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2010 Update on the status and progress on management goals for American Eel in Ontario

Mise à jour de 2010 sur l'état et les progrès en matière d'objectifs de gestion de l'anguille d'Amérique en Ontario

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ABSTRACT

American Eel recruitment to Ontario waters has declined by approximately 97% since the early 1980s. Two fisheries-independent yellow eel abundance indices show similar declines over the same timeframe. The American Eel is identified as an Endangered Species under Ontario's *Endangered Species Act* (ESA) 2007, which prohibits the killing, harming, harassing, possessing, buying, selling, trading, leasing or transporting of this species. In 2005, the Canadian Eel Steering Committee for Downstream Passage and Habitat Issues developed a "Decision Analysis" aimed at developing mitigation measures to increase the number of eels migrating out of the St. Lawrence River (SLR). Ontario commercial eel fisheries were closed in 2004 and the recreational fishery for eels was closed in 2005. A yellow eel trap and transport pilot project was initiated in 2008 as part of the Ontario Power Generation Action Plan for offsetting turbine mortality of American Eel at the Saunders GS on the SLR. Large eels, >800 mm, captured as by-catch from existing multi-species commercial fisheries in Lake Ontario and SLR were transported around the two generating stations or released back into SLR. Between 2008 and 2010, over 3,000 eels have been transferred downstream of all barriers to facilitate safe downstream migration. Preliminary results suggest that some of these fish do migrate out of the SLR successfully, however it seems unlikely that the numbers of eel transported can be increased significantly with the current approach to capturing them. Moreover stocking with glass eels and elvers from Atlantic Canada began in 2006 as a means of maintaining the presence of eels in these waters. Approximately 4 million eels have been stocked into Lake Ontario and the SLR. Stocked eels appear to be surviving well, growing rapidly and distributing from the stockings sites, however it is not yet known if these stocked eels will contribute to the spawning stock. Estimates indicate that eel mortality in Ontario have been reduced by more than 50% relative to the 1997 to 2002 reference point. This decline can be attributed to the closure of the Ontario fisheries and to the very steep decline in abundance of eels in Ontario.

RÉSUMÉ

Le recrutement de l'anguille d'Amérique dans les eaux ontariennes a chuté d'environ 97 p. 100 depuis le début des années 1980. Deux indices d'abondance de l'anguille jaune, n'ayant aucun lien avec les pêcheries, indiquent un déclin semblable pour la même période. L'anguille d'Amérique est inscrite sur la liste des espèces en voie de disparition en vertu de la *Loi sur les espèces en voie de disparition* (2007) de l'Ontario, ce qui interdit de tuer, harceler, posséder, acheter, vendre, échanger, louer ou de transporter cette espèce. En 2005, le comité directeur canadien sur l'anguille pour le passage en aval et les questions d'habitat a élaboré une « analyse décisionnelle » visant à mettre au point des mesures d'atténuation en vue d'accroître le nombre d'anguilles qui migrent du fleuve Saint-Laurent. On a mis fin à la pêche commerciale de l'anguille en Ontario en 2004, et à la pêche récréative en 2005. Un projet pilote de capture dans des trappes et de transport de l'anguille jaune a été lancé en 2008 dans le cadre du plan d'action d'Ontario Power Generation en vue de compenser le taux de mortalité des anguilles d'Amérique dû aux turbines à la centrale Saunders sur le fleuve Saint-Laurent. Les grosses anguilles, >800 mm, capturées comme prises accessoires des pêcheries commerciales multispécifiques en place dans le lac Ontario et le fleuve Saint-Laurent ont été transportées dans les environs des deux centrales ou remises en liberté dans le fleuve Saint-Laurent. Entre 2008 et 2010, plus de 3 000 anguilles ont été transférées en aval de tous les obstacles afin de faciliter la migration en aval. Les résultats préliminaires donnent à penser que certains de ces poissons réussissent à migrer du fleuve Saint-Laurent; toutefois, il semble peu probable de pouvoir considérablement accroître le nombre d'anguilles transportées avec la méthode actuelle de capture. En outre, on a commencé en 2006 à augmenter les stocks avec des civelles et des pibales du Canada atlantique, et ce, comme moyen de maintenir la présence des anguilles dans ces eaux. Environ 4 millions d'anguilles ont été stockées dans le lac Ontario et le fleuve Saint-Laurent. Les anguilles stockées semblent bien survivre, croître rapidement et se distribuer à partir des sites de stockage; cependant, on ignore encore si les anguilles de ces stocks contribueront au stock reproducteur. Les estimations indiquent que le taux de mortalité de l'anguille en Ontario a diminué de plus de 50 p. 100 par rapport au point de référence de 1997 à 2002. Cette baisse est attribuable à la fermeture des pêcheries ontariennes et à la diminution très marquée de l'abondance d'anguilles en Ontario.

INTRODUCTION

This research document was produced as part of the Fisheries and Oceans Canada (DFO) Zonal Science Advisory Process (ZAP) – Gulf, Central and Arctic, Maritimes, Newfoundland and Labrador, Quebec regions – held to describe the status and progress on management goals for American Eel. The science peer review meeting to develop science advice was held at 200 Kent Street, Ottawa (ON), on September 2, 2010.

American Eel is a panmictic species in eastern North America. It has been fished commercially and recreationally in all regions throughout its range. American Eel is also impacted by non-fishing related activities including fish passage constraints at barriers and turbine mortality associated with hydro-electric developments. In 2006, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed American Eel in Canada as “Special Concern”. A National Management Plan for American Eel in Canada has been drafted and components of the plan are delivered by the appropriate DFO administrative regions and by the provinces of Quebec and Ontario. Management agencies and stakeholders have initiated a number of measures to address threats to American Eel. In general, the main causes of ‘human-induced’ mortality are thought to be fishing and hydroelectric turbines. The long-term management goal expressed in the plan is to rebuild overall abundance of American Eel in Canada to its level in the mid-1980s, as measured by the key available abundance indices. The short-term goal is to reduce eel mortality from all sources by 50% relative to the average for the 1998-2002 time period.

Fisheries and Aquaculture Management Branch (DFO FAM) has requested scientific advice on the following questions:

1) What is the current status of eels in Canada?
2) What progress has been made toward meeting the goal of a 50% reduction in mortality relative to the baseline of average mortality in 1997-2002?
3) What is best methodology for setting recruitment and escapement targets for a watershed, taking into account cumulative impacts?

The objectives developed for the science peer review meeting are:

1) Based on the region specific abundance indices, to assess the present status of eel in eastern Canada relative to the objective of rebuilding the overall abundance of American Eel to the level in the mid-1980’s
2) To describe the management measures which have been introduced in response to the objective of achieving a 50% reduction in mortality of eel
3) To advise on the metric which should be used in the context of evaluating reductions in mortality (absolute number of animals or proportion of the stock)
4) To the extent possible, to assess the level of mortality from all sources occurring on the stocks and to assess the level of mortality reduction which has been achieved
5) To the extent possible, to evaluate the appropriateness of the existing management measures and to advise on other measures which could be considered, and their contribution, to achieving the objectives of reducing mortality on eels and rebuilding the abundance as expressed in the management plan,

6) To the extent possible, to advise on a reference mortality level for the American Eel which could be applied on a watershed, regional scale to guide the management of activities which result in human-induced mortality of American Eel.

This research document will address the above questions from the viewpoint of the Province of Ontario, and DFO's Central and Arctic Region.

1) STATUS OF THE AMERICAN EEL IN ONTARIO

DISTRIBUTION

American Eel were once widespread through the St. Lawrence River and Ottawa River watersheds (Figure 1). The constriction of the species range in Ontario appears to have been underway by the turn of the twentieth century, long before adequate fish community records were kept (MacGregor et al. 2009). MacGregor et al. (2010) identified post-2000, post-1980 and historic ranges of eels in the province using a combination of ATK, archaeological evidence, local community knowledge and recorded captures via netting (Figure 1). Rare occurrences in the Great Lakes above Niagara Falls (Lakes Erie, Huron and Superior) are the result of stocking and / or dispersal through the Erie and Welland canals and should be considered as introductions outside the historic range (Scott and Crossman 1973, Trautman 1981, COSEWIC 2006, MacGregor et al. 2010).

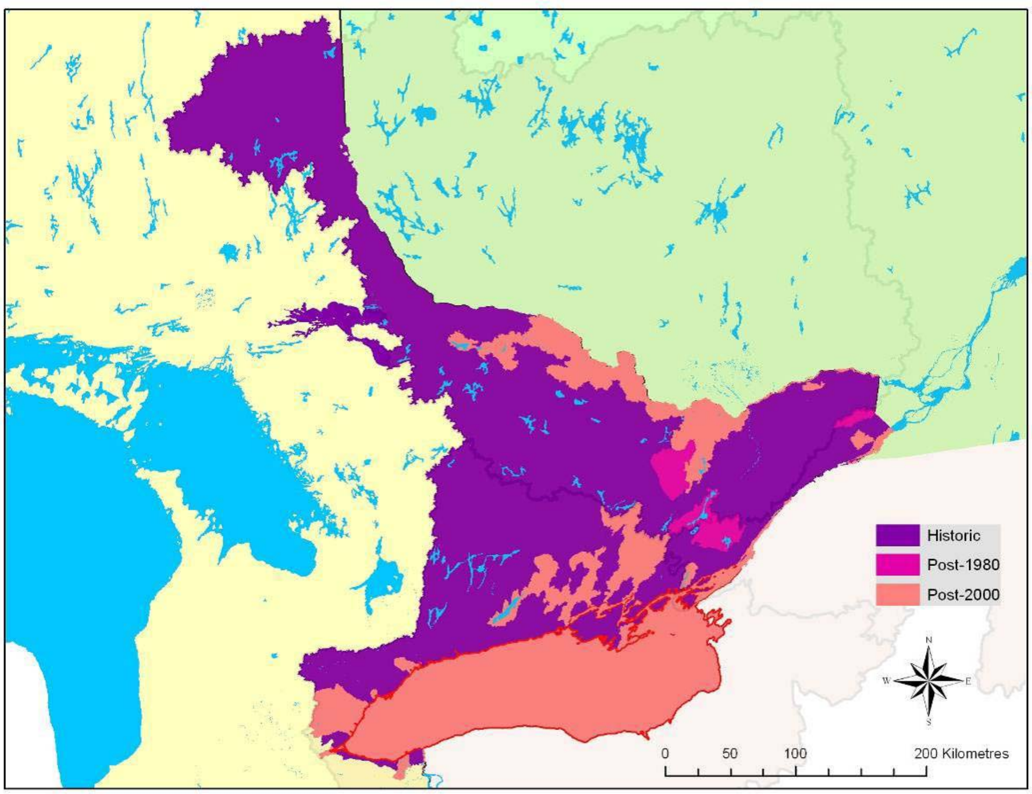

Figure 1. Contraction of the distribution of American Eel in Ontario. Information used to depict the distribution of American Eel in Ontario was compiled by the American Eel Recovery Team from Aboriginal traditional knowledge, local community knowledge, archaeological data and recorded captures via netting (MacGregor et al. 2010).

STATUS OF YELLOW EELS

A long-term dataset showing the recruitment of young eels in Ontario is available from the Moses-Saunders eel ladders (initiated in 1974). Two other series targeting older yellow eel exist: the Bay of Quinte trawling survey, starting in 1972, and a standardized boat electrofishing series in Lake Ontario, which was initiated in 1984.

The Saunders eel ladder, located on the Canadian side of the Moses-Saunders generating station was built in 1974 and is operated by Ontario Power Generation. In 2006, a second ladder (Moses ladder) was put into operation, on the US side of the generating station (NYPA 2010a). This long term data-set shows a catastrophic decline in eel abundance from the mid-1980s to the early 2000s, with a 97% loss of recruitment to the system (Casselman et al. 1997; Figure 2). Recruitment has been fairly stable at low levels for the past few years, with slight improvements in recruitment apparent in the most recent assessments. A variety of improvements have been made to the ladder since its inception, including recent additions of improved substrate on the ladder and the addition of an exit pipe that releases eels approximately 300 m upstream of the generating station to reduce fallback. Despite the concerns about how the addition of a second ladder at the facility and the alterations affect the comparability of the index, there can be no argument that the decline was large, and any recovery has been relatively minor.

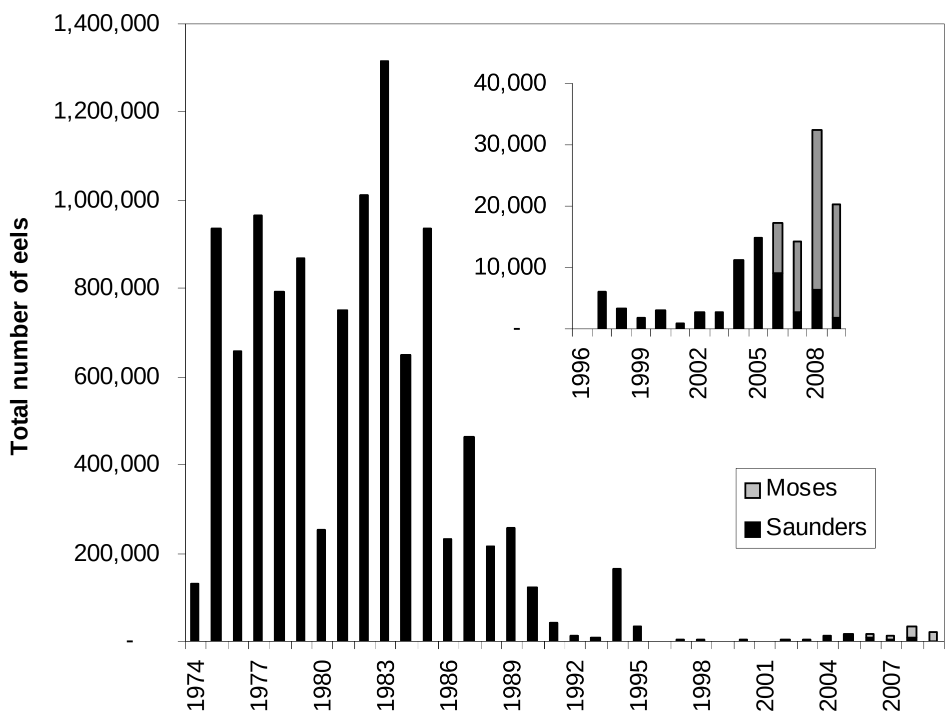

Figure 2. The Moses-Saunders ladder index of American Eel recruitment to the upper St. Lawrence River. The insert shows recruitment in recent years, including the addition of a second ladder in 2006 on the Moses (United States) side of the generating station.

The size and age of eels observed at the Saunders ladder has changed over time (Marcogliese and Casselman 2009). Age composition of eels ascending the Saunders ladder during 2003 to 2008 ranged in age from 3 to 19 (Figure 3, Casselman 2008; OMNR data). Very few young fish were present in the samples from 2003 and 2004 (modal ages of 10 and 9 years, respectively). Since that time fish in the 4–7 age range, particularly the 2002 and 2003 cohorts, have been more strongly represented.

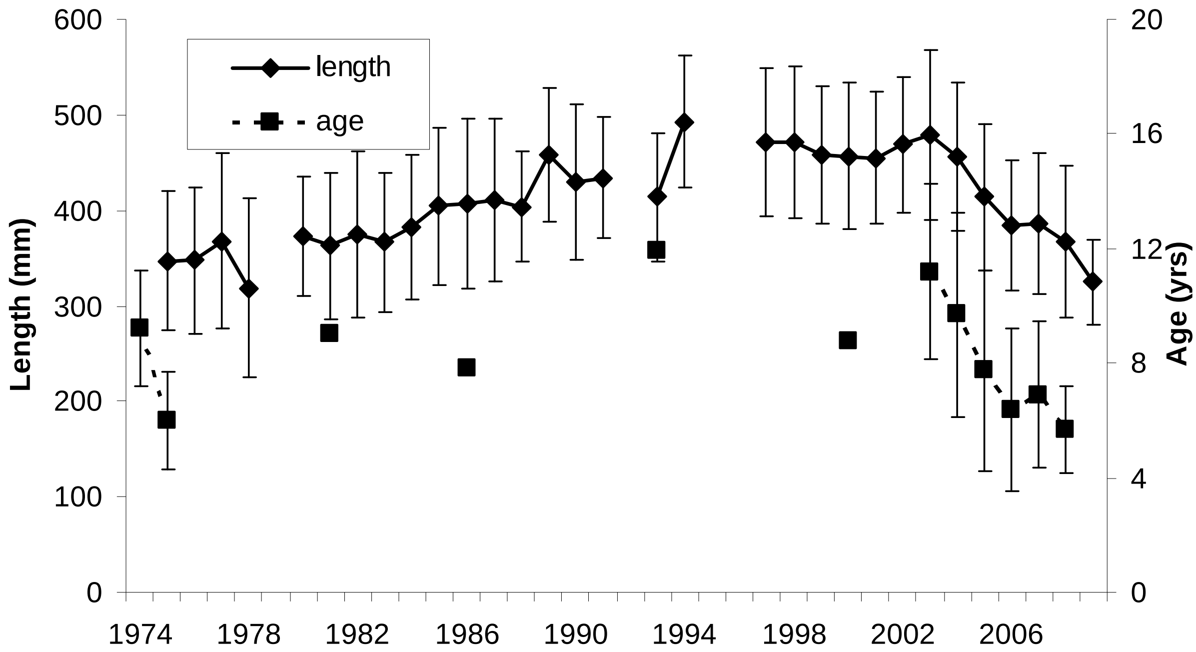

Figure 3. Mean length and age of American Eel recruits ascending Saunders GS eel ladder on the St. Lawrence River. Error bars represent standard deviation. Data sources include Liew (1976), Casselman (2003), Greer (2008), OMNR data, and Oliveira, unpublished.

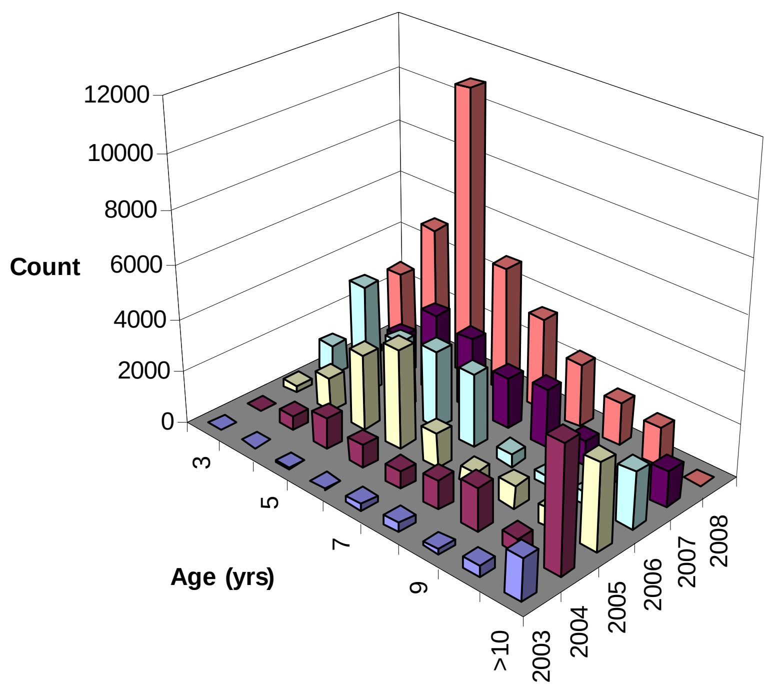

Figure 4. Age class distribution observed in eels ascending the Saunders eel ladder. (Casselman 2008; OMNR data).

Two other indices provide long-term trends of the abundance of larger-yellow eels in Lake Ontario. Catches in both the Bay of Quinte trawling index and an electrofishing index in the eastern part of Lake Ontario during the 2000s have declined to 1% and 3% respectively relative to the 1980s and are currently not significantly different from zero (OMNR 2010; Figure 5). Both of these indices are strongly correlated with the decline of the eel passage at Moses-Saunders (Casselman et al. 1997). The best correlation (r=0.7773) between immigration up the ladder and trawl catches in the Bay of Quinte was with a 4-year lag. Electrofishing catch was best explained (r=0.8888) by the number of eels that ascended the ladder 5 years earlier.

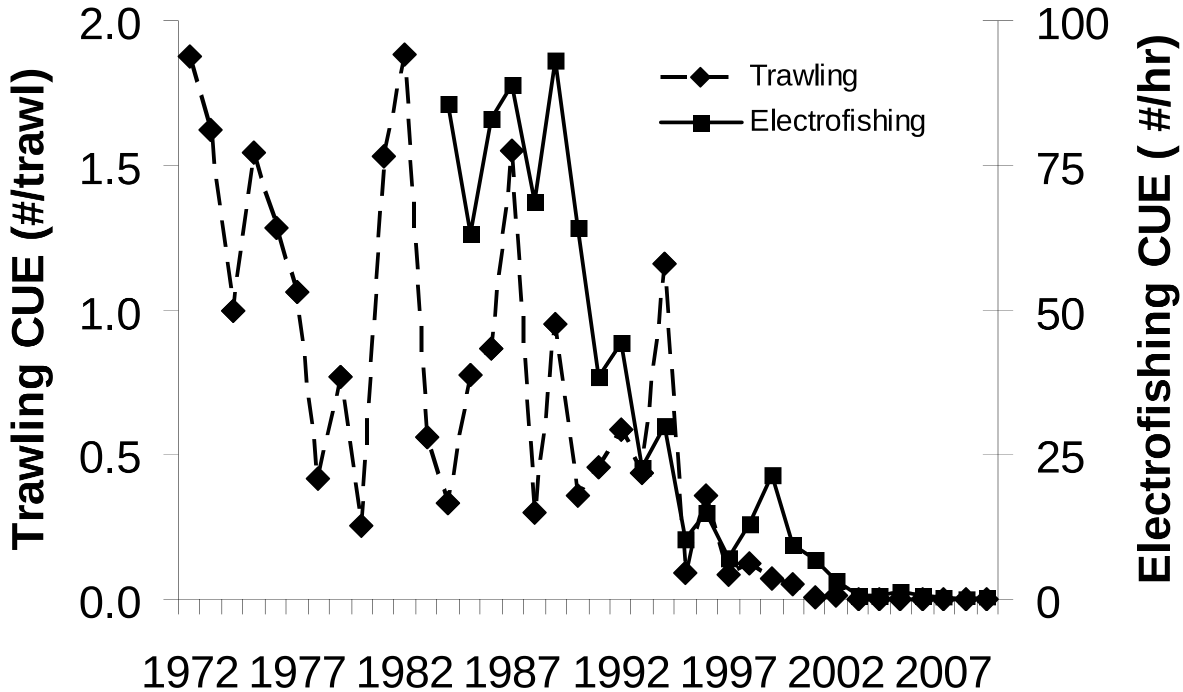

Figure 5. Resident American Eel abundance indices for trawling in the Bay of Quinte (diamonds) and boat electrofishing in eastern Ontario (squares).

Although the indices above cannot be combined into a quantitative assessment of the overall abundance population, they clearly reveal a severe decline as a consequence of reduced recruitment in the Ontario waters of Lake Ontario and the upper St. Lawrence River.

Some eels are still observed in the Ottawa River watershed, however Aboriginal Traditional Knowledge (ATK) and commercial harvest records suggest that eel numbers have been very low since the 1950s – particularly in the upper reaches. Early records indicate that abundance in these areas was substantial. For instance, Quebec commercial eel harvests from the Ottawa River ranged from 3.4 -15.0 m.t. annually between 1930 and 1937 (Dymond 1939). Commercial harvest records for the North Bay MNR District waters of the Ottawa River show thousands of pounds of eels harvested during the period 1924-1938, peaking at 4,027 kg in 1932 (OMNR 1984). Recent data from the Ottawa River watershed are scarce and existing data for the 1980s and 1990s are summarized in MacGregor et al. (2009). A 2009 electrofishing survey found low densities, 3.6 eel/ha, below the Carillon Dam, the first barrier on the Ottawa River. Even lower densities were observed above the dam, ranging from 0.2 to 1.2 eels/ha, depending on the river segment surveyed (Casselman and Marcogliese 2010b).

STOCKING

Between 2006 and 2010 a total of 4 million glass eels and elvers, collected from commercial fisheries in Atlantic Canada, have been stocked into Ontario waters of the upper St. Lawrence River and Lake Ontario (uSLR-LO) (Table 1). A health testing protocol was developed after consultation with fisheries health experts (Williams and Threader 2007). All stocked eels were marked with a fluorescent dye to distinguish them from naturally migrating eels, although eels must be killed to observe the mark. This conservation stocking experiment is part of the Ontario Power Generation Action Plan for offsetting turbine mortality of American Eel at the R.H. Saunders Generating Station 2006-2011 (OPG Action Plan). Stocking was conducted to supplement recruitment of eels to the uSLR-LO until the number of wild eels climbing the ladders recovers. In addition, these fish will also provide a stock to allow for future studies.

Young eels of this life stage have never occurred naturally in Ontario. Boat electrofishing is being conducted to monitor the effectiveness of the stocking program. During the 70 transects surveyed during the spring 2009, average densities of 25.7 (± 6.4) and 30.0 (± 7.6) eels/ha were observed in the uSLR and Bay of Quinte stocking sites, respectively. The 91 transects surveyed during the fall 2009 revealed densities of 55.5 (± 15.6) and 199.1 (±35.0) eels/ha at the uSLR and Bay of Quinte stocking sites, respectively.

In addition, incidental eel captures reported by other agencies (e.g., DFO's sea lamprey control program, Conservation Authority surveys) showed that very small eels had traveled hundreds of kilometres from the stocking sites to as far away as the Credit River and Hamilton Harbour. The eels were too small to be naturally migrating eels, and in some cases the specimens were collected and the florescent mark unique to stocked eels was observed.

The initial goals (survival, dispersal, and growth) of the experiment have been met. Whether the long-term goal of having the stocked female eels mature, migrate out of Ontario waters, and contribute to the global spawning stock will be met remains unclear at this time. Additional discussion of the stocking project can be found in the sections below.

Table 1. American Eel stocking in Canadian waters of the upper St. Lawrence River and eastern Lake Ontario. Note that the 2010 data are preliminary.

Year	Number	Weight (kg)
2006	144,300	100[a]
2007	450,000	90
2008	2,001,561	375
2009	1,303,000	299
2010	142,033	28
Total	4,048,861	894

[a]*Fish in 2006 were reared until fall fingerling stage and stocked in September*

STATUS OF SILVER EEL EMIGRATION

Fully mature silver do not naturally occur in Ontario. However, fish displaying the early stages of sexual maturity have been identified (McGrath et al. 2003). Surveys of the tailwaters of the Moses-Saunders have identified dead and injured eels and provide an index of the number of eel leaving this system on their downstream migration since 2000 (NYPA 2010b). The survey indicates that most eels out-migrate from the uSLR-LO area during a rather broad period from late June/early July through mid-late September which is consistent with early migration from inland lakes reported by Facey and Van Den Avyle (1987) and Lowe (1952). The majority (>63%) of outmigrating eels were observed when water temperatures were above 19°C. The numbers of these eels has declined by approximately 20% annually since the start of the survey in 2000 (Figure 6). Allowing for a 10- to 15-year yellow eel growth phase in the upper St. Lawrence and Lake Ontario (Casselman 2003), this decrease in number of downstream migrants is consistent with the decline observed in upstream juvenile migrants beginning in the mid-1980s. The best correlation (r= 0.8651) between the abundance of upstream migrants and the numbers of eels observed in the tailwaters is with an 18-year lag.

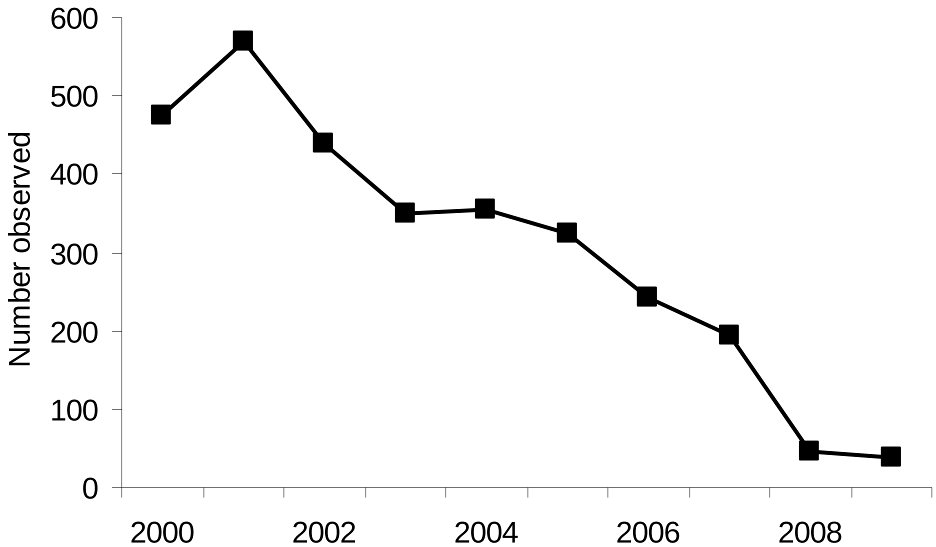

Figure 6. Counts of out-migrating American Eel carcasses detected downstream of the Moses-Saunders GS. Data from NYPA 2010b.

A similar protocol has recently been established on other generation stations to document the presence of silver eel in the Mississippi and Ottawa rivers during their tailrace survey at hydro generation facilities in these systems (Thompson et al. 2010).

SUMMARY

Although eels have 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 uSLR and LO), albeit now at very low densities in all instances (MacGregor et al. 2008, 2009). LO and uSLR remained as the last provincial stronghold for American Eel, and their steep decline in these waters since that time has been well documented (Casselman 2003, MacGregor et al.2008, Lees 2008). All the long-term Ontario abundance indices indicate that eels are at ~3% of their mid-1980s abundance, so the Province is far from the objective of rebuilding stocks to mid-1980s levels.

2) UPDATE ON RECOVERY ACTIONS TO REDUCE EEL MORTALITY BY 50%

In 2004, the DFO, along with the Quebec Ministry of Natural Resources, Wildlife and Parks and the Ontario Ministry of Natural Resources announced a goal of reducing eel mortality by 50% and called on stakeholders and jurisdictions to take the necessary measures to reach this goal. Since that time both Ontario has announced plans to undertake mitigation or offsetting measures to reduce mortality and set the scene for recovery of American Eel.

RECOVERY PLANNING

The American Eel is identified as an *Endangered* species under Ontario's ESA 2007, which prohibits the killing, harming, harassing, possessing, buying, selling, trading, leasing or transporting of this species. Hydroelectric generation facilities in the eel's range within the province are provided an exemption from the Act until June 30, 2011 (Ontario Government

2008). Companies may develop agreements with the Province that describe steps to minimize adverse effects on eel populations in the area and appropriate monitoring programs that hydro companies will undertake. Continued operation without an agreement may be in contravention of the Act. A recovery strategy for the American Eel in Ontario is being developed (MacGregor et al. 2010) and the government response statement to this document will be completed within 9-months of the strategy being completed.

Quebec, Ontario and Fisheries and Oceans Canada (DFO) are nearing completion of the National Management Plan for the American Eel required under the federal *Species at Risk Act*. A draft framework for eel recovery in the upper St. Lawrence River/Lake Ontario segment of the eel range and a formal MOU to develop coordinated management and science approaches for eel conservation across the North American range are near completion. In 2005, the Canadian Eel Steering Committee for Downstream Passage and Habitat Issues developed a “Decision Analysis” aimed at developing mitigation measures to increase eel survival in the Lake Ontario/upper St. Lawrence system (Greig et al. 2006).

EEL FISHERIES

The Ontario commercial eel fisheries were closed in 2004 and the recreational fishery for eels was closed in 2005. Prior to the closure of these fisheries, commercial fishing quotas were reduced by 50% on two occasions; however, this form of regulation had little or no impact on harvest given the steep decline in eel abundance. Even though local fisheries have been closed, silver eels escaping from Ontario are still exploited in the Gulf of St. Lawrence fisheries; however, reductions in these fisheries have been 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, including gear and season restrictions, have also been changed in the Maritimes.

UPSTREAM MIGRATION

In the United States, there is a push to restore passage for migratory fish species (including eels) to the inland waters of many states (GMCME 2007; MacGregor et al. 2010). 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 of Lake Ontario where eels once were highly abundant but disappeared due to hydroelectric installations) and on the upper St. Lawrence River now has been required during a FERC re-licensing exercise of waterpower facilities. In Ontario, there is only one upstream passage facility that has been developed for American Eel. A major recommendation of the draft Provincial recovery strategy is to ensure that access is provided to former eel rearing habitats (MacGregor et al. 2010). To date, there is only one other instance of requiring passage at a generating station in Ontario, but it is anticipated that upstream passage will be a component of many of these agreements between hydro companies and the Province that are developed under the provisions of the Ontario *Endangered Species Act*.

The provision of upstream passage may not be a panacea for eel restoration. Electrofishing surveys conducted during 2009 showed that eel densities in the Ontario waters of the St. Lawrence River below the Moses-Saunders generating station where ~ 25x higher than the densities observed in waters upstream of the dam (Casselman and Marcogliese 2010a). This may indicate that even the presence of the two eel ladders at that facility could not facilitate effective upstream passage, though the densities of eels are much higher in Lake St. Francis (below the generating station) than Lake Ontario.

DOWNSTREAM MIGRATION AND TURBINE MORTALITY

The issue of downstream migration remains the largest management challenge in Ontario for American Eel. Where effort has been applied in other jurisdictions, some success has been achieved in reducing downstream mortality (e.g., Boubée et al. 2001, Watene and Boubee 2005). One example is the installation of a grid on the water intake at a small hydro dam on the Rimouski River, Québec (Guy Verreault, Quebec MNRF, pers. comm.). The provision of 1-inch trash rack overlays are required on all three Brookfield facilities in the Oswego River to deter large fish from entering turbine intakes (Elmer and Murphy 2007). Hydroelectric facilities are present on the two main American Eel watersheds in Ontario, and the question of how to safely pass eels around existing turbines on very large rivers has been the focus of much effort (Grieg et al. 2006 - see section 5). Turbine mortality at the Moses-Saunders GS, located on the upper St. Lawrence River, was estimated at 26.5% (NYPA 1998, Verreault and Dumont 2003). No estimates of mortality are available for generating stations on the Ottawa River, though mortality is occurring as dead eels have been observed downstream of some of the facilities (Thompson et al. 2010).

Negotiations with some power companies in Ontario and Québec have led to formal action plans to further address and offset turbine-related mortalities in specific locations in the St. Lawrence River. The development of the agreement under the ESA to address eel mortality at Saunders Generating Station was the first regulatory requirement for safe eel downstream passage in Ontario.

As no short-term solutions to provides safe downstream passage at large generating stations were apparent (Greig et al. 2006), a large-yellow eel trap and transport pilot project was initiated in 2008 as part of the Ontario Power Generation Action Plan for offsetting turbine mortality of American Eel at the R.H. Saunders Generating Station 2006-2011 (OPG Action Plan). Large yellow eels that were expected to “silver” in the near term were used for this experiment, as opposed to silver eels, which are very difficult to capture in this system (McGrath et al. 2003). American Eels > 800 mm, captured as by-catch from existing commercial fisheries in Lake Ontario and Lake St. Francis, were purchased, biologically assessed, tagged, and either transported around the generating station(s) or released back into Lake St. Francis as a control. To date, over 3000 eels have been transferred downstream of the Moses-Saunders and Beauharnois GSs.

Table 2. The number of large-yellow eels captured, tagged and released as part of an experimental trap and transport project in 2008-2010. In 2008, all eels were released in Lac St. Pierre, approximately 100 km east of Montréal. In 2009 and 2010, all Lake Ontario / upper St. Lawrence River eels and approximately 50% of the Lake St. Francis eels were released in Lac St. Louis, near Montréal, while the remaining Lake St. Francis eels were released back into Lake St. Francis to serve as control animals.

Year	Capture Location		Release Location
	Lake Ontario & upper St. Lawrence River	Lake St. Francis	
2008	161	1016	Lac St Pierre
2009	212	1000 / 868	Lac St. Louis / Lake St. Francis
2010	234	732 / 734	Lac St. Louis / Lake St. Francis

CONSERVATION STOCKING OF EELS

Conservation stocking of eels in Ontario began in 2006 and has intensified since then, with glass eels and elvers from Atlantic Canada stocked into the uSLR and LO. Funding and support for stocking has been provided by Ontario Power Generation and the federal and provincial governments. Approximately 4 million eels have been stocked since the inception of the experiment (Table 1). Stocking programs have shown some promise as a means of maintaining the presence of eels in these waters (good survival and growth), but stocking is not seen as a desirable long-term recovery measure (Parnell and Greig 2005) as it does not address the causes of the decline and it is unclear if stocked fish will be able to contribute to the spawning stock.

SUMMARY

The Province of Ontario has made great strides to meet and exceed the 50% reduction objective. Commercial and recreational fisheries have been closed, the species has been listed as Endangered under provincial legislation, and large-scale large yellow eel trap and transport and conservation stocking pilot projects have been initiated. Negotiations are underway with hydro-electric generators to ensure that they are in compliance with *the Endangered Species Act* provisions in an effort to address turbine mortality issues and a Recovery Strategy for eels in the Province is being developed.

3) TOWARD CONSENSUS ON AN AMERICAN EEL MORTALITY METRIC

Canadian Eel Science Working Group (CESWoG) recommended that anthropogenic mortality (including fishing and hydro turbine mortality) of eels in Canada be reduced by 50% in 2004, in comparison with mean mortality levels of the previous five years (Cairns and Casselman 2004). This recommendation was subsequently put forward as a goal in the draft National Management Plan for American Eel. To evaluate the status of this goal in Ontario, the rate of mortality of silver eel “equivalents” was estimated. Given that mortality of eels could occur at any of the eels’ life stages, calculation of silver equivalents provides a way of standardizing the effect on the population – that is, the mortality of a glass eel does not have the same effect on the population as the mortality of a silver eel. In Ontario, the abundance of eels has declined to less than 10% of the abundance of eels that were present during 1998 to 2002, based on the electrofishing index of yellow eel abundance. Given this decline, it is important to estimate the rate of mortality rather than calculate the number of mortalities so that the effect of management actions can be adequately evaluated.

4) ASSESSMENT OF AMERICAN EEL MORTALITY IN ONTARIO

Eel harvest during 1998 to 2003, calculated in 'silver eel equivalents', was calculated from commercial harvest records based on the assumptions that eels weighed 1.17 kg (OMNR data), would remain in the system 2 to 3 years post harvest and assuming an instantaneous rate of mortality (Z) of 0.265 (Verreault 2002). Verrault and Dumont (2003) calculated that less than half a million silver eels left the uSLR-LO each year during 1996 and 1997 based on modeling and a mark-recapture population estimates in the St. Lawrence estuary. A model was constructed to estimate the number of silver eels leaving the system during 1998 to 2010 by extrapolation of 1996 and 1997 population estimates with scaling provided by the data from the eel ladder (with a 14-yr lag), Bay of Quinte trawling (with a 5-yr lag), and electrofishing (with a 9-yr lag) indices of abundance.

Based on this analysis the average rate of anthropogenic mortality of eels in the uSLR-LO during 1997 to 2002 was 31% (45,270 fish). Fishing mortality rate during this time period was approximately 6% while turbine mortality was 24% of the measured anthropogenic mortality of the silver eel stock leaving the uSLR-LO. It should be noted that when the fishery was more actively focused on eels it is thought that fishing mortality and turbine mortality were approximately equal (Beak 2001). Since the closure of the commercial fishery in Ontario in 2004, the average rate of anthropogenic mortality of eels in the LO-uSLR has been 16% (4,359 fish) about half the value for 1997 to 2002, with all the mortalities attributed to turbines. All of these mortalities were attributed to turbine mortality. The reduced mortality rate due to turbines relative to the values in the mid-1990s is the result of a proportionally higher production of eels in Lake St. Francis compared to Lake Ontario, given that eels from Lake St. Francis have to transit only one hydroelectric dam (Beauharnois) during their downstream migration. All these mortality calculations exclude the lower St. Lawrence River silver eel fisheries and turbine mortality at Beauharnois GS. It is also important to note that the mortality rate of eels passing through turbines is positively correlated with length and the observed increase in mean weight (and presumably length) in the fisheries landings from the uSLR-LO indicates that there may have been an increase in turbine mortality rate.

The OPG trap and transport program is a feasibility study and not part of a full-scale program, nevertheless, the transport of 1,200 eels annually around the two generating stations during the operation of the project resulted in a reduction in turbine mortality of about 245 eels per year.

Our estimates (Figure 7) indicate that eel mortality in Ontario has been reduced by more than 50% relative to the 1997 to 2002 reference point. This decline can be attributed to the closure of the Ontario fisheries and to the very steep decline in abundance of eels in Ontario.

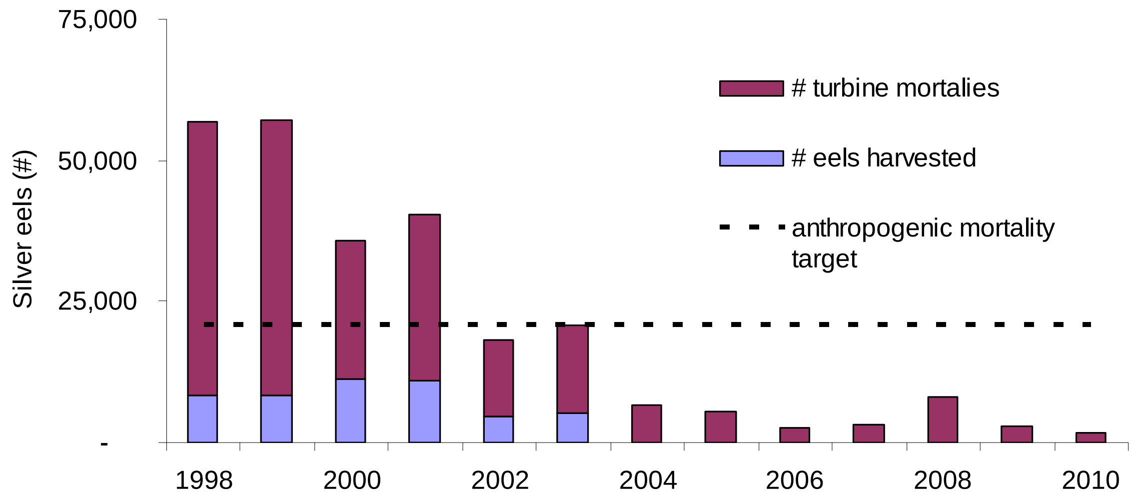

Figure 7 Estimated number of eels harvested by commercial fisheries or killed in hydro generation turbines in Ontario waters of the Lake Ontario and the upper St. Lawrence River during 1998 to 2010. All numbers were calculated as 'silver eel equivalents'. The anthropogenic mortality target is 50% of the number of eels that died (harvest and turbine mortalities) during 1997 to 2002.

5) ASSESSMENT OF CURRENT AND FUTURE MANAGEMENT MEASURES

Like all jurisdictions facing declining fish stocks, creating consensus on a path to reduce mortality has been difficult. A committee struck to deal with American Eel passage on the St. Lawrence River completed a decision analysis (DA) process aimed at identifying the best approach for facilitating downstream passage at the St. Lawrence River hydroelectric facilities (Greig et al. 2006). It is estimated that approximately 40% of the outmigrating silver eels are killed in the turbines at the Moses-Saunders and Beauharnois GSs as they travel downstream during their spawning migration. The DA, based on the PrOACT approach (Hammond et al. 1999), was conducted to deal with the large number of objectives associated with the American Eel issue (Greig et al. 2006). One of the focuses of the DA was to aid decision-makers in determining the best mitigation measure(s) in the face of uncertainty about eel ecology and the likely effectiveness of potential mitigation measures. Alternative mitigations considered in the DA included:

- Spilling water at hydro stations
- Installation of "Eel Friendly" turbines at hydro facilities
- Diversion of migrant eels to a bypass
- Trapping eels upstream of hydro facilities and transporting them downstream
- Stocking
- Fishery reductions

Fisheries reductions and stocking were identified as the most cost effective, most feasible and had the lowest uncertainty of the outcome. Trap and transport was identified as the most desirable of the alternatives that directly addressed the issue turbine mortality, but its cost effectiveness feasibility and uncertainty were poor relative to stocking and fisheries reduction alternatives (Greig et al. 2006).

The closure of the commercial and recreational American Eel fisheries resulted in the cessation an important source of anthropogenic mortality in the province. The decision to close the fishery was shown to be prescient, given the collapse and absence of meaningful recovery in Ontario, and the measure has been effective at eliminating one source of anthropogenic mortality.

The conservation stocking has transferred over 4 million glass eels and elvers into Ontario waters. Some of the initial outcomes of this experiment have been positive; stocked eels are surviving and growing quickly, and have dispersed throughout the watershed. However, there remain some important questions with the experiment that have yet to be answered. As with the Verreault et al. (2009) stocking in Lac Morin, ~ 50% of the stocked American Eel in Lake Ontario have been male. This is a concern because historically all eels in this system were female. There are also questions as to whether the stocked eels will mature and migrate normally, which is necessary if the long-term goal of increasing the number of fecund, female spawners outmigrating from Ontario waters is to be achieved. Verreault et al. (2010) observed eels stocked into Lake Champlain in 2005 in the Quebec silver eel fishery in 2009. This finding was surprising, as it was thought that stocked eels would reside in the watershed for 10-15 years, but it does demonstrate that stocked eels can mature and migrate to at least the St. Lawrence River successfully. However, the stocked silver eels were ~30 cm smaller than their non-stocked counterparts, which raise additional questions about whether their energy stores will be sufficient for the long migration back to their spawning grounds. A final concern is not biological, but instead revolves around the ability to access a supply of disease and parasite free glass eels for conservation stocking that is both timely and cost-effective and will not have negative effects on the donor stock. The price of glass American Eels has fluctuated fivefold in the past decade, making it difficult to imagine how a longer term stocking program could be developed with such variation in potential costs. In addition, it has not always been easy to meet health screening requirements which require a large supply of glass eels which are available early in the fishing season from only a few source rivers. Assessment of the conservation stocking experiment will continue, but it is unclear whether stocking will continue in Ontario.

In the past three years, over 3000 large yellow eels have been captured above the Moses-Saunders and Beauharnois GSs and moved downstream as part of the trap and transport program. The number of eel mortalities that have been reduced by this pilot project is small (~approx 3 %) relative to the estimates of turbine mortality. An additional 1600 eels have been released back into Lake St. Francis as control animals to evaluate the effects of transporting eels. So far the results of the experiment have been positive, American Eels marked in the trap and transport experiment have been captured in the Quebec silver eel fishery and it is estimated that over 30% of American Eels from 2008 and 2009 trap and transport projects have migrated. Trap and transport eels are physically and physiologically indistinguishable from naturally migrating silver eels (Stanley and Pope 2008, 2009). This provides optimism that if a larger-scale trap and transport mechanism can be developed that transported eels will continue to mature and migrate similar to natural migrants. One concern with the experiment to date is that the trap and transport might be triggering an earlier maturation and migration; it is hoped that this concern will be resolved by the large number of control eels released back into Lake St. Francis the past two years. A drawback to the current trap and transport program is the inability to collect large numbers of large yellow via bycatch in existing commercial fisheries. Despite the offer of a reward 2 to 5x the market value of American Eels, commercial fishers on LO have supplied <250 large yellow American Eels per year (Stanley and Pope 2008, 2009) In addition, it seems unlikely that the numbers of eel transported can be increased significantly with the current approach to capturing them. Alternative techniques to capture eels in the uSLR are being explored in cooperation with NYPA and US management agencies. On small Ontario watersheds a wide variety of options (e.g., bypass, turbine shutdown during migration, trap and transport etc.) for providing safe downstream passage of eels around hydro facilities need to be explored.

6) REFERENCE MORTALITY LEVEL

Meeting participants were asked, to the extent possible, to advise on a reference mortality level for the American Eel which could be applied on a watershed, regional scale to guide the management of activities which result in human-induced mortality of American Eel. Modeling of the uSLR-LO eel abundance has been conducted using the best available data, including an instantaneous natural mortality rate (M) of 0.2 (or an annual survival rate of 81.9%) (Vollestad and Jonsson 1988, Adam 1997, Verreault 2003). The model suggests that recruitment to the system would have to be 3 times higher than what was observed in order to sustain a fishery of the magnitude seen during the 1970-1990 period. While some refinements of the model may be helpful, we think that a better understanding of the basic dynamics of this sub-population is required to fix realistic and well documented long-term goals and a reference mortality level.

Given that in Ontario the eel population has declined dramatically, some way of effectively guiding management actions for eels is needed. The mortality level goal in the draft National Management Plan for American Eel provides one target. We recommend that consideration be given to developing a mortality target based on the theoretical natural mortality rates determined for European eel by Bevacqua et al. (2010).

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