Ministère des Forêts, de la Faune, et des Parcs American Eel Action Plan

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MINISTÈRE DES FORÊTS, DE LA FAUNE ET DES PARCS

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Background

The American Eel (*Anguilla rostrata*), hereafter referred to as eel, is a semelparous and facultative catadromous migratory species, meaning that it generally matures in fresh water and migrates to the sea to spawn once before dying (Schmidt, 1922). Its range extends from southwest Greenland to Venezuela, and it spawns in the Sargasso Sea (Schmidt, 1922; Scott and Crossman, 1974; Tesch, 2003). The eel is a panmictic species (Côté et al., 2013), meaning that all individuals of the species belong to the same population and reproduce randomly. The population is considered to be in decline, although abundance indicators in certain regions of its range show more mixed trends (Casselman, 2003; COSEPAC, 2012; Jacoby et al., 2017). Several neighbouring jurisdictions and national or international organizations have assigned a conservation status to the species:

- International Union for Conservation of Nature (IUCN): endangered, 2013.
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC): threatened, 2012.
- Ontario: endangered, 2008.
- Newfoundland: vulnerable, 2007.
- United States : Atlantic States Marine Fisheries Commission (ASMFC): depleted, 2012.

The latest genetic knowledge on eels has confirmed that the environmental characteristics of the habitats in which eels reside foster the selection and existence of ecotypes with specific genetic and morphological characteristics (Côté et al., 2014; Gagnaire et al., 2012; Pavey et al., 2015). The spatial heterogeneity of male and female abundance across North America (Atlantic States Marine Fisheries Commission, 2012; Cairns et al., 2014; Vladikov, 1970) means that the situation in Québec could have a particular impact on the entire population. Indeed, a very large proportion of eels produced in Québec waters are large females with high fertility (Dutil et al., 1985; Tremblay, 2009; Verreault, 2002).

The status of the eel is of great concern in Québec (Comité scientifique sur l'anguille d'Amérique, 2019). The ministère des Forêts, de la Faune et des Parcs (MFFP) has added it to the list of species likely to be designated as threatened or vulnerable in Québec. The longest data series documenting the relative abundance of the species in its Québec range is derived from monitoring juveniles returning to rearing sites in the Upper St. Lawrence River and voluntary reporting of landings by commercial fishers. Annual recruitment of juvenile eels upstream of the St. Lawrence system, at the outlet of Lake Ontario, has been very low since the mid-1990s, and landings of yellow and silver eels have been in steady decline since the early 1990s. The status of eels in the tributaries of the Gulf of St. Lawrence and Baie-des-Chaleurs is more difficult to determine, as recruitment and downstream migration monitoring covers only a short period of time. Monitoring suggests that the decline may be less pronounced in eastern Québec than in the upper St. Lawrence River.

Recovery efforts in Québec have been carried out through ongoing MFFP activities, initiatives by community partners (dam owners, Aboriginal communities, etc.), and Hydro-Québec's 2009–2013 American Eel action plan (Comité scientifique sur l'anguille d'Amérique, 2019). These actions were consistent with the principles of the draft American Eel Management Plan for Canada (CEWG, 2009, unpublished) as well as those established as part of the Recovery Potential Assessment for the American Eel (*Anguilla rostrata*) in eastern Canada (DFO , 2014), and they have contributed to achieving some of its objectives. These actions have resulted in measurable gains for the species in the St. Lawrence River system, including reductions in mortality from commercial fishing. Seven fishing licence buyback programs allowed to cease targeted eel harvesting upstream of Lac Saint-Pierre, a 14% to 37% reduction in the harvest of predominantly yellow eels (growing residents) in Lac Saint-Pierre, and

a maximum 5% reduction in fyke net catches in the Pont Laviolette–Île d'Orléans sector. In addition, these programs have reduced by half the harvest rate of silver eels migrating downstream in the St. Lawrence Estuary. Moreover, a project to reintroduce eels to historically favourable habitats was carried out from 2005 to 2008 by transferring glass eels to Québec. In 2021, it was estimated from eel catches in the estuary that 16.3% of the 175,000 migrating eels produced in the Upper St. Laurence River were from these transfers (Doucet-Caron et al., in prep.). This value is lower than previous years (2018–2020 average of 32.6%). Since 2014, Hydro-Québec, MFFP, the Ontario Ministry of Natural Resources and Forestry, and local stakeholders have been transferring approximately 400 eels every year from the fishway at the Beauharnois hydropower generating station to the Ottawa River. These transfers are intended to maintain the presence of eels in this watershed, with the aim of long-term recovery. In addition, eel ladders were installed on a few barriers to eel migration to restore its historical distribution. Despite these large-scale actions, surveys still indicate an abundance well below historical levels in the Upper St. Lawrence River.

Throughout its range, the eel faces six main threats (Chaput et al., 2014; Drouineau et al., 2018):

- **Habitat fragmentation:** Barriers to eel passage (dams, weirs, culverts, etc.) limit or slow access to rearing habitats during upstream migration, as well as during migration to eel spawning site in the Sargasso Sea. It is estimated that the reduction in free access to rearing habitats upstream of dams listed in Québec resulted in a production loss of close to 1,000 tonnes or 835,000 reproductive eels annually (Verreault et al., 2004).

- **Turbine passage mortality:** Mortality due to hydroelectric dams is highly variable (<5% to 100%) and depends on turbine characteristics and fish size (Larinier and Dartiguelongue, 1989; Larinier and Travade, 2002). The only available estimate of turbine mortality in the Québec range is from the Beauharnois–Les Cèdres hydroelectric complex, where the combined mortality rate from turbines blades and propellers on both dams is estimated to be 17.8% (Desrochers, 1995; Verreault and Dumont, 2003). More than 150 hydroelectric generating stations are present in the eel's range in Québec, which can result in migrating eel mortality when the species is present upstream of these structures.

- **Parasites and diseases:** Although the eel is recognized as a potential host for several parasites, the data available for the St. Lawrence River are only for *Anguillicola crassus*. The presence of this nematode, an exotic parasite that lodges in the eel's swim bladder, was suspected in 2007 in glass eel samples from Nova Scotia and New Brunswick destined for transfer to Lake Ontario and Rivière Richelieu (Threader et al., 2011). Transfers to Québec stopped the following year, but they continued in Ontario until 2010. This parasite was subsequently confirmed in Ontario and Québec in 2010 and 2015, respectively, in translocated eels (Pratt et al., 2019). The frequency of individuals infected with *A. crassus* has varied in Québec since 2015, ranging from 0.3% to 5.5% in eels migrating to the Sargasso Sea and caught in the estuary's commercial fisheries. Today, the parasite is also found in eels from natural recruitment (Verreault and Dussureault, 2018). The effect of the parasite on the migration or survival of eels in Québec has not been documented, but studies of European and American eels have determined that the parasite may cause certain changes in swimming and feeding behaviours, various bacterial infections, inflammation, obstruction, and even rupture of the swim bladder (Lefebvre et al., 2012; Sokolowski and Dove, 2006).

- **Commercial fishing:** In Québec, eel is commercially fished in the St. Lawrence River and Estuary, as well as in Îles-de-la-Madeleine. Aside from the annual volume of commercial landings reported by fishers, relatively little information is available for fisheries upstream of the estuary. Silver eels in downstream migration are harvested in the Upper Estuary, while fisheries in Lac Saint-Pierre and the Fluvial Estuary mainly harvest yellow eels. In this area, six fishing licence buyback programs have been established as part of the Yellow Perch management plans and Hydro-Québec's 2008–2013 American eel action plan. The eel harvest rate in the Ottawa River is now zero as a result of the 2012 buyback program for fishing licences and gear. Eel landings reported in the Québec portion of Lake St. Francis have been less than one tonne since 2012, following the aforementioned buyback program and the closure of the Ontario commercial eel fishery (the historical average had reached 25 tonnes in the first half of the 2000s). In Lac Saint-Pierre, it is estimated that the impact of the buybacks on reducing commercial eel landings is between 14% and 37%, depending on the indicator used (MFFP, unpublished data). In the Pont Laviolette–l'Île d'Orléans (PLIO) fishing sector, the impact of the buyback program on eel landings was more modest, estimated at a maximum of 5% (MFFP, unpublished data). The trend for landings in these two sectors is still declining. The estuary fishery is very well described in terms of both the stock being harvested and the fishing parameters. The average harvest rate, which was 21.5% in the late 1990s (Caron et al., 2003), fell to 9.2% after a voluntary buyback program in 2009 (Daigle and Julien, 2012; Talbot et al., 2011) that reduced the number of licences delivered from 67 to 21. A recent update now estimates a 5.5% harvest rate for silver eels in downstream migration in the estuary fishery (Desbois-Bédard and Daigle, 2022; Desbois-Bédard and Daigle, 2021). The fishery in Rivière Richelieu has been closed since 1998 and banned in the fishing plan since 2002, following a significant decline in commercial catches (Dumont, 1998). In Îles-de-la-Madeleine, eel landings are not monitored annually, and the harvest rate has not been estimated in the archipelago.

- **Contaminants:** Although the impact of contamination on the recovery potential of this species is unknown, eels have characteristics (long lifespan, being a predatory species, high lipid content) that make them sensitive to contaminants found in the aquatic environment. In the past, eel harvesting, consumption, and export to international markets have been restricted due to high contamination levels of their flesh, notably from mercury and Mirex (Desjardins et al., 1983; Dumont, 1996; Nilo and Fortin, 2001). Even though, since 2012, tested eels no longer exceed Canadian standards for human consumption for polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and organochlorine pesticides, current contamination levels exceed the targets set by the International Joint Commission for the protection of birds and animals that consume fish (Byer et al., 2013).

- **Climate and ocean changes:** Projected climate change and anticipated changes in ocean currents (e.g., Gulf Stream) may affect the species' dynamics, and some experts fear negative impacts on future eel abundance in North America (Drouineau et al., 2018; Knights, 2003). Despite the great plasticity demonstrated by this ubiquitous species that exploits aquatic ecosystems from northern Venezuela to Greenland, the potential speed of climate change and the increased frequency of extreme events could have unpredictable effects on local stocks. In Québec specifically, there is concern that changes in ocean currents and productivity in the Gulf Stream will decrease the abundance of larvae that reach the shores of the St. Lawrence River (Castonguay et al., 1994b; Knights, 2003; Miller et al., 2016).

To mitigate the impact of these threats on eels, the MFFP has the authority to act both directly (e.g., issuing authorizations under the *Act respecting the conservation and development of wildlife* [ACDW],

delegating fisheries management under the *Québec Fishery Regulations*, specific projects aimed at species recovery) and indirectly (e.g., developing wildlife expert advisories for ministère de l'Environnement et de la Lutte contre les changements climatiques [MELCC], etc.) (Figure 1). Direct action authority refers to threats against which MFFP itself can implement or require mitigation measures as part of the authorizations and permits it issues in its capacity as resource manager. Indirect action authority refers to actions on which MFFP has an advisory role or contributes to discussions or projects initiated by third parties.

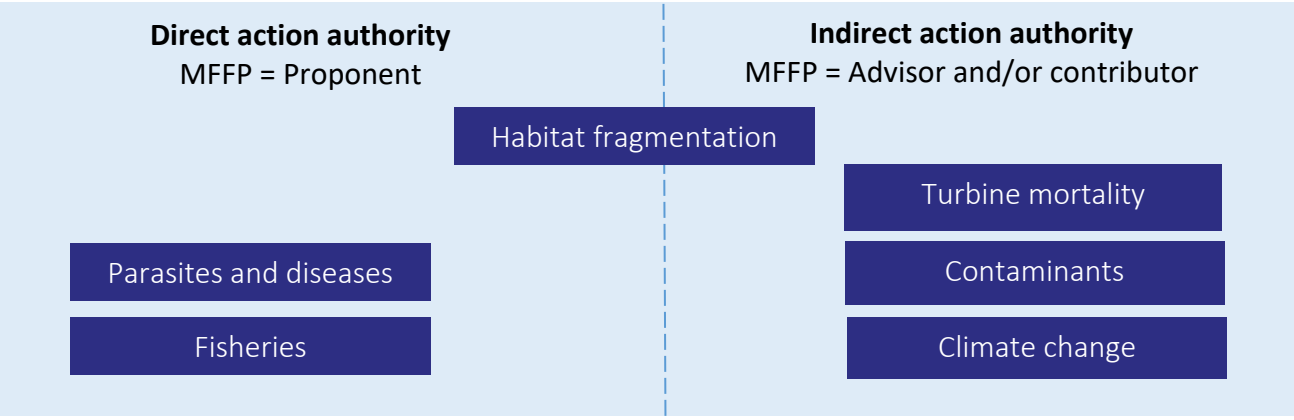


Figure 1: MFFP's authority to act on threats to the American Eel

Objective

The overall objective of MFFP's American Eel Action Plan is to ensure the recovery and sustainable management of the species in Québec. The selected actions will allow Québec to contribute to the main guidelines proposed by the Canadian Eel Working Group (CEWG, 2009, unpublished), as part of the draft National Management Plan for American Eel in Canada and taken up by the Canadian Science Advisory Secretariat in its Recovery Potential Assessment for the American Eel (DFO, 2014) (Appendix 1).

Work to be done under the action plan is aimed at achieving the short-term objectives and targets proposed by the two working groups, as well as contributing to the joint efforts of other jurisdictions involved in the recovery of the species. The locations of the main water bodies and barriers to migration targeted in the action plan are illustrated on the summary map in Appendix 2.

Actions

MFFP's American Eel Action Plan has three components:

1) increase eel production, 2) increase eel escapement to their spawning site, and 3) improve our knowledge of the species. The 15 priority actions identified are organized around seven themes.

Table 1: MFFP American Eel Action Plan

Directions	Themes	Actions
1. Increase eel production	1.1. Transfer of glass eels	1.1.1. Search for glass eel concentrations for transfer purposes
		1.1.2. Transfer glass eels to sites favourable to their growth
	1.2. Restore and maintain habitat connectivity	1.2.1. Map the eel's historical and current distributions and migration barriers
		1.2.2 Identify key obstacles to restoring free movement of eel
		1.2.3. Facilitate passage through barriers and monitor their performance
		1.2.4. Develop a best practice guide for the construction and remediation of migration barriers
2. Increase eel escapement to their spawning site	2.1. Capture and transfer of eels from upstream to downstream of the Beauharnois-Les Cèdres complex	2.1.1. Conduct interviews with commercial eel fishers in Lake St. Francis and assess the effectiveness of harvesting methods
		2.1.2. Identify eel concentration areas and develop catching methods for yellow and silver eels
		2.1.3. Transfer eels captured upstream to downstream of the Beauharnois–Les Cèdres complex
	2.2. Dam management	2.2.1. Participate in the work of the Eel Passage Research Center
		2.2.2. Take advantage of opportunities to implement best practices or leverage technologies aimed at reducing the impact of turbine mortality on eels in downstream migration
3. Acquire and update knowledge	3.1. Monitor population indicators	3.1.1. Establish a recruitment monitoring network
		3.1.2. Estimate silver eel abundance and harvest rates by the estuary's commercial fisheries
	3.2. Identify and characterize yellow eel stocks	3.2.1. Assess the relative abundance of yellow eels in targeted water bodies
	3.3. Characterize harvesting	3.3.1. Characterize the fisheries of the Lac Saint-Pierre, Pont Laviolette–Île d'Orléans, and Îles-de-la-Madeleine sectors

1. Increase eel production

The longest time series on juvenile eel abundance data are from monitoring elver runs at the fishways of the Moses-Saunders and Beauharnois hydropower generating stations, operated by hydroelectric companies. Despite the increase in eels passing through the eel ladder at Beauharnois since 2017, this survey indicates that abundance is several orders of magnitude below historical levels in the upstream portion of the St. Lawrence system. Annual recruitment of juvenile eels in the upper St. Lawrence River system, at the outlet of Lake Ontario, has been very low since the early 1990s. The average number of juvenile eels passing through the Moses-Saunders fishways in the past five years is estimated to be 1.5% of the average for the period between 1975 and 1985 (Figure 2).

Note that the MFFP continues to benefit from the collaboration of Hydro-Québec, which conducts annual monitoring of the migratory movements of eels at the Beauharnois hydropower generating station and the Chambly dam, where fishways have been in operation since the early 2000s and 1998, respectively. The government corporation has also invested $2.5 million in various eel-related programs and projects during the 2009–2013 period (Pouliot and Caumartin, 2014).

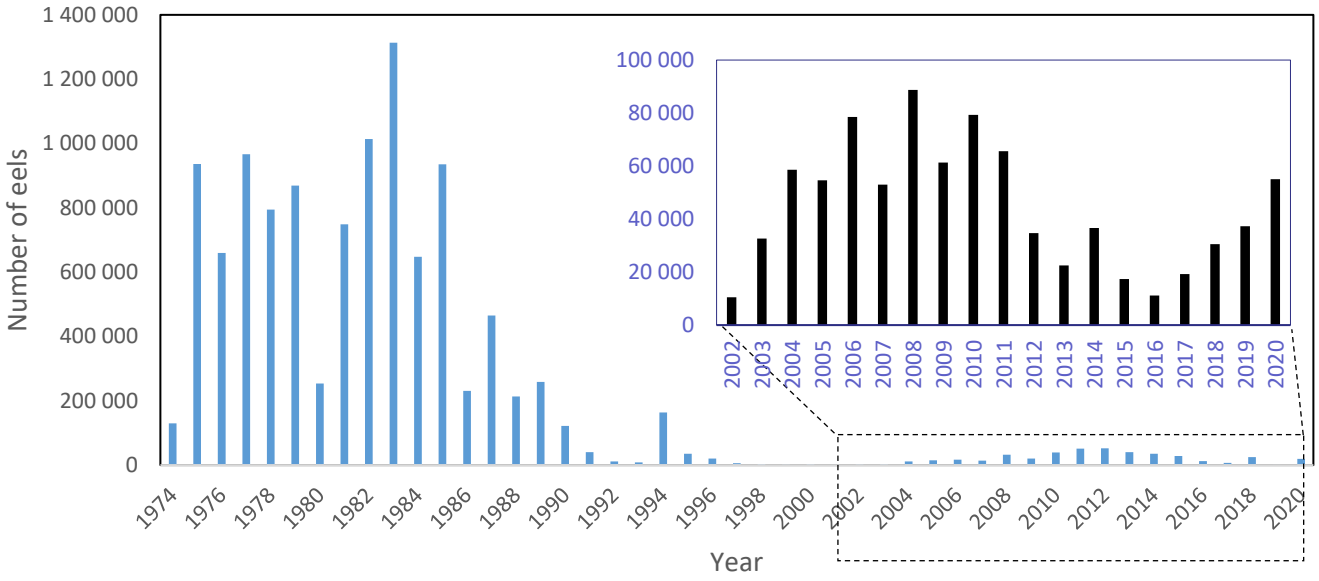


Figure 2: Recruitment index

Number of juvenile eels counted during upstream migration at the Moses-Saunders hydropower generating station fishways. From 1975 to 2005, only one fishway was in operation on the Ontario side of this dam. A second fishway has been in operation since 2006 on the New York side (source: Ontario Power Generation and New York Power Authority). The average age of eels at this site ranges from four to seven years. The inset graph shows the number of juvenile eels counted during upstream migration at the Beauharnois hydropower generating station fishways. In 2002 and 2003, only one fishway was active on the west side of this dam. A second fishway has been operating on the east side since 2004 (source: Hydro-Québec). The average age of eels at this site ranges from four to five years.

Therefore, actions to increase eel production in Québec are a priority and align with the objectives of the Canadian management plan and the targets set in the Recovery Potential Assessment (GTCA 2009, unpublished; DFO , 2014). Two strategies are being considered: Optimizing historically productive rearing areas through glass eel transfer and facilitating access to historical habitats that have been lost due to the construction of dams or other barriers to migration.

1.1. Transfer of glass eels

The aim of these actions is to recover eels whose survival is compromised by migration barriers or commercial fishing and transfer them to non-harnessed waterways where growth potential is high. Transfers of glass eels from Nova Scotia and New Brunswick were carried out in Rivière Richelieu from 2005 to 2008 and in Lake Ontario from 2006 to 2010. Transfers were halted after the *A. crassus* parasite was detected in glass eels destined for transfer. Recent results have confirmed the effectiveness of the recovery measure. In 2019 and 2020, translocated eels accounted for 33.0% and 34.5% of the commercial harvest in the estuary, respectively, whereas previously, translocated eels were less than 750 mm in size and their average size in 2020 was 809.7 mm, compared to the 889.0 mm average size of naturally recruited eels. The size distribution of translocated and naturally recruited eels is now unimodal. However, translocated eels have a lower average size and weight than natural eels, and an average age 0.8 years younger (Doucet-Caron and Dussureault, 2021). Harvest monitoring in the estuary and telemetry studies show that the migration patterns of translocated eels are similar to those of naturally recruited eels, and that translocated eels are able to migrate at least as far as the Cabot Strait (Béguer-Pon et al., 2018; Verreault et al., 2010). This evidence helps to reduce doubts about the ability of translocated eels to reach their spawning site.

1.1.1. Search for glass eel concentrations for transfer purposes

This action aims at finding new sources of glass eels in Québec, in the tributaries of the Estuary and Gulf of St. Lawrence. Inventories to assess the relative abundance of glass eels will be conducted. To avoid impeding recruitment in one rearing area over another, sample sites will be located in dammed rivers where eels cannot migrate upstream, where habitats are suboptimal for rearing, and where eels are subjected to turbine mortality during their downstream migration. A subsample of captured glass eels will be tested to ensure that individuals are not infected with the *A. crassus* parasite. Priority areas to sample are the estuaries of Côte-Nord rivers, such as the Amédée, Manicouagan, Outarde, Riverin, Sault-aux-Cochons, and Portneuf rivers. Following the development of a genetic test to detect the presence of *A. crassus*, juvenile glass eels caught early in the season by commercial fishing in the Maritimes could be a solution worth reconsidering.

1.1.2. Transfer glass eels to sites favourable to their growth

Captured glass eels will be transferred to water bodies where their growth will be optimal and where they can move downstream without turbine mortality. Recent analyses have identified Rivière Richelieu and Lake Champlain as favourable sites for glass eel transfer (Verreault, pers. comm.). This system historically supported a large commercial eel fishery, and there is minimal mortality during downstream migration because the Saint-Ours and Chambly dams on Rivière Richelieu are used for water level regulation, not hydroelectric power. Consultation with the border provinces and states will be necessary as such transfers will affect eel abundance in their waters and glass eel transfers must meet all safety standards governing fish transport.

1.2. Restore and maintain habitat connectivity

Habitat fragmentation has been identified as one of the main causes of the species' decline (Drouineau et al., 2018; Verreault et al., 2004). There are more than 3,200 dams in the eel's historical range, in addition to culverts, which limit access to approximately 12,140 km² of habitat in the St. Lawrence River watershed (Tremblay et al., 2011; Verreault et al., 2004). To guide interventions to improve connectivity, it is essential to know the eel's historical distribution, the location of all anthropogenic barriers to migration, the relative abundance of eels at the foot of these barriers, and the surface area and quality of habitats upstream from these barriers. This series of actions will focus primarily on watersheds with barriers, but that are exempt from hydroelectric power generation due to problems with turbine mortality.

1.2.1. Map the eel's historical and current distributions and migration barriers

It will be necessary to gather all data on the historical and current distribution of eels, and to update the eel migration barrier passability characterization produced by Tremblay et al. (2011). A mapping exercise will therefore be undertaken to list, in a single database, all fish survey results, reported eel observations, barriers with their passability rating, and the presence of fishways. This mapping tool will allow to calculate the surface areas of potential habitat upstream of impassable barriers, prioritize the sectors to be documented, and ultimately identify habitats where production is to be restored by installing crossing structures.

1.2.2. Identify key obstacles to restoring free movement of eels

The objective of this action is to prioritize dams where restoring the ability for eels to pass freely would be most relevant. To do this, the relative abundance of eels will be measured in certain tributaries of the St. Lawrence River where connectivity restoration is being considered. Environmental DNA (eDNA) sampling and standardized fishing will be conducted at the foot of impassable barriers, where downstream migration mortality would be very low to zero once free passage is restored. Standardized protocols will be developed to quantify abundance downstream of obstacles and characterize their passability by eels. Inventories will also contribute to updating the eel's current distribution.

1.2.3. Facilitate passage through barriers and monitor their performance

This action aims to increase eel production in habitats made inaccessible due to waterway fragmentation by installing eel ladders or removing certain migration barriers. Eel-specific crossing devices will be installed on migration barriers where mortality during downstream migration would be minimal once free passage is restored, and the presence of eels downstream has been confirmed by the inventories described in the previous section.

Under the ACDW (Chapter C-61.1), MFFP may impose conditions when authorizing the construction, remediation, or reconstruction of dams. Installation and maintenance of crossing devices may be included in these conditions. Through these authorization conditions, MFFP can also provide expertise to support dam owners in implementing these concepts. In addition, when the *Environment Quality Act* (Chapter Q-2) applies, MFFP sends concerns regarding eels to MELCC through wildlife expert advisories.

MFFP could also suggest that owners of existing structures that are within priority areas where production should be restored collaborate on crossing device projects. The proponent will be asked to monitor the performance of these facilities, either through ad hoc monitoring or ongoing monitoring using counters installed in the fishways.

Fisheries and Oceans Canada also has legislative powers to impose certain obligations with respect to the free passage of fish. According to the *Fisheries Act* (R.S.C. [1985], c. F-14), this department has the authority to require the owner or person in charge of an obstruction to take any action it considers necessary to ensure the free passage of fish.

1.2.4. Develop a best practice guide for the construction and remediation of migration barriers

A best practices guide will be developed to provide the biologists responsible for authorization requests with the tools they need to analyze projects involving the construction and remediation of migration barriers (dams, weirs, culverts, etc.), and to define the conditions to be met when wildlife expert advisories are issued. This will provide analysts and project proponents with a list of mitigation measures to prevent the restriction of eel movement upstream or downstream of an obstacle. In addition, a description of the historical distribution of the species will be added to define where connectivity restoration projects are suitable for eels.

2. Increase eel escapement to their spawning site

Landings of yellow and silver eels based on voluntary declarations by commercial fishers have been declining steadily since the early 1990s. This can be explained by the declining abundance of the species, combined with the various commercial gear buyback programs conducted during the 2002–2013 period. In 2016, reported commercial landings for the entire St. Lawrence River were the lowest on record (33.3 tonnes) and represent only 7.2% of the average for the 1975–1990 period (Figure 3).

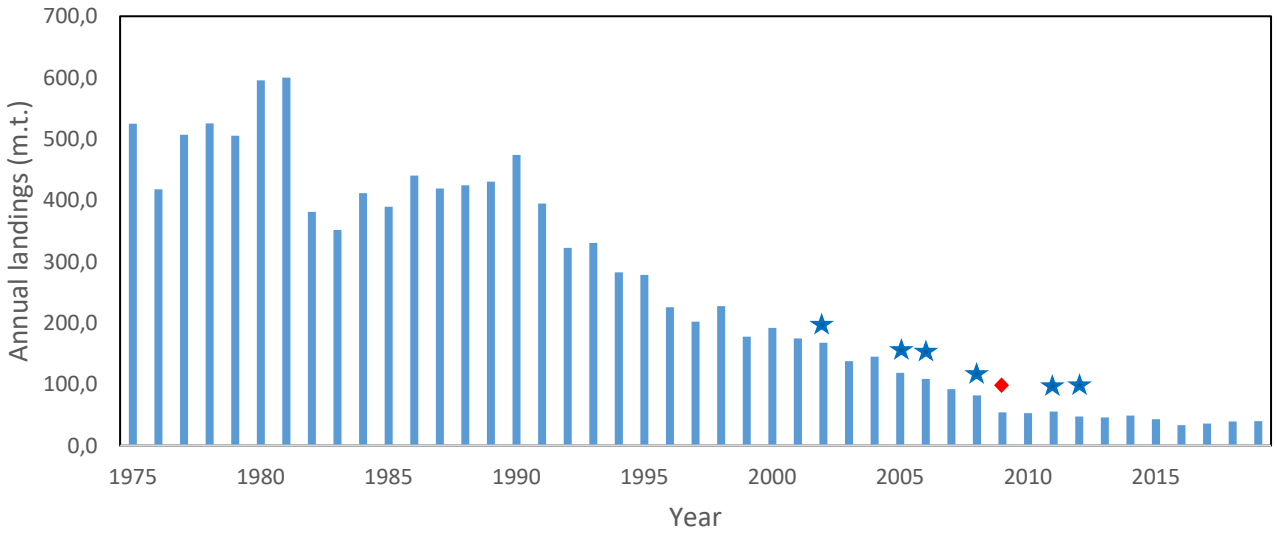


Figure 3: Eel landings reported by commercial fishers

Landings of yellow and silver eels in the St. Lawrence River declared by commercial fishers. Silver eels have an average age of 12 to 17 years. No recent biological information is available for yellow eels. The red diamond indicates the eel-specific licence and gear buyback program, and the blue stars represent multispecies licence and gear buyback programs.

Two of the main threats that limit eel escapement to their spawning site are commercial fisheries that target the species directly or indirectly and turbine mortality. Significant efforts have been made in Québec to reduce eel mortality through commercial fishing. Various commercial fisheries licence buyback programs, which were implemented in the early 2000s with the financial participation of Hydro-Québec, resulted in a very significant decrease in eel mortality during their migration to the Sargasso Sea. However, very few measures have been implemented to limit eel turbine mortality during the eels' downstream migration. Therefore, actions leading to an increase in eel escapement to their spawning site will be focused on reducing turbine mortality in the coming years.

Various strategies can be implemented to reduce turbine mortality for migrating eels. Some strategies involve intercepting and moving eels to prevent passage through the turbines, such as capturing and transferring eels from upstream to downstream of hydroelectric dams. Other strategies aim to limit mortality through passive actions, such as installing screens on turbine intakes, installing fish-friendly turbines, using spillways at critical migration times, constructing behavioural guidance structures, and constructing by-pass channels.

2.1. Capture and transfer eels from upstream to downstream of the Beauharnois–Les Cèdres complex

A decision analysis was conducted in 2005 as part of the eel action plan for the St. Lawrence River to determine the best compensation measures to reduce eel turbine mortality (Parnell and Greig, 2005). The capture and transfer of silver eels from upstream of the Moses-Saunders dam to downstream of the Beauharnois–Les Cèdres complex in Lac Saint-Louis was identified as a potential compensation measure that has been carried out since 2008 by Ontario Power Generation. Studies have found that handling the eels via this action does not appear to compromise their maturation or migration (Béguer-Pon et al., 2018; Dumont et al., 2010; Dussureault and Verreault, 2013).

Nearly 60% of elvers that pass upstream through the Beauharnois hydropower generating station remain in Lake St. Francis (Caumartin et al., 2018), suggesting that capturing and transferring eels from this lake could be effective in mitigating the 17.8% mortality rate caused by the station. However, before implementing such a strategy, research and development projects must be conducted, particularly to identify the best areas and methods of capture. A capture and transfer pilot project will be conducted in the Québec waters of Lake St. Francis to complement the compensation work being carried out by Ontario Power Generation in Ontario waters upstream of the Beauharnois–Les Cèdres and Moses-Saunders dams.

2.1.1. Conduct interviews with commercial eel fishers in Lake St. Francis and assess the effectiveness of harvesting methods

In Lake St. Francis, commercial fishers operate multi-species fishing gear that is likely to catch eels. These fishers could be involved in the eel capture and transfer strategy via their incidental catches or by granting them an experimental fishing licence.

A survey of Lake St. Francis commercial fishers will be conducted to estimate the number of eels caught accidentally and to ascertain the fishers' interest in collaborating on the project. If the number of incidental eel catches is low, contracts for eel capture and holding may be awarded to commercial fishers to assess the effectiveness of eel capture using additional fishing gear than that currently in use. Captured eels will then be retrieved for characterization.

2.1.2. Identify eel concentration areas and develop catching methods for yellow and silver eels

To increase the number of eels caught and transferred, additional efforts besides capture through commercial fisheries will have to be implemented. Recent work to determine eel migration patterns in Canal de Beauharnois identified the main path used by silver eels in that sector. Various capture gear and sites will need to be tested in Canal de Beauharnois, as well as in the preferred habitats identified in action, “3.2. Identify and characterize yellow eel stocks” to determine the best capture method for maturing yellow eels and migrating silver eels in Lake St. Francis. Expertise could be developed jointly by MFFP and Hydro-Québec, which operates the Beauharnois–Les Cèdres complex.

2.1.3. Transfer eels captured upstream to downstream of the Beauharnois–Les Cèdres complex

Eels caught in Lake St. Francis by commercial fishers and alternative methods will be transferred downstream of the Beauharnois–Les Cèdres complex. A subsample could be tagged with a passive integrated transponder (PIT-tag) transmitter so that the monitoring and characterization of commercial fisheries landings and the Estuary Fish Inventory Network can confirm the effectiveness of the measure (see actions 3.1.2. and 3.3.). MFFP will support the operator in carrying out this action.

2.2. Dam management

Dams can have a double impact on eels. They limit access to rearing habitats by slowing or blocking eel migration, and they are one of the main causes of turbine mortality during eel migration to the Sargasso Sea (Verreault et al., 2004).

2.2.1. Participate in the work of the Eel Passage Research Center

The Eel Passage Research Center (EPRC) is a virtual research centre overseen by the Electrical Power Research Institute (EPRI). Its goal is to identify and develop cost-effective, biologically and operationally efficient ways to enable migrating adult eels to pass safely downstream of medium and large hydroelectric facilities. The EPRC’s technical committee includes representatives from hydroelectric power companies (Hydro-Québec, New York Power Authority, Ontario Power Generation, and Duke Power) and provincial and federal government ministries and departments (MFFP, Fisheries and Oceans Canada, Ontario Ministry of Natural Resources and Forestry, New York State Department of Environmental Conservation, and U.S. Fish and Wildlife Service).

An initial round of work took place from 2013 to 2018, to evaluate the effectiveness of different types of behavioural guidance structures for eels (e.g., light, electricity, sound, etc.). A second round of work is planned from 2019 to 2024. Over the next few years, work will focus on designing and implementing a prototype light diversion structure, and possibly one for sound diversion. MFFP will continue to be a member of the technical committee to guide and participate in EPRI’s research on the St. Lawrence River in order to share Québec’s expertise in eel management and learn from the techniques that may be developed.

2.2.2. Take advantage of opportunities to implement best practices or leverage technologies aimed at reducing the impact of turbine mortality on eels in downstream migration

In addition to EPRI's research on developing a behavioural guidance structure, other mitigation measures may be evaluated, notably as part of the authorization conditions that will be imposed on proponents of projects to construct and remediate barriers to fish migration. Accordingly, the best practices guide described in Section 1.2.4. will include alternative dam management methods to increase eel escapement to their spawning site. For example, adapted management of turbine water flow, the use of spillways and the addition of screens upstream from turbines during critical downstream migration periods, as well as changing turbine types for models causing lower mortality rates, are possible solutions to facilitate the downstream migration of silver eels.

3. Acquire and update knowledge

Knowledge of the eel's status in Québec is heterogeneous. Recruitment in the western part of the Upper St. Lawrence, near the Beauharnois hydropower generating station is well documented compared to the situation in the watersheds associated with the St. Lawrence River and Gulf, where eels spend a large part of their life cycle. Actions to maintain existing monitoring and develop new monitoring will be undertaken to improve understanding of the eel's status locally, regionally, and across the province.

3.1. Monitor population indicators

3.1.1. Establish a recruitment monitoring network

The most comprehensive knowledge on eel recruitment relates to the Upper St. Lawrence region. Annual data on the number of migrating eels, as well as regular estimates of age structure and growth (length–age relationship) are available at the Moses-Saunders and Beauharnois dams. More recently, similar monitoring was implemented on Rivière Richelieu at Chambly. These operations are coordinated by the hydroelectric power companies responsible for these structures, in collaboration with MFFP for laboratory analyses. To improve the understanding of eel recruitment across the province, there is a need to quantify and characterize recruitment in other watersheds that are productive for eels. These watersheds are to be determined. For example, data collection since 2001 on eel recruitment and movement in Rivière Saint-Jean in Gaspésie, and MFFP's annual presence on this control river for Atlantic Salmon may make it a good candidate. Another watershed that could also be considered is Petite rivière de la Trinité, where eel-related work has already been done and where a team from MFFP is working nearby to monitor another control river for salmon.

The purpose of this action plan is therefore to maintain MFFP's participation in existing monitoring programs at Beauharnois and Chambly, and to set up others throughout the eel's range in Québec. Refining our knowledge of recruitment and continuing long-term monitoring will enable us to assess the effectiveness of the recovery actions that have been implemented.

3.1.2. Estimate silver eel abundance and harvest rates by the estuary's commercial fisheries

The most detailed knowledge of the number of adult eels that escape the St. Lawrence system to their spawning site in the Sargasso Sea comes from commercial fisheries monitoring in the St. Lawrence Estuary (Kamouraska region). The number of eels harvested, their size, age, origin (translocated or not),

and the presence of the parasite *A. crassus* are rigorously monitored each year by characterizing a sample of eels recovered from commercial fishers.

Based on evaluations of the harvest rate by capture-mark-recapture that were conducted in 1996–1997, 2010–2011, and 2020–2021, the number of eels captured by estuary fishers makes it possible to estimate the abundance of eels migrating downstream in the St. Lawrence River that were produced upstream of the fishing area. This monitoring will be maintained and the harvest rate re-evaluated with the previously used protocol (Caron et al., 2003; Daigle and Julien, 2012; Talbot et al., 2011).

3.2. Identify and characterize yellow eel stocks

3.2.1. Assess the relative abundance of yellow eels in targeted water bodies

A lack of knowledge on the distribution of growing (yellow) eels will be addressed by deploying a standardized protocol to assess the relative abundance of eels in Québec waters. These inventories will also estimate the relative contribution of different rearing areas to the overall spawning stock and determine the eels' size and age distribution as well as their growth rate. The water bodies targeted are the Ottawa River, Lake St. Francis, Lac Saint-Louis, Lac des Deux-Montagnes, Lac Saint-Pierre, Rivière Richelieu, and the brackish estuaries and lagoons in Gaspésie. Habitat will be characterized at the same time as fish inventories.

3.3. Characterize harvesting

Little information is available on the characteristics of the fisheries and harvested stocks of Lac Saint-Pierre, in the area between Pont Laviolette and Île d'Orléans, and in Îles-de-la-Madeleine. The last efforts to characterize fishing activity in the first two sectors date back to 2008 and 2014, and the last commercial fishery profiles of Îles-de-la-Madeleine are from 2007 and 2008. It is essential to improve knowledge of eel harvesting in these rearing areas.

3.3.1. Characterize the fisheries of the Lac Saint-Pierre, Pont Laviolette–Île d'Orléans, and Îles-de-la-Madeleine sectors

The characterization of commercial eel fisheries will be adapted to different regional realities. In Îles-de-la-Madeleine, Lac Saint-Pierre, and in the section between Pont Laviolette and Île d'Orléans, multi-species or eel-specific fishing activity will be quantified by fishing gear inventory. In addition, a sample of catches recovered from commercial fishers will be characterized to establish age, size, sex, origin (translocated or not), the prevalence of *A. crassus*, and the proportion of yellow and silver eels in the harvest of the three sectors. In Îles-de-la-Madeleine, conducting surveys of commercial fishers and develop a sentinel fishery program will be additional strategies used to characterize the fisheries. In addition, eel samples will be sent to MELCC to assess the presence of contaminants and heavy metals that could affect the eel, and to develop the American eel consumption guide for the sector.

A provincial action plan in the context of local, regional, national, and international collaborations

Due to the panmictic nature of the species, the heterogeneity of the male-to-female ratio, and its long migrations extending far beyond Québec, MFFP will continue to collaborate with neighbouring jurisdictions and partners. MFFP's participation in various working committees will allow the pursuit of its involvement in concerted actions with other jurisdictions and demonstrate Québec's willingness to work towards the recovery of the American Eel throughout its range. In parallel with the implementation of the eel action plan, MFFP will participate in scientific and technical meetings and take advantage of any opportunities for knowledge acquisition that may arise. Disseminating the results obtained through the action plan will also be a priority.

More locally, a number of knowledge acquisition initiatives and actions to improve barrier passability are being led by non-governmental partners. To name just a few, watershed organizations, not-for-profit lake and waterway protection organizations, and Indigenous communities are undertaking knowledge acquisition work on the distribution of American Eel and the passability of migration barriers. The knowledge of these partners will be put to good use, not only in mapping the eel's current and historical distributions, but also in all other actions to which they contribute their expertise.

Appendix 1: Objectives and targets of the Canadian Management Plan and the Recovery Potential Assessment for the American Eel for Eastern Canada

National Management Plan for American Eel in Canada (CEWG, 2009, unpublished)

Long-term objective:

Restore the overall abundance of the American Eel in Canada to its mid-1980s level, as measured by the key available abundance indices, specifically:

- Ensure the American Eel is present in all areas of its historical range.
- Establish a sustainable fishery of elvers[1] and large eels that produces economic, social, and cultural benefits for fishers and society in all areas where fisheries have been present in the past.

Short-term objective:

Reduce eel mortality from all sources by 50% compared to the average from 1997 to 2002.

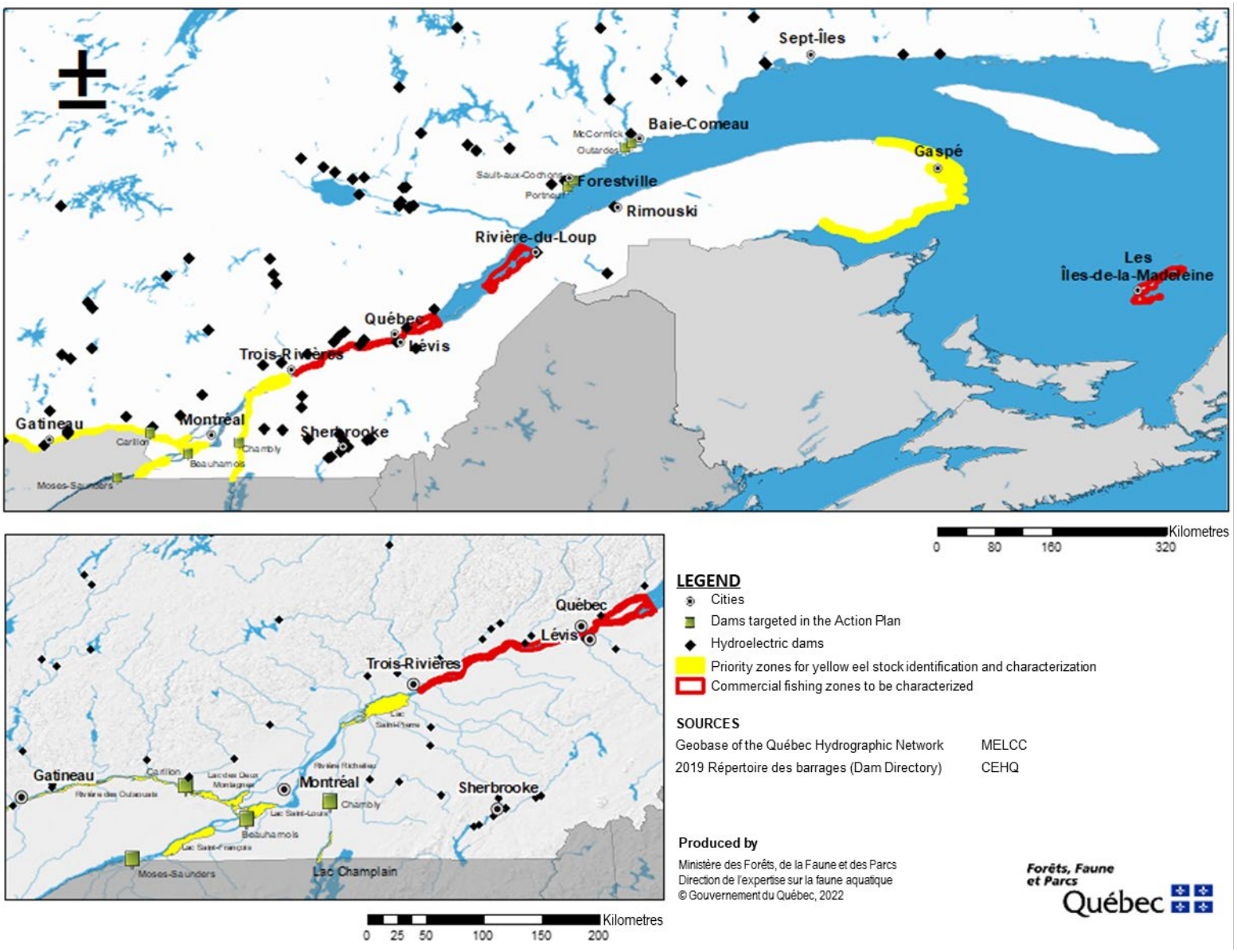
[1] Glass eel fishing is not permitted in Québec.

Recovery Potential Assessment for the American Eel (*Anguilla rostrata*) for Canada (DFO , 2014)

This document reflects the objectives of the unpublished National Management Plan for American Eel in Canada and defines recovery targets regarding range and abundance in the short, medium, and long terms.

Targets	Short term (one generation, ~16 years)	Medium term (three generations, ~50 years)	Long term (> 50 years)
Range	Maintain eel range at its current level and increase its distribution to improve eel escapement from rearing areas so that an area's recruitment is equivalent to what was lost during the last generation.	Increase the eel's range in the zones so that recruitment in rearing areas is equivalent to what was lost over the past three generations.	Restore eel recruitment and escapement in the majority of historically suitable and productive habitats across Canada to support abundance targets.
Abundance	Stop the decline in abundance indices (recruitment, resident stock, and spawner production) where declines have occurred and demonstrate increases in these indices within a generation, and—where benchmarks have been established—increase abundance outside the critical zone.	Restore the overall abundance of the American Eel, in regions of Canada and across the country, to its mid-1980s levels, based on the available primary abundance indices.	Restore and maintain abundance in the Healthy zone of the precautionary approach framework.

Appendix 2: Location of projects and sectors targeted by MFFP's American Eel Action Plan



Appendix 3: Timeline and collaborators for MFFP's American Eel Action Plan

Actions	Completed actions			Upcoming actions			Desired collaborators
	2019–2020	2020–2021	2021–2022	2022–2023	2023–2024	Subsequent years	
1.1.1. Search for glass eel concentrations for transfer purposes							Hydroelectric power companies operating on targeted rivers
1.1.2 Transfer of glass eels to sites favourable to their growth							Vermont Fish & Wildlife Department New York State Department of Environmental Conservation–U.S. Fish and Wildlife Service Hydro-Québec
1.2.1. Map the eel's historical and current distributions and migration barriers							Indigenous communities Watershed organizations Non-profit lake and waterway protection organizations
1.2.2 Identify key obstacles to restoring free movement of eels							
1.2.3. Facilitate passage through obstacles and monitor their performance							Owners of targeted dams Proponents of projects to construct and remediate migration barriers
1.2.4. Develop a best practice guide for the construction and remediation of migration barriers							DFO MELCC Independent stakeholders in the hydropower industry
2.1.1. Conduct interviews with commercial eel fishers in Lake St. Francis and assess the effectiveness of harvesting methods							Commercial fishers Hydro-Québec Ontario Power Generation
2.1.2 Identify eel concentration areas and develop catching methods for yellow and silver eels							
2.1.3. Transfer eels captured upstream to downstream of the Beauharnois–Les Cèdres complex							Hydro-Québec
2.2.1 Participate in the work of the Eel Passage Research Center (EPRC)							Members of EPRC's technical committee

Actions	Completed actions			Upcoming actions			Desired collaborators
	2019–2020	2020–2021	2021–2022	2022–2023	2023–2024	Subsequent years	
2.2.2. Take advantage of opportunities to implement best practices or leverage technologies aimed at reducing the impact of turbine mortality on eels in downstream migration							Dam owners Proponents of projects to construct and remediate migration barriers MELCC DFO
3.1.1. Establish a recruitment monitoring network							Dam owners Hydro-Québec for the Beauharnois hydropower generating station and the Chambly dam Indigenous communities Watershed organizations
3.1.2. Estimate silver eel abundance and harvest rates by the estuary's commercial fisheries						As needed	Commercial fishers
3.2.1. Assess the relative abundance of yellow eels in targeted water bodies							
3.3.1. Characterize the fisheries of the Lac Saint-Pierre, Pont Laviolette–Île d'Orléans, and Îles-de-la-Madeleine sectors							Commercial fishers MAPAQ MELCC

MELCC: Ministère de l'Environnement et de la Lutte contre les changements climatiques
DFO: Fisheries and Oceans Canada
MAPAQ: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec

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