Superior) are the result of recent dispersal through the Erie and Welland Canals and should be considered as introductions outside the historic range.

Historically, the American eel had the largest range of any fish species in the western Hemisphere, and had a dominant position by numbers and biomass in many habitats it occupied. As such American eel is a very important component of Canadian biodiversity, possibly playing a key role in habitats where it exists.

A closely related species, the European eel (*Anguilla anguilla*) is distributed widely in the eastern Atlantic from Scandinavia and the Baltic Sea to Morocco and through the Mediterranean and Black Seas. Other *Anguilla* species are found in the Pacific and Indian Oceans (Fishbase 2006).

Life history

The American eel has a complex life history, stages of which occur in oceanic, coastal, estuarine and freshwater environments. Spawning and hatching occur in the Sargasso Sea. Larvae, called leptocephalus because of their transparent and leaf-like form, move in and across the Gulf Stream system, transforming to the glass eel stage on continental shelves. The glass eel stage has the typical elongate and serpentine form of the species but is not pigmented. Glass eels

[1] Unless otherwise noted, the source for information in this section is COSEWIC, 2006.

become progressively pigmented as they move across continental shelves to the shoreline, and are termed elvers when pigmented. The elver stage is followed by the yellow eel stage, characterised by thick, tough skin (in contrast to the thin skin of glass eels and elvers), yellow to olive-brown coloration on the belly and dark coloration on the back, which typically occurs in freshwaters. Sexual differentiation occurs in the yellow eel stage and this is also the principal growth stage for American eels. With maturation yellow eels transform into silver eels which are greyish to white ventrally and which have a number of morphological and physiological adaptations for long-distance migration, including an enlarged pectoral fin, enlarged eye and modified retinal pigments, and increased levels of somatic lipids.

The leptocephalus larval stage is generally completed within 7 to 12 months, and metamorphosis occurs at 55 to 65 mm in length and a mean age of 200 days. Estuarine arrival of glass eels occurs on average at an age of 255 days. The elver stage lasts from three to twelve months, during which considerable upstream migration in freshwaters can occur. In Atlantic Canada timing of elver migration varies geographically. In coastal Nova Scotia most elvers arrive between late April and late June, although arrival may continue into August, and arriving elvers typically range between 50 and 70 mm in length. In Prince Edward Island elvers have been caught between the end of June and August, while arrival occurs during the month of July at lengths of 60-70 mm on the north shore of the Gulf of St. Lawrence.

Yellow eels may continue to migrate upstream for many years and may show seasonal peaks in migration, typically between June and August at Canadian locations for which information is available. Eels with access to salt water may move from fresh water to estuaries in spring and return to fresh water in the fall. In Canada, eels typically hibernate in mud during winter, entering torpor at temperatures below 5C, although there are records of eels being active during winter.

Mature silver eels spawn in the Sargasso Sea between February (peak) and April, and outmigration of silver eels from Canada is timed to allow adults to reach the spawning habitat at the appropriate time. Outmigration begins in May from the Richelieu River (Québec) and June from Lake Ontario, and continues into November from Nova Scotia.

Size, age and growth

Maximum length of American eel observed in Canada is around 1 m, while maximum age observed is around 32 years. Mean observed age at the spawning migration is 19.3 yrs with a range of 12-23 years. Length at the spawning migration varies geographically, with individuals from the St. Lawrence River being larger at migration (840-1000 mm) than those from the Gulf of St. Lawrence and Atlantic regions (650-700 mm). All the above observations are from eels of freshwater origin, for which information is easier to obtain than for individuals which have spent their life in salt waters. Growth is faster in saltwater habitat than in freshwater; one study of individuals from salt water bays suggested growth to the migration length of 700 mm by 7 years of age. In freshwater habitats growth appears to be faster in rivers than in lakes.

The above observations apply to females, which predominate in most areas in Canada (male silver eels are more common in areas south of the St. Lawrence River and Gulf and along the Atlantic coast of the USA). A length threshold of 400 mm can be used to identify male silver eels (ie all silver eels below this threshold would be considered males). Males from a river in Rhode Island had a mean length of 340mm and a mean age of 11 years in one published study.

Sexual differentiation of eels is considered to be complete at 270 mm total length.

Population structure

American eel is presently considered a panmictic population throughout its range, that is, there is no detectable genetic heterogeneity among individuals or sub-groups in the population. The most recent research on genetic characteristics of the population (Wirth and Bernatchez 2003), based on sampling from several widely-separated locations within the overall distribution and on analytical techniques which have shown genetic substructure in populations of other fish species, confirmed this conclusion. Results of the genetic work are consistent with the general picture of the life cycle of the species: all mature adults spawn together in one area and larvae and juveniles from this single spawning population are the source of eels throughout the northwest Atlantic range.

However, the available information is incomplete in that samples from the Great Lakes and upper St. Lawrence, a large and important part of the range in North America, have not been included, and the sample size has been relatively low. Genetic studies including samples from previously unsampled areas are currently planned.

Recent studies pointed to the existence of a genetic mosaic in the closely-related European eel, with several identifiable spawning groups (van Ginneken and Maes 2005), confirming the need for a more extensive study on American eel genetic structure. The large variations in biological characteristics in American eel over its range (size, growth, sex ratio) are currently considered to be the result of phenotypic variations in response to environmental conditions, but could be the result of genetic variability.

Better knowledge of the genetic structure of American eel in North America is essential as a basis for management, since evidence for genetic components might mean that different management goals and actions would be required for the various components.

Biological characteristics of eels vary considerably over their range. Sex ratios vary widely with geographic location. In most Canadian waters more than 95% of sexually differentiated eels are females; in Lake Ontario and upper St. Lawrence River areas virtually all mature eels are females. Males are more common in the Nova Scotia-Bay of Fundy region: studies have shown around 7% males in the St. John River (Bay of Fundy), and 55% males in the East River (Nova Scotia), while elvers captured in the Bay of Fundy and reared in a lake on the south shore of the St. Lawrence yielded 27% males after 4 years of growth (this may not represent natural conditions). In a Rhode Island river the proportion of males has varied between 77% (1977) and 94% (1991). Studies in specific areas have suggested that high adult densities of eels are associated with higher proportions of males, and that watersheds with a higher proportion of lake habitat produce a higher proportion of males.

As noted above (*Size, age and growth*) there is also considerable geographic variability in size at maturation/outmigration and growth rate. In general eels from more northerly areas show slower growth and greater length, weight and age at migration, and a higher proportion of females.

Population status and trends[2]

American eel abundance has declined in Canada since the mid-1980's, precipitously in the upper St. Lawrence and the Great Lakes, which used to supply the largest amount of spawning escapement. The only area that has shown relative stability is the southern Gulf of St. Lawrence where mortality due to anthropogenic interaction is low. Although the reasons for the decline are not completely known, key threats have been identified. The following sections describe aspects of natural production conditions, human threats, and the extent and nature of declines in individual areas.

Habitat and environmental conditions

Given their complex life history, eels are dependent on conditions in a wide range of aquatic habitats including the open ocean, continental shelf areas, coastal and estuarine areas, and inland waters. In freshwater habitats, eels are highly plastic in their habitat use, being found in a wide range of habitat types, cover, substrate, water temperature, aquatic communities and density of predators.

Changes in environmental conditions in the Sargasso Sea and western tropical and subtropical Atlantic (Gulf Stream system) could affect eel productivity and abundance. Decreases in Gulf Stream transport have been considered unlikely to have been a major reason for declines in Canadian eel populations observed up to the early 1990's (Castonguay et al. 1994), but further decreases have been

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[2] unless otherwise noted the source for material in this section is COSEWIC (2006). Recent updates on eel science are provided in Cairns and Caron (2006)

reported since that time (Knights 2003) and the hypothesis of a link between Gulf Stream transport and eel abundance may merit further exploration. A strong negative correlation has been observed between the North Atlantic Oscillation Index (an environmental index linked with a number of recent changes in marine fish populations) and abundance indices of eels (eels passing upstream at the Moses-Saunders dam on the St. Lawrence River, eels captured in electrofishing surveys on the Miramichi River), suggesting a possible effect of changing oceanic conditions on eel recruitment to the upper St. Lawrence and Lake Ontario (COSEWIC 2006, Cairns and Caron 2006). It has also been hypothesized that warming in the Sargasso Sea may reduce food production and slow the drift of leptocephalus larvae, negatively impacting recruitment (Knights 2003).

Anthropogenic impacts

Fisheries

Fisheries for American eel have existed in Canada for centuries. The species was important to Native Americans and early settlers as a predictable, accessible food source at specific seasons and substantial harvests were taken by both groups (Casselman 2003; COSEWIC 2006). More recently eel fisheries have existed in areas throughout the range in Canada, including Ontario (Lake Ontario and upper St. Lawrence River), Québec (Lac Saint-Pierre, Lac Saint-François, Richelieu River and upper St. Lawrence estuary), the Gulf of St. Lawrence, Nova Scotia and Newfoundland (Peterson ed. 1997, COSEWIC 2006). All fisheries have been for yellow and silver eels with the exception of experimental fisheries for elvers which began in the early 1990's in Nova Scotia and Newfoundland and continue today in Nova Scotia. Restrictions on number of licences and on seasons for large eels, and on harvests for elvers, have been in place in all areas since the mid-1990's. All eel fisheries were closed in Ontario in 2004 in response to the serious decline in abundance. Fishing mortality in Québec has been reduced by the complete closure of the Richelieu River fishery in 1998 and through large-scale licence buy-back in Lake Saint Pierre (reduced from 42 to 18 licences). In the St. Lawrence estuary, a gradual decrease in fishing effort (from 34 km of tidal weirs installed in 1997 to 12 km in 2006), in response to the decreasing abundance of eel, also contributed to the catch decline. In the Maritimes Region minimum sizes have been increased and mandatory escape mechanisms in traps and holding boxes put in place, elver licences have been frozen and quotas reduced by 10%, resulting in an overall reduction in fishery removals.

Total harvests ranged between 500 and 1200 t/yr between 1961 and 2003; harvests declined from around 1100 t/yr in the late 1980's to around 500 t/yr in 2003. Unreported catches are not thought to be significant; estimates are less than 5% of reported catches in Lake Ontario and less than 8% of reported catches in the St. Lawrence.

Although fisheries have existed in many parts of the range, there are extensive areas in which no fisheries have occurred. There is no commercial fishery on the north shore of the Gulf of St. Lawrence, and most freshwater habitat in the southern Gulf of St. Lawrence, Nova Scotia and Bay of Fundy areas does not have commercial eel fisheries. Limited recreational fisheries exist in some of these areas.

Fishing mortality estimates are relatively high in the few localities where these have been made but overall fishing mortality is poorly known. Fishery removals have been estimated to be as high as 90% of yellow and silver eels in the Prince Edward Island commercial fishery. Mark-recapture estimates of annual exploitation rate in the St. Lawrence estuary were 19% in 1996 and 24% in 1997. Local captures of elvers may be substantial in terms of numbers – estimated removals were 30-50% of arriving elvers in a Nova Scotia river – but this fishery is not widespread and impact would probably be local.

Dams

Presence of dams creates potential impacts on eel populations by restricting access to upstream habitat, and in the case of those associated with hydroelecric generation, mortality in turbines during downstream passage.

In the St. Lawrence River watershed over 8,000 dams restrict access to more than 12,000 km^2 of freshwater habitat for eels, with estimated reductions in potential escapement of more than 800,000 large female eels from three tributaries alone (Verreault et al. 2004 cited in COSEWIC 2006; these figures may have changed somewhat following addition of fishways on the Richelieu and St. Lawrence). Although there are few dams potentially restricting access to eel habitat in the southern Gulf of St. Lawrence, such dams do exist in Nova Scotia, the Bay of Fundy and Newfoundland. Small eels (less than 10 cm long) have some capacity to creep up damp vertical barriers such as dam walls but larger eels are generally unable to get past large waterfalls and dams, so fishways offering unobstructed passage are required to reduce upstream passage restrictions.

Downstream passage mortality of migrating silver eels is a function of eel size (greater in larger individuals), turbine spacing, turbine type and operating conditions. Eels migrating downstream from Lake Ontario and the upper St. Lawrence are estimated to suffer at least 40% mortality due to passage through two power dams (Moses-Saunders and Beauharnois). Mortality due to downstream passage has not been estimated for other dams in Canada but could be significant. Mortality rate in small dams is probably higher than in large dams because of turbine design.

Entrainment

Although little studied to date, entrainment in water intakes (for example municipal water intakes, industrial water intakes, thermal generating stations) is a potentially significant source of eel mortality.

Chemical pollution

Eels are likely to accumulate chemical contaminants, since they are relatively long-lived, benthic, and are high in fat content favouring accumulation of lipid-soluble chemicals such as PCBs, pesticides, dioxins and furans. Eel habitats in the upper St. Lawrence and Great Lakes have been subject to high levels of chemical pollution due to industrial discharges. High summer mortalities in the upper St. Lawrence River in the early 1970s were attributed to acute toxicity from environmental contaminants. A positive relationship between chemical contaminant levels and intensity of pathological lesions has been observed in eels from the St. Lawrence, and reduced oxygen consumption in PCB loaded eels has been observed in laboratory studies. Also, at the time of gonad maturation, contaminated fat is transferred from storage tissues (mostly muscle in eels) to the gonads, so that persistent fat-soluble organic contaminants accumulate in the developing eggs and may negatively affect growth and survival of developing embryos and larvae.

Contaminant levels in Lake Ontario have decreased significantly since the 1970s and there is little evidence to suggest that chemical contaminants are currently impacting natural reproduction or health of aquatic biota in Lake Ontario. Despite the lack of evidence for specific contaminant effects on eels, sub-lethal effects of contaminants could lead to reduced physiological performance and swimming capability, which could impact the ability to make the long-distance spawning migration and could contribute to reduced recruitment.

Many rivers in the southern uplands area of Nova Scotia (southern and southeastern parts of the province) have low pH due to acid precipitation, and acidic conditions in these rivers may limit survival of American eels.

Increase in intensive agriculture in many watersheds where eels occur has led to much increased runoff of fertilizer and pesticides. The impact of this increasing source of pollution on eels is unknown but could be significant.

Introduced nematode parasite

The swim bladder nematode parasite *Anguillicola crassus* spread into Europe in shipments of Japanese eels to aquaculture sites in Germany in 1982. The parasite was first discovered in North America in South Carolina in 1995 and has subsequently been found in eels in the Chesapeake Bay, the Hudson River, Massachusetts and Maine. The parasite may be found within 40 km of the New Brunswick border. The parasite has not been found in Canada to date but its arrival may be imminent. Heavy infections can lead to hemorrhagic lesions, swim bladder shrinkage, fibrosis or collapse, skin ulceration, reduced appetite and reduced swimming performance. Given the need to make a long-distance spawning migration, reduced swimming performance could be a significant sub-lethal effect of this parasite.

Population trends

No comprehensive quantitative assessment of status of American eel in Canada is available, and assessment of overall status of the population is made difficult by the wide distribution in a range of habitats.

In 2000, the ICES Working Group on Eel compiled relevant data and attempted to conduct an overall assessment of the American eel population (ICES 2001). The WG concluded that available information was not adequate to develop an assessment or provide detailed advice for management. However, the WG did note that abundance was declining or stable across the range, recruitment was declining in the St. Lawrence system, habitat had been adversely affected in large parts of the range, and oceanographic conditions might be having a negative effect on recruitment. The Working Group advised the following:

- that there be no increased exploitation in areas where exploitation occurs, no development of fisheries in areas where there is currently no exploitation, and efforts be made to reduce human-induced mortality wherever possible
- future management would require international coordination, including an international forum where fishery scientists could exchange information and guide monitoring and research
- better information is required on catches, fishing effort, exploitation, life history parameters and demography for determination of current and sustainable exploitation rates; on carrying capacity of eel habitat; and long-term monitoring programs of recruitment and spawner output are required

Results from key abundance and population indices are described below, based on the best recent summary of population status information (COSEWIC 2006). Trends in commercial harvest are not included, as these may not accurately reflect abundance.

Nova Scotia, New Brunswick and southern Gaspé

Elver abundance in two Nova Scotia rivers (East River, Sheets Harbour 1989-2001; East River, Chester 1996-2005) have shown no long term trend, although one shows higher abundance 1999-2003 than in years before and after these years. In the southern Gulf of St. Lawrence, electrofishing surveys for juvenile eels in two rivers (Miramichi 1952-2004, Margaree 1957-2004) show declines in the late 1970’s and levels much lower than historical since then; in a third river (Restigouche 1972-2004), electrofishing shows no long-term trend. Results from electrofishing surveys in 8 rivers in Nova Scotia and New Brunswick (mid-1970’s to 2004) are difficult to interpret because of methodological variations over time and high variability in the indices; generally no trends are detectable in New Brunswick rivers (5) while declines since the late 1990s are observed in Nova Scotia rivers (3). Catch per unit effort of sublegal and legal sized eels in Prince Edward Island (1996-2004) have generally increased since the mid-1990s.

Newfoundland
Electrofishing surveys on two rivers (Highlands River 1979-1999, Northeast Brook 1984-1998) show decreased abundance in the 1990's relative to the early 1980's.

Lake Ontario/St. Lawrence River
Catch per unit effort of silver eels in two eel fishing operations in the St. Lawrence estuary (1985-2004) shows some decline from the beginning to end of the series but has been relatively stable since the mid-1990's. Catch of silver eels in an experimental trap fishery at St.-Nicolas near Québec City (1971-2004) declined from the early 1970s to the mid 1980s but has been stable or increasing since then.

Mean weight, and probably mean age, of eels taken in the St.-Nicolas experimental fishery and in the St. Lawrence estuary commercial catch has been increasing since the mid-1990s, reflecting an ageing population that has not been supplemented by new recruits. Mean weight of silver eels migrating through the Richelieu River in Québec increased 50% in the period 1987-1997, while total harvest in the eel fishery in the Richelieu River (an approximate index of abundance since effort has not varied substantially) declined from 73t/yr in 1981 to 5 t/yr in recent years. This abrupt decline in recruitment to Lake Champlain was probably partly related to rebuilding in the 1960s of two dams on the Richelieu River (Saint-Ours and Chambly)(Verdon et al. 2003). The fishery was closed in 1988. Eel ladders were retrofitted at Chambly (1997) and Saint-Ours (2001) and efficiency is high. However, as elsewhere in the St. Lawrence watershed, the number of small eels ascending the river is still very low. In recent years upstream migrants have been 3,500 or less, while to support historical landings (around 35 t annually), hundreds of thousands of migrants per year would have been necessary.

Number of yellow eels migrating upstream past the Moses-Saunders dam near Cornwall, Ontario (1974-2004) have declined by three orders of magnitude over the past 20 years, from around 1 million per year in the early 1980s to fewer than 15,000 per year during the past decade. Trawl catch per unit effort of yellow eels in the Bay of Quinte, Lake Ontario (1972-2004) and an electrofishing index in eastern Lake Ontario (1984-2004) have also declined by 1-2 orders of magnitude to near 0 between the 1980s and the recent past.

Mean age of upstream migrants at the Moses-Saunders dam increased from about 6 years in 1975 to about 12 years in the 1990s.

Summary
In Lake Ontario, the area furthest from the sea, abundance of American eel has apparently collapsed and mean size of individuals has increased substantially, consistent with a decline in recruitment.   There has also been a severe decline in the Richelieu River/Lake Champlain system as measured by fishery catches, an increase in mean length, and low upstream migration in recent years. In the St. Lawrence estuary there are indications of increasing size in recent years but not of a catastrophic decline as in Lake Ontario; abundance indices show relative stability in recent years after declines in the 1980s.   In the Atlantic region indices are more variable and show conflicting trends; many areas show declines in abundance, others show relative stability or even recent increases in abundance.

Although the North American population is apparently genetically homogeneous, there is considerable variation in biological characteristics over the geographic range which must be considered in assessing overall status. The fact that the largest eels, almost exclusively females, have undergone catastrophic decline in Lake Ontario and the upper St. Lawrence suggests that population fecundity may have been heavily affected by the decline in that area.   Estimates of the relative contribution of watersheds to population fecundity are based on large, untestable assumptions, but it is clear that the St. Lawrence drainage contributed a substantial proportion of total spawners to the spawning population.

Information on abundance of American eel in the United States is similarly fragmentary and subject to uncertainties, but there is significant concern about population status (Haro et al. 2002), and a petition to list the species under the US Endangered Species Act was submitted in 2004 (http://www.fws.gov/northeast/ameel/).   Populations of the closely related European eel have declined substantially in Europe, where yellow eel abundance indices have declined by approximately an order of magnitude since the 1950s (ICES 2004).

Although the available indices cannot be combined into a quantitative assessment of the overall population, they are consistent with a substantial overall decline due to reduced recruitment, and reduction of the area of distribution with reduction in abundance. Relative stability in abundance indices in areas closer to the population centre (Atlantic Canada and St. Lawrence estuary) and decline in peripheral areas (Lake Ontario/upper St. Lawrence), such as observed since the early 1980's, would be consistent with this scenario.   An alternative scenario would be that some unknown environmental factor is reducing recruitment to Lake Ontario/upper St. Lawrence, while other areas are receiving "normal" recruitment; however there is no evidence for this.   Despite the uncertainties, all recent assessments of the status of American eel in Canada agree that there is strong evidence for significant overall population decline (Anon. 2003; Casselman 2003; COSEWIC 2006; Haro et al. 2000).

Although causes of the population decline cannot be determined unequivocally (Casselman 2003; Haro et al. 2000; COSEWIC 2006), the most recent work (summarized in Cairns and Caron 2006) points to fishing, dams and contaminants as the factors most likely to have contributed to declining abundance of spawners and declining recruitment in the past 2-3 decades. Mortality due to some sources (fishing, dams in the upper St. Lawrence) is known and has been substantial.

Management issues and recent actions

The management challenge

American eel poses difficult challenges to management agencies. The species is very widely distributed and is considered a single shared population in North America, so protection of spawning potential requires widespread cooperative work. Because of phenotypic variation, some areas (ie those where large females are concentrated) may be particularly important to maintenance of the spawning population and may require particular management attention. Even if genetic subcomponents were identified within the North American population, a combination of management measures across the entire range and attention to specific areas and issues would be required. American eel is subject to a wide range of threats in essentially all aquatic habitats in eastern North America, including habitat and fishery threats, and is also subject to fluctuations in conditions in ocean and freshwater environments. Mitigation of threats would require substantial modifications to important human activities including hydroelectric production, urban and industrial development, and fisheries. Jurisdictional responsibility for management of these activities is fragmented, including federal, provincial/state, and municipal authorities in Canada and the USA. Finally, there are many uncertainties about population and threat assessment: overall status of the population cannot be accurately assessed or forecasted with current information, relative importance of threats and relative impact of mitigation measures are not fully known, and the relative contribution of natural environmental changes and human impacts is not well known.

Despite the uncertainties and gaps in knowledge, enough is known about status of eel in Canada to justify urgent, robust management action. Mortality due to some key threats is known (fisheries and dams in the upper St. Lawrence) and there have been catastrophic abundance declines in areas which contribute significantly to spawning potential. A precautionary approach to prevent irreparable harm to the population in the face of uncertainty is the appropriate approach to management, consistent with the Government of Canada’s policy on implementing the precautionary principle (Government of Canada 2003). .

Regulatory basis for American eel conservation and management in Canada

Canada's federal government has responsibility for conservation and management of fisheries and fish habitat under Canada's Constitution, while provincial governments have responsibility for fish as "property" once harvested. The principal basis for conservation and management of aquatic species is the federal *Fisheries Act,* under which the federal Minister of Fisheries and Oceans can manage fisheries, prohibit the killing of fish by means other than fishing, and prohibit damage to fish habitat by physical alteration or chemical pollution. Under agreements between the federal government and some provincial governments, the latter are responsible for administration of fisheries management provisions of the *Fisheries Act*; governments of Ontario and Québec have responsibilities for management of eel fisheries under such arrangements. The Department of Fisheries and Oceans has delegated to Environment Canada delivery of the *Fisheries Act* provisions relative to chemical impacts on fish habitat. Provincial legislation also provides for protection of species, including species at risk, and habitats.

As a result of these responsibilities and arrangements, conservation and management of American eel requires cooperative work by a wide range of government agencies:

- the Department of Fisheries and Oceans for overall leadership, managing *Fisheries Act* provisions for: fishways, obstructions to fish passage and fish guards; authorizing the destruction of fish; fish habitat protection; and for fisheries management in the Atlantic provinces.
- the governments of Ontario and Québec for fisheries management, and for fish and habitats under provincial legislation
- Environment Canada for the pollution prevention provisions of the *Fisheries Act*.

Under recent legislation (the *Species at Risk Act,* 2003) the federal Minister of Fisheries and Oceans is responsible for protection and recovery of listed extirpated, endangered, threatened and special concern aquatic species. American eel was designated Special Concern by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) in April 2006 but no decision on adding the list to Schedule 1 of the Species at Risk Act has yet been made.

The federal government has lead responsibility for international relations in Canada. The Department of Fisheries and Oceans leads international cooperative activities related to fisheries and oceans, such as would be required to ensure international cooperation on American eel conservation and management.

Although the federal government may have an overall coordinating role in activities mentioned above, participation by all jurisdictions is essential. Provinces are actively involved in aquatic species at risk protection and recovery and in international fisheries forums and such involvement would be essential in the case of American eel.

Institutional and governance issues

Given the wide distribution of American eel, actions by a single jurisdiction, agency or enterprise will have limited effectiveness unless they are part of an overall plan. A number of cooperative mechanisms are in place for eel conservation and management, but none covers the full range of areas and threats relevant to the species.

Within Canada two interjurisdictional groups have recently been established to coordinate eel management actions: the Canadian Eel Working Group (CEWG), which includes governments of Canada (DFO), Ontario (Ministry of Natural Resources) and Québec (Ministère des Ressources naturelles et de la Faune) and the Eel Task Group of the Atlantic Council of Fisheries and Aquaculture Ministers (ACFAM) which includes Canada, Québec, and the Atlantic provinces. The CEWG has 4 working groups on specific issues: Canadian Eel Science Working Group (CESWoG); Fisheries Managers; International Issues; and a Steering Committee on Passage and Related Habitat Issues in the St. Lawrence. Neither fully covers distribution of American eel since Atlantic areas are not included on the CEWG, and Ontario is not included on the ACFAM Task Group.

The Canadian Eel Science Working Group (CESWoG) held its first meeting in December 2003. Membership is from governments of Ontario and Québec and from Department of Fisheries and Oceans, including scientists from all DFO regions in eastern Canada, and specialists from non-government agencies may be invited. The CESWoG provides scientific support to the CEWG and to jurisdictions responsible for eel management.

The Committee on Eel Passage and Related Habitat Issues in the St. Lawrence River conducted a Decision Analysis to identify priority management actions to reduce mortality from dams in the Lake Ontario/upper St. Lawrence area. This Committee, established under the CEWG, includes representatives of power generation companies as well as agency representatives.

Internationally, the Great Lakes Fisheries Commission (GLFC) has recently established an American Eel Working Group under its Council of Lake Committees to foster international cooperation for eel conservation and management in the Great Lakes and St. Lawrence watershed. Québec government representatives are included in this WG although Québec is not a member of the GLFC. The Working Group has initiated development of an international action plan for American eel in its area of responsibility. In the USA the Atlantic States Marine Fisheries Commission (ASMFC) is responsible for interstate cooperation on eel fishery management, but has a limited role in managing habitat issues.

The International Council for the Exploration of the Seas (ICES), of which Canada and the US are members, provides a forum for international cooperation in eel science, but its focus has primarily been on European eel to date (although advice on American eel was provided in 2002).

In summary, despite recent developments, there is presently no interjurisdictional forum in Canada which includes all jurisdictions with an interest in eel management and covers all relevant issues (fisheries, habitat, science), nor is there an international forum to coordinate Canada-US actions relative to the eel population as a whole.

Scientific knowledge

Scientific information plays a key role in conservation and management of aquatic species. Information on many aspects of American eel biology in relation to anthropogenic threats exists, although there are gaps and uncertainties in the information.

Information is available on basic life history and distribution, abundance trends and mortality in specific areas, impact of habitat restrictions on production of spawners in specific areas, relationship of specific environmental indices to abundance trends at specific localities, and on age, growth and maturation in specific areas.

Key uncertainties lie in the following areas:

- genetic structure of the overall population
- a complete picture of age, growth, maturation and related life history parameters, covering all representative habitats, such that an “average” or “typical” picture of the eel population can be built.
- a complete picture of mortality due to the various threats. In particular information on downstream passage mortality due to dams throughout the range, and fishery mortality overall is needed. Currently information is available on passage mortality at two large dams, and mortality estimates are available from some fisheries
- impact of habitat degradation, in particular blockage of upstream passage, on abundance of spawners, throughout the range.
- relative contributions of spawners originating in different parts of the range to overall spawning abundance and recruitment
- sublethal effects of pollution and parasites, in particular on swimming performance (relative to the requirement to make the long spawning migration).
- possible effects of environmental changes on recruitment and production, notably considering recent information on reductions in Gulf Stream transport
- based on a compilation of the above information, a population model allowing assessment of increased or decreased mortality at specific points in the life history on overall abundance and on recruitment

Obtaining the information necessary to build a complete picture of the American eel population would be a long-term proposition requiring interjurisdictional and international cooperation.

Given the uncertainties, what **is** known about mortality from some sources, and the apparently substantial decline in recruitment and in overall abundance, precautionary action to minimize the risk of irreversible harm is called for, consistent with the Government of Canada's policy on implementing the precautionary principle (Government of Canada 2003). Action is required to ensure that abundance is maintained in all parts of the range in Canada, given the geographic variability in biological characteristics and the potential for specific areas to contribute disproportionately to spawning biomass or other important population characteristics.

Recent management initiatives

A number of management measures have been initiated in response to concerns about population status.

In 2004 the Minister of Fisheries and Oceans announced a goal of reducing eel mortality by 50% within 2 years and called on stakeholders and jurisdictions to take the necessary measures to reach this goal. The CESWoG had earlier (December 2003) recommended an immediate 50% reduction in anthropogenic mortality relative to the average of the previous 5 years.

In 2005 the Planning and Implementation Task Group (PITG), with membership from government agencies and stakeholder groups from Canadian and US jurisdictions in the Lake Ontario/upper St. Lawrence area, developed a "Decision Analysis" aimed at identifying the key threats to American eel in this area and best short-term and long-term measures to address these threats (Greig et al. 2006). Short-term measures included stocking to maintain depleted populations, reducing fishing mortality, research into means of reducing downstream passage mortality, and basic research to improve population information; long-term measures included trapping eels upstream of dams and transporting them downstream, and research into effective dam bypass mechanisms. Installation of a grid on the water intake at a small hydro dam on the Rimouski River, Québec, has reduced mortalities at this installation.

Stocking began in 2001 and has intensified in 2005 and 2006, with elvers and bootlace eels from Atlantic Canada stocked into the Richelieu River and Lake Ontario. Funding support for stocking has been provided by power generation companies and provincial governments.

Commercial fisheries for American eel were closed in Ontario in 2004, recreational fisheries in 2005. In Québec, fishery removals in the St. Lawrence have been reduced over the past two years by licence retirement and the Richelieu River fishery was closed in 2000. In the southern Gulf significant reductions in fishing mortality were achieved with the implementation of severe effort and other management measures beginning in 1998. These measures led to the termination of eel fishery in the Gulf sector of Nova Scotia. They contributed to increasing spawning escapement. In Maritimes Region the minimum retention size was increased to 35 cm total length and escape mechanisms became mandatory on all fishing gear and holding boxes in 2005. Elver licences were frozen at existing levels, quotas were reduced by 10%, and the option for licence holders to apply for a 30% quota increase was removed. The 10% reduced quota can be fished if the elvers are destined for conservation stocking in Canadian waters.

Negotiations with power companies in Ontario and Québec are under way to finalize an overall plan to address dam-related mortalities. One option under such an agreement would be further reductions in Québec fishery removals over the next 5 years through a combination of licence and harvest buyback.

Research on population dynamics, trap and transport methods, and monitoring continues.

Guiding principles

Management of American eel in Canada will be guided by the following principles:

- *Application of the precautionary principle: absence of scientific certainty will not be considered a reason not to take action*
- *Long-term sustainability of American eel in Canada is the ultimate goal*
- *No further loss in habitat for American eel, and a net gain in habitat through management action*
- *Conservation and management will be guided by the Canadian Biodiversity Strategy*
- *Agencies and organizations responsible for American eel conservation and management will work in active partnership to ensure that management objectives are met*

Long-term management goal

Rebuild overall abundance of American eel in Canada to its level in the mid-1980's, as measured by the key available abundance indices, in particular

- *Ensure presence of American eel in all areas throughout its historic distribution*
- *Sustainable fisheries for elvers and large eels are producing economic benefits for fishermen in all areas where fisheries were historically present*

Short-term management goal

Reduce eel mortality from all sources by 50% relative to the 1997-2002 average

Background and rationale. Although there are gaps and uncertainties in our knowledge of the threats to eels, enough is known to justify urgent, robust action to halt the abundance decline and to rebuild the population. Concrete steps forward are needed while gaps in knowledge are being filled in. Action must be taken quickly to "get ahead of the curve" of declining abundance.

Mortality due to fisheries and to dams in the upper St. Lawrence is relatively well known, and has been significant. Catastrophic declines in abundance have occurred in areas which contribute a significant proportion of spawners to the total population (Lake Ontario/upper St. Lawrence). While some actions have been taken to reduce or offset mortality from known sources, further reductions are necessary. Attaining a 50% reduction will be challenging, particularly given the difficulties of reducing impacts of dams in the short term, but as has been shown by the 2006 Decision Analysis on dam impacts in the upper St. Lawrence, creative approaches to overall reduction in mortality can be developed. This plan sets further actions with a focus on reducing mortality due to the two known and significant sources (fishing, dams and turbines) while continuing to identify and establish mitigating actions for other sources of mortality.

An immediate reduction in mortality of 50% was recommended by the Canadian Eel Science Working Group in 2003 and the Minister of Fisheries and Oceans called for a 50% reduction over two years in 2004. Although this goal has not been reached, it remains a clear statement of what must be done in the short term to reverse abundance declines and set the stage for population rebuilding.

Specific objectives and actions

Objective 1. Develop a detailed implementation plan, based on Identifying priority actions, for reducing eel mortality from all sources by 50%

Background. Although some actions to address mortality from fisheries and dams in the upper St. Lawrence have been identified and taken, further actions are required to reduce mortality from these two significant sources. In addition, identification of priority actions to be taken with respect to all threats over the Canadian range of eel is still necessary. A “decision analysis” approach, as used to identify priority actions to reduce or offset eel mortality from dams in the upper St. Lawrence region (Greig et al. 2006), could be a good approach to identifying priority actions for reducing eel mortality throughout the Canadian distribution. Conducting a formal analysis to establish priorities could also help to formalize the baseline for the 50% mortality reduction objective.

Actions

- Clarify the meaning of the 50% goal. Specify whether mortality in numbers or mortality rate is the target; establish and quantify the baseline (if 1997-2002 as recommended by CESWoG, provide the numbers); specify the timeframe to meet the 50% reduction; establish the relative importance of targeting the reduction on silver eels and large yellow eels
- Focus on further reductions and offsets in mortality from the two known and significant sources (fishing across the Canadian range, and the two dams on the St. Lawrence River)

- Evaluate the relative importance of threats by areas. The Freshwater Ecological Areas (FEAs) defined in the COSEWIC Status Report could be a good basis for such an assessment.
- Identify the potential for additional gains to achieve 50% reductions in mortality in the various sectors (fishing, habitat, dams/turbines, pollution etc). Ensure that all sources of mortality are identified and managed, including those not addressed to date such as entrainment (industrial and municipal water intakes) and increased predation on eels concentrated below dams.
- Identify and recommend agreed priority short-term and longer-term actions to be taken to ensure that the goal of reducing mortality from all sources by 50% is met
- Evaluate the effectiveness of management actions in reducing mortality to date and on an ongoing basis (annually) in future.

Implementation notes. Selection of participants for conducting the analysis would be key to ensuring success, since the outcome depends on who participates. Given the need to have a manageable number of participants, one option might be to conduct decision analyses for specific sub-sectors (for example fisheries management; dams in areas other than the upper St. Lawrence) as modules and conduct a final wrap-up to summarize actions in the various modules and cross-cutting issues.

Objective 2. Achieve a net gain in abundance and escapement by ensuring access to and passage from quality habitats:

- *ensure no net loss of habitat from new structures*
- *ensure a net gain in habitat through modifications to existing structures; specifically, provide upstream and downstream passage to an additional 10% of lost eel habitat in each jurisdiction every 5 years*
- *continue action to reduce contaminant and pollution impacts*

Background. New and existing obstructions present different challenges and opportunities for achieving gains in habitat for eels, with much greater scope for action at new facilities. Work on reducing impacts of dams must take into account different dam types and location: smaller hydro dams tend to have larger turbine mortality rates than larger dams, while many dams restricting access to eel habitat are not for power generation and accordingly do not cause turbine mortality. Although dams have received most attention to date, many other types of obstructions and human activities impact eel habitat (causeways, culverts, road construction, municipal development, wetland destruction) and these must be taken into account in improving eel habitats.

Information on the lethal and sub-lethal impacts of contaminants on eels, at all life stages, is far from complete. There has been considerable progress in reducing contaminant levels in waters inhabited by eels since the 1970s, but new sources of contaminants (new generations of chemicals) and pollution (agricultural runoff) are of concern, as are continued impacts of existing contaminants and pollutants such as acid precipitation.

Actions – no net loss from new facilities

- Use existing provincial and federal regulatory review processes for new projects to only allow projects which include upstream and downstream passage facilities
- Implement a moratorium on dam construction which would have negative impacts on eel in key habitats
- Work with the hydro industry to develop engineering solutions for future construction such as low-mortality turbines, downstream fish passage devices, etc.

Actions – net gain at existing facilities

- Set priorities for habitat work in each of the river systems, based on an inventory of potential eel habitat and existing dam and other structures throughout the eel's range in Canada (decision analysis and decision support tool)
- Remove dams and other obstructions that are no longer required, based on the priority-setting system
- Identify and recommend priority dam sites for which upstream eel passage should be established and considered for implementation under provisions of the *Fisheries Act*
- Conduct coordinated bi-national national research aimed at improving trap and transport technologies and bypass systems to provide safe downstream passage
- Work with the hydro industry to develop engineering solutions for existing structures such as low-mortality turbines, downstream fish passage devices, etc.
- Ensure that research and monitoring programs are in place to establish baseline levels of mortality and to monitor reductions in mortality from measures put in place

Actions – contaminants and pollution

- Control entry of point-source (industrial, domestic) and non-point source (agriculture, forestry spraying, road maintenance, long-range transport) contaminants and pollutants which can impact eels
- Coordinate actions with agencies responsible for contaminant and pollutant regulation and with other regulatory strategies (drinking water, species at risk programs etc)
- Ensure that homologation of new chemicals (for example via Canadian Environmental Protection Act) addresses requirements of eels
- Continue research on impacts of contaminants on eels

Implementation notes. Setting priorities for action to improve habitats for eels is a central theme for actions to meet this objective, although as noted above (short-term goal) action is needed now while new information to guide activities is being developed. The “decision analysis” (objective 1) would be an important first step in setting priorities. Preliminary analysis suggests that action to reduce downstream passage mortality might have a more immediate effect at small dams than at large dams (techniques to reduce turbine mortality are available for small dams but not for large dams), and at new facilities than at existing facilities. The two large existing dams on the St. Lawrence River are know to kill a substantial number of mature female eels during their downstream migration and must be included in management programs. Similarly, action to increase upstream passage may have a more immediate effect when there is substantial good-quality habitat above the obstruction and when the likelihood of downstream passage mortality is low. Ensuring that the most important sources of mortality are addressed across the Canadian range of eel will require development of a decision support tool, based on compiling and making available information on eel habitat and distribution of obstructions (see objective 4 below).

Relatively little is known about the effect of contaminants on eel survival, and reducing impacts of contaminants and pollution requires action by organizations with no specific responsibilities for eel management but with responsibilities for regulation and management of chemical discharges in Canada (for example Environment Canada). The actions identified require that responsible agencies and their responsibilities be identified, and that there be close collaboration among all responsible organizations to ensure that regulatory programs take account of the requirements of eels.

Objective 3. Ensure that mortality due to fisheries is consistent with the overall goal of reducing mortality from all sources by 50%

Background. Over the past 3 years measures have been put in place to reduce mortality from fishing: all fisheries in Ontario have been closed, numbers of licences have been reduced in Québec (licence reduction in Lake Saint Pierre and complete closure of the Richelieu River fishery), and limits on minimum sizes and fishing seasons for large eels and on harvest levels for elvers have been put in place in Atlantic Canada. Fishermen have experienced losses of income as a result of these measures.

Identifying additional fishery management measures to reduce mortality will be essential to ensure that fisheries are managed such as to contribute to meeting the overall goal of reducing mortality by 50%.

Accurate catch and effort information from fishermen is essential for understanding fishery mortality and trends in abundance (catch per unit effort indices). Mandatory logbook systems to report catch and effort have been put in place in most eel fisheries in recent years; these need to be maintained and where necessary strengthened. Data from all jurisdictions managing fisheries (DFO, Ontario, Québec) should be in a standard format and easily accessible.

Actions

- identify and recommend additional management measures to reduce fishery mortality, using the "decision analysis" or through other means
- put in place a standardized, mandatory reporting system for catch, effort and location within 3 years, including a requirement to report nil catches, for all areas with eel fisheries (elvers and large eels)
- put in place a national repository for catch and effort data with access to data from DFO, Ontario and Québec
- develop an education program for fishermen emphasizing their accountability for providing accurate catch and effort information
- explore the potential to include data from buyers in the system for verification of catches (possible use of *Fisheries Act* Sec 61)

Objective 4. Develop a decision support tool for identifying and prioritizing actions to improve habitat for eels

Background. Setting priorities for action to improve eel habitats – ie identifying interventions which will have the greatest impact for a given level of effort -- is essential to ensure that management is effective. Initially the "decision analysis" (objective 1) should identify priority habitat actions, but in the longer term it will be necessary to develop and maintain comprehensive, easily accessible information to guide priority actions.

Considerable information exists on distribution of eel habitat and on distribution of habitat impacts such as dams and other obstructions, but the information must be compiled and made available in a form that is easily usable by managers and interested parties. Information on other habitat impacts such as contaminants, pollution, and lesser-known human activities such as entrainment is not as complete as for obstructions, and further studies are needed to improve knowledge of these impacts. Information should be compiled and organized in a "decision support tool" which is easily accessible by field biologists and managers responsible for authorizing projects which impact eel habitat. The decision support tool would essentially identify obstructions and sources of downstream mortality (ranked by relative importance), mapped on historical and present eel distribution, in such a way that priorities for mitigation of impacts and restoration of habitat were clear.

Actions

- Conduct a GIS-based inventory of historic and present eel habitat based on watershed carrying capacity, to identify target watersheds for action
- Include in the GIS-based system an inventory and mapping of obstructions (dams and others), ranked by their importance in impeding access to eel habitat and causing eel mortality (hydro vs non-hydro etc)
- Improve knowledge of eel habitat requirements in marine and freshwater environments, particularly with respect to carrying capacity, and incorporate results in habitat inventory

- Improve knowledge of impacts of contaminants, pollution, entrainment and other lesser-known habitat impacts on eels

Implementation notes. The actions identified relate to both development of new information and compilation of existing information into easily accessible forms. Considerable time and effort would be required to develop a functioning, comprehensive decision support tool, and it will be important to continue to take interim management action based on available information as the components of the decision support tool are put into place.

With respect to entrainment (for example at municipal and industrial water intakes, thermal generating stations), better understanding and quantification of impacts would help to resolve an important uncertainty in understanding threats to eel. Both field studies of impacts and mapping of facilities which might impact eels is required.

Objective 5. Maintain and, where required, develop fishery-independent abundance indices.

Background. Long-term abundance indices (for example electrofishing and trawl indices, ladder passage indices at dams, fishery catch per unit) are essential to understanding status and trends of American eel. Indices track abundance of specific life stages in particular areas. Maintaining current indices is essential but can be challenging; for example the index at the Moses-Saunders dam will be affected by construction of a second ladder for eel passage, and maintenance of electrofishing indices is costly and affected by priorities for the target species, Atlantic salmon. Current indices are limited in geographic scope (essentially only 3-4 indices exist which allow tracking long-term changes), and broader coverage would provide a more complete picture of abundance of the overall population and would provide back-up in case maintenance of existing indices is threatened.

Actions. The Canadian Eel Science Working Group (CESWoG) is developing a series of priority research activities which includes maintenance and development of abundance indices (Cairns and Caron 2006). This work should provide the basis for identifying and recommending new indices to be put in place, and maintenance and recalibration of existing indices.

Objective 6. Ensure presence of eels in areas where abundance has collapsed by stocking young eels

Background. With eels showing catastrophic declines in areas where they were formerly abundant, one possible strategy for ensuring presence of the species throughout its natural range is stocking of young individuals. Although superficially attractive, stocking is subject to many risks and uncertainties, and should be considered a short-term measure pending rebuilding of abundance from natural recruitment. Risks and uncertainties include (1) conservation implications to donor populations (2) genetic conservation risks (if the North American eel population is not panmixic) (3) parasite/disease transfer (4) potentially negative interactions with natural migrants (5) potential to alter sex ratios in receiving waterbodies and (6) concerns that stocked individuals will not migrate or spawn successfully

Stocking of young European eels (elvers) has proven to be successful in support of fisheries production in Europe, but stocking for conservation purposes (ie to support return of adults to the spawning grounds, spawning and production of recruits) in North America has not yet been shown to be successful. The proportion of eels stocked from a distant area surviving to adulthood is unknown (although a high proportion survived in the only trial to date, in Lac Morin, Québec), and it is not certain that the adults which do survive will successfully migrate to the oceanic spawning area and spawn successfully. Any transfer of fish from one area to another involves risks of introducing diseases, parasites, or "fellow-travellers" (non-target species). Stocking density may be critical to maintaining the high proportion of females in Lake Ontario and the upper St. Lawrence, since eels maturing at lower densities apparently produce a higher proportion of females.

Young eels have been stocked on several occasions in recent years. In 1999 40,000 elvers (mean length 6 cm) were marked with tetracycline and released in Lake Morin (4 km^2) on the south shore of the St. Lawrence estuary. In May 2005 (600,000 elvers) and May 2006 (1,000,000 elvers) elvers were transferred to the upper Richelieu River. In October 2006 144,000 "bootlace eels" (ca. 10 cm in length) were stocked into Lake Ontario's Thousand Islands region. These juveniles were reared from elvers to bootlace size in commercial holding facilities, in part to help assess risks of disease and parasite transfer. Risk analyses for the transfers (diseases, parasites) were conducted following the Canadian Code on Introductions and Transfers of Aquatic Organisms. Young eels for these transfers came from quota-managed elver fisheries in Canada's Atlantic region, from acid-impacted rivers in which they would probably not have survived to adulthood. Tetracycline marks were incorporated into otoliths to allow for identification of individuals caught later in life.

Actions:

- develop guidelines for a conservation stocking program in Canadian waters, covering such elements as: objectives, desired outcomes, and end-points for stocking programs; best sizes for stocking; marking protocols; stocking densities; optimal areas for stocking; measures to monitor success of stocking. Development of guidelines could be based on consultations with European experts, one or more workshops, and/or development of a "white paper" on state of the art.
- develop guidelines to protect donor stocks
- continue interim stocking actions as and when possible, using existing information and introductions and transfers protocols, considering these as experimental

- develop a stocking program based on agreed guidelines and stable funding to ensure presence of eels in areas where abundance has collapsed

Objective 7. Develop a binational management plan

Background. Integrating management actions and science activities across the entire distribution of American eel in North America would be necessary to ensure protection and recovery of the species. Development of a Canada-wide plan addressing all threats (the current Management Plan and follow-up implementation plan) will be a good first step. Developing a binational plan would help improve Canada-US communication and coordination on eel issues, bring together the various multijurisdictional initiatives (ASMFC, GLFC, CEWG etc), and support development of a binational Commission or similar mechanism for eel management.

Actions

- Initiate discussions between Canadian and US agencies on a binational management plan
- Complete a binational management plan

Implementation notes. The Canadian Eel Working Group (CEWG) with its four working groups has proved to be a good mechanism for coordinating eel conservation and management action in Canada, and should continue to be the primary forum for developing and implementing coordinated management action in Canada. CEWG and its working groups have a role in annual (or regular) work planning and monitoring of progress as well as in developing a strategic management plan.

Objective 8. Explore setting up a binational Commission for eel conservation and management

Background. A permanent mechanism for binational coordination of eel conservation and management activities, covering the entire range of issues (fisheries, habitat, science) would provide strong support for protection and recovery of the species. Adapting existing mechanisms to cover eels has been considered, but does not appear possible: for example the North Atlantic Salmon Commission is unlikely to agree to broaden its scope to include other species, and the Trans-boundary Resource Assessment Committee covers marine species of the Georges Bank area, and has a science rather than a management role. At least one binational eel conservation mechanism has been set up, the Great Lakes Fishery Commission’s Eel Task Group, but this does not cover the entire range of jurisdictions and interests.

The Commission model has worked well for a range of binational (Great Lakes fisheries, boundary waters) and international aquatic conservation issues. Scope of an “eel Commission” would have to be explored: options range from focusing on a single high-priority issue such as dam passage in the beginning, to including other cross-border diadromous species which face a similar threat environment (sturgeons, shad, striped bass, gaspareau).

Actions

- Develop costed options for an "eel Commission" based on current knowledge of international fisheries governance mechanisms
- Initiate discussions between relevant Canadian and US jurisdictions on setting up a Commission, led by the Canadian Eel Working Group for Canada
- If discussions conclude that a Commission is desirable, develop a proposal for consideration by authorities in Canada and the USA.

Implementation notes. Cost will be a key consideration in developing a proposal for an "eel Commission". A "bare bones" approach is probably appropriate to ensure that actions remain well-focused and resources are well used. An upcoming book on fisheries governance to be published by the American Fisheries Society may be a good source of information for developing an "eel Commission" proposal.

Cross-cutting issues and implementation strategies

The focus of eel conservation and management efforts should be on ensuring spawning escapement levels (silver eels) necessary to support future recruitment and population abundance. Escapement is currently difficult to quantify population-wide but is the parameter of ultimate importance. Geographic variation in spawner production must be recognized in managing the population; production of large females in the upper St. Lawrence/Lake Ontario region is probably very important, but spawner production in other areas must also be considered.

Resolving uncertainties through science programs will continue to be an important part of eel management, and coordination within the science community and between scientists and managers will be essential to eel conservation and management. CESWoG has proved to be an effective mechanism for coordinating eel science in Canada. Enhanced interactions between biological scientists and physical scientists (geomorphologists, engineers) would contribute to designing engineering solutions to habitat problems such as dam passage. Interactions between eel scientists and managers are contributing to design of management strategies, and structured interactions should continue. A number of studies to resolve key uncertainties have been identified by CESWoG, and it will be important to have a clear sense of priorities for science work to ensure that resources are used effectively. Potential funding sources exist which should be explored for additional support for eel science. Coordination of science work throughout the North American distribution of eel would help to ensure that resources are used to best effect, to maximize leverage of funding from different sources, and to ensure that eel scientists learn rapidly from results in other areas. The "Commission" approach would help to ensure broad coordination of science.

The Canadian Eel Working Group (CEWG), with its associated working groups, has proven to be an effective mechanism for management coordination in Canada, and should continue to have the lead role in finalizing and implementing this Management Plan.

References

Anon. 2003. Québec Declaration of Concern. Fisheries 18(12) 28-30.

Cairns, D. and F. Caron 2006 in press. Third meeting of the Canadian Eel Science Working Group. Can. Sci. Adv. Secretariat Proceedings 2006.

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

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.

Fishbase, a global information system on fishes. www.fishbase.org/home.htm

Government of Canada 2003. A Framework for the Application of Precaution in Science-based Decision Making about Risk 13 pp. (available at http://www.pco-bcp.gc.ca/docs/Publications/precaution/precaution_e.pdf)

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, ON, for Hydro Quebec, Fisheries and Oceans Canada, Ontario Ministry of Natural Resources, Ontario Power Generation, and the US Fish & Wildlife Service, on behalf of the Passage and Associated Habitat Subcommittee of the Canadian Eel Working Group. 153 pp.

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

ICES 2001. Report of the ICES/EIFAC Working Group on Eels. ICES CM 2001/ACFM03: 91 pp.

ICES 2004. Report of the ICES/EIFAC Working Group on Eels (WGEEL). ICES CM 2005/I:01, Ref G, ACFM: 184 pp.

Knights, B. 2003. A review of the possible impacts of long-term oceanic and climate changes and fishing mortality on recruitment of anguillid eels of the Northern Hemisphere. Science of the Total Environment 310: 237-244.

Peterson, R. H. (ed) 1997. The American eel in eastern Canada: stock status and management strategies. Proceedings of Eel Workshop, January 13-14, 1997, Québec City, QC. Can. Tech. Rep. Fish. Aquat. Sci. 2196: v + 174 pp.

van Ginneken, V.J.T. 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.

Verdon, R., D. Desrochers, and P. Dumont. 2003. Recruitment of American eels in the Richelieu River and Lake Champlain: provision of upstream passage as a regional-scale solution to a large-scale problem. D. A. Dixon, ed., Biology, Management and Protection of Catadromous Eels. American Fisheries Society Symposium 33: 125-138.

Wirth, T and L. Bernatchez 2003. Decline of North Atlantic eels: a fatal synergy? Proc. R. Soc. Lond. B 270: 681-688.