2011

Management Plan

American Eel (*Anguilla rostrata*)

Prepared by the Wildlife Division

Department of Environment & Conservation

Wildlife Division

Newfoundland Labrador

What is the *Endangered Species Act*?

The *Endangered Species Act* was enacted in 2001 to ensure that species at risk of extinction in Newfoundland and Labrador, as well as their residence and habitat critical to their survival and recovery, receive protection. Furthermore, the *Endangered Species Act* ensures that efforts to recover these species are initiated. This legislation applies to species, sub-species and populations that are native to the province, but does not include marine fish, bacteria, or viruses. It also does not apply to introduced species, except in extraordinary circumstances. The *Endangered Species Act* fulfills the province's commitments to the *Accord for the Protection of Species at Risk*. The *Species at Risk Act*, was enacted in June 2003 as the federal government's contributing piece of legislation to the Accord.

What is recovery?

For species at risk of continued population decline or extinction, such as those listed in the *Endangered Species Act* as endangered, threatened, or vulnerable, recovery is the process by which its population decline is stopped, stabilized, and reversed. This occurs when a threat to the whole population or individuals is removed or reduced. A species is not considered to be recovered, and thereby removed from the *Endangered Species Act*, until its long-term persistence in the wild is secured. It is possible that a species will always be considered rare. This typically occurs when the species is restricted to an extremely unique or uncommon habitat or habitat loss has been extensive. For each species listed as endangered or threatened a recovery team is put in place to oversee the recovery process and write a recovery plan. For each species listed as vulnerable a management plan is written to guide the recovery process.

What is a management plan?

A management plan is developed by staff of the Wildlife Division in conjunction with species experts. It sets the goals and actions deemed necessary to prevent a species from further decline and identifies threats to the species' recovery. Section 24 of the *Endangered Species Act* states that a management plan will identify measures for the conservation of a species and include information that may be prescribed in regulations made by the Minister under subsection 44(2). A management plan has to be developed within three years of a species being listed under the *Endangered Species Act*. These management plans are reviewed regularly and updated as necessary.

What's the next step?

Implementing the plan! Many people work towards implementing the actions outlined in a management plan, including people from municipal, provincial, and federal governments, aboriginal groups, industry, universities, interest groups, and local communities. Each play a significant role in the implementation of the management plan. Success in species recovery depends on the commitment and cooperation of many different people and requires all responsible jurisdictions, as well as all Newfoundlanders and Labradoreans, to work together to support and implement management plans.

Disclaimer

A species listed as vulnerable under the Newfoundland and Labrador *Endangered Species Act* requires the development of a management plan. These management plans are prepared in cooperation with jurisdictions responsible for the species. Implementation of the goals and actions identified in this document ultimately depends on the ongoing program priorities and budgetary constraints of the participating jurisdictions and organizations. The goals and actions identified in a management plan are based on the best existing knowledge and are subject to modifications resulting from new findings and revised objectives. They do not necessarily represent the official positions of the governmental or non-governmental organizations, or individuals, involved.

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COVER PHOTOGRAPH

Adult American Eel, United States Fish and Wildlife Service.

RECOMMENDED CITATION

Wildlife Division. 2010. Management Plan for the American Eel (*Anguilla rostrata*) in Newfoundland and Labrador. Department of Environment and Conservation, Government of Newfoundland and Labrador, Corner Brook. Canada. v + 29 pp.

PREFACE

Management of the American Eel and other fish species in Newfoundland and Labrador falls under the jurisdiction of the federal Department of Fisheries and Oceans (DFO). The province of Newfoundland and Labrador does own the inland fish resource and therefore has the mandate to license anglers (excluding American Eel) and regulate the use of the resource. Additionally, through the environmental assessment process and various land use referrals, the province has the opportunity to provide input into the management of inland American Eel habitat. However, the province does not have any direct jurisdiction over the management of American Eel.

While this management plan has been developed by the Department of Environment and Conservation, success in the conservation of this species will depend on the commitment and cooperation of agencies that will be involved in implementing the direction set out in the plan and will not be achieved by the Department of Environment and Conservation or any other party alone.

AUTHORS

The initial draft of this plan was prepared by Karen Rashleigh and Emily Herdman (Wildlife Division, Government of Newfoundland and Labrador (NLWD)). Robert Perry (NLWD) provided expertise and direction on data analysis and presentation of final results.

ACKNOWLEDGMENTS

We wish to thank the authors of the American Eel Assessment and Status Report: V. Tremblay, D.K. Cairns, F. Caron, J.M. Casselman and N.E. Mandrak. Much of the information in this document originates from the Status Report. Thanks also to Roger Gallant (Mi'kmaq Alsumk Mowimsikik Koqoey Association) for additional information and revisions to the draft document. Revisions were completed by Robert Perry, Don Keefe, Susan Squires and Shelley Pardy Moores (NLWD), and Helen Griffiths, Mary Dawe, Geoff Veinott (Department of Fisheries and Oceans).

RESPONSIBLE JURISDICTIONS

Fisheries and Oceans Canada

Government of Newfoundland and Labrador

EXECUTIVE SUMMARY

The American Eel (*Anguilla rostrata*) has been assessed by COSEWIC as a species of Special Concern and has been listed under the Newfoundland and Labrador *Endangered Species Act* as a Vulnerable species.

In North America, American Eel are found from Hamilton Inlet-Lake Melville, Labrador in the north to the Gulf of Mexico, Panama and the West Indies in the south. Within Canada, they occur in the provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador. All American Eel spawn in the Sargasso Sea and they are considered a panmictic species.

American Eel are found in a variety of habitats including streams, rivers, and muddy or silt-bottomed lakes during their freshwater stage, as well as oceanic waters, coastal bays and estuaries. They are extremely mobile and may access habitats that appear unavailable to them. Habitat availability may be reduced by factors such as habitat deterioration, barriers to upstream migration (larger eels), and barriers to downstream migration, such as turbines, that can result in mortality.

Eels are fished commercially, recreationally and by aboriginal peoples in the province. These fisheries target the yellow and silver eel life history stages, with commercial fisheries generally concentrated at the mouths of rivers.

Population declines have been documented for American Eel over the past three decades throughout much of this species' range, particularly during the past decade. Declines have been observed in areas assessed from the St. Lawrence River, Lake Ontario and Gulf of St. Lawrence regions. These declines may have had significant impact on total reproductive output, as they historically formed a substantial proportion of the breeding population. There is comparatively little information available related to eel abundance in many regions, including Newfoundland and Labrador.

Within the province, quantitative electrofishing surveys in three rivers in the 1980s and 1990s indicated decreased abundances. However, commercial logbook data and landings data indicate a decrease in both annual landings and participation in the fishery over the period of 1990 to 2009, while Catch per Unit Effort (CUE) has remained relatively constant.

The purpose of this management plan is to establish the goals and actions required to ensure the American Eel long-term persistence as a self-sustaining viable species throughout its current range in Newfoundland and Labrador. To this end, the following three goals have been identified:

> Goal 1**.** Complete research to close gaps in our understanding of American Eel population trends and demographics.

Goal 2. Assess the extent of existing and potential threats to American Eel populations within the province and develop mitigation strategies to address them.

Goal 3. Collect traditional and local knowledge and increase interaction and knowledge-sharing among jurisdictions, stakeholders, and traditional knowledge holders with respect to American Eel management.

Specifically, these goals will achieve the following objectives:

- Assess abundance and trends in American Eel in Newfoundland and Labrador;
- Design and implement systematic fisheries-independent research monitoring programs;
- Assess threats to American Eel habitat and populations in the province and develop mitigation strategies to protect against future harm;
- Collect information on traditional and historical use as well as the importance of American Eel in the province;
- Develop partnerships with stakeholders, management agencies, and the public to share information about American Eel in the province.

The success in the conservation of this species will depend on the commitment and cooperation of the agencies and partners involved in the implementation of the plan.

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ASSESSMENT AND LEGAL STATUS

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<tr><td colspan="4">Reason for designation: Indicators of the status of the total Canadian component of this species are not available. Indices of abundance in the Upper St. Lawrence River and Lake Ontario have declined by approximately 99% since the 1970s. The only other data series of comparable length are from the lower St. Lawrence River and Gulf of St. Lawrence, where four out of five time series declined. Because the eel is panmictic, i.e. all spawners form a single breeding unit, recruitment of eels to Canadian waters would be affected by the status of the species in the United States as well as in Canada. Prior to these declines, eels reared in Canada comprised a substantial portion of the breeding population of the species. The collapse of the Lake Ontario-Upper St. Lawrence component may have significantly affected total reproductive output. Time series of elver abundance, although relatively short, do not show evidence of an ongoing decline and recent data suggest that declines may have ceased in some areas. However, numbers in Lake Ontario and the Upper St. Lawrence remain drastically lower than former levels, and the positive trends in some indicators for the Gulf of St. Lawrence are too short to provide strong evidence that this component is increasing. Possible causes of the observed decline such as habitat alteration, dams, fishery harvest, oscillations in ocean conditions, acid rain, and contaminants, may continue to impede recovery.</td></tr>
<tr><td colspan="4">Newfoundland and Labrador occurrence: Widespread on the island portion of the province, including freshwater and estuarine waters on the Avalon Peninsula, eastern Newfoundland, central Newfoundland, the south-west coast and Great Northern Peninsula. In Labrador, the Northern Limit has been described as Hamilton Inlet-Lake Melville, although rare occurrences have been documented further north on the English River.</td></tr>
<tr><td colspan="4">Canadian occurrence: The Canadian range of the American Eel includes suitable and accessible freshwater, estuaries, and coastal marine waters connected to the Atlantic Ocean, including the provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland and Labrador, as far north as the Labrador coast(see aforementioned). The natural limit of their inland distribution in the Great Lakes region is Niagara Falls.</td></tr>
<tr><td colspan="4">Current legal protection: Endangered Species Act (NL)
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DESCRIPTION

American Eel are from the family Anguillidae and are the only member of the genus *Anguilla* in North America. Although *Anguilla* are considered “freshwater eels”, they may complete part of or their life cycle in salt water (COSEWIC 2006). The distribution of European eel (*Anguilla Anguilla*) and American Eel overlap in the Sargasso Sea and Iceland (COSEWIC 2006). Hybrids of these species have been identified in Iceland (Avise et al. 1990). Genetically, these two species are “closely related” but are distinct from other *Anguilla* species (Jessop 2006).

All American Eel spawn in the Sargasso Sea and are considered to be panmictic with all members mating randomly as a single breeding population and therefore there is “no geographic heterogeneity” (COSEWIC 2006). This understanding is based largely on genetic evidence presented by Avise et. al (1986) and Wirth and Bernatchez (2003), and additional genetic sampling throughout the species’ range is warranted. This management plan treats the American Eel as a single population throughout its distribution.

American Eel have a snake-like shape, with a single continuous dorsal fin that extends from approximately one third of the way down the back around the tail to the vent (Jessop 2006). Coloration varies with developmental stage, ranging from a lack of pigmentation in early stages (Scott and Crossman 1973) to bronze or black on the back and silvery below in sexually mature adults (Jessop 2006).

American Eel can reach lengths of 1.5 m and weights of 6.8 kg (Scott and Scott 1988). Eels sampled from insular Newfoundland range from 19 g to 1650 g (Bouillon and Haedrich 1985; Jessop et al. 2009) and 329 mm to 931 mm total length (silver eels) and 159 mm to 840 mm (yellow eels) (Gray and Andrews 1970, 1971; Bouillon and Haedrich 1985; Jessop et al. 2009). Females reach greater lengths than their male counterparts (Bouillon and Haedrich 1985; Jessop 2006; Jessop et al. 2009) and eels >400 mm captured in insular Newfoundland are almost exclusively female (Bouillon and Haedrich 1985; R. Gallant, pers. comm.).

ECOLOGY

The life histories of American Eel encompasses marine (coastal and oceanic), estuarine, and freshwater environments. Inferences from the distribution of sampled larvae indicate that spawning and hatching occur in a single location in the Sargasso Sea (DFO 2010). American Eel are semelparous (i.e. spawn only once) with a late onset of maturity. The various life history stages are differentiated according to migration and morphology – egg, leptocephalus, glass eel, elver, yellow and silver eel (Figure 1).

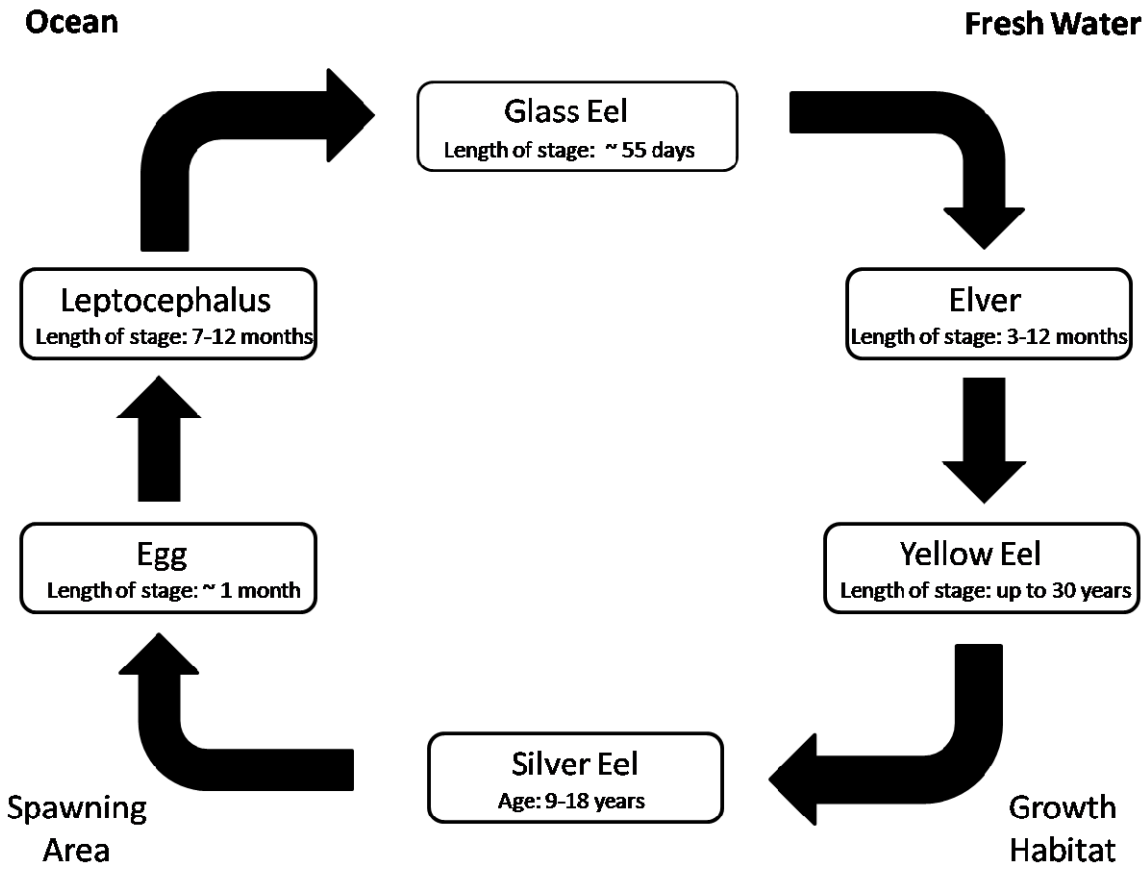

Figure 1. American Eel Life Cycle (adapted from Jessop 2006). Life stages on the right hand side of the figure are found predominantly in fresh water and those on the left hand side are found mostly in salt water. Glass eels and Silver eels move from salt water to fresh water and vice versa.

Eggs are deposited in the Sargasso Sea and once hatched into leptocephali (larvae) they are transported northward with the Gulf Stream to the coastal waters of eastern North America (Jessop 2006). At 55-65 mm, leptocephali metamorphose into transparent glass eels, and begin actively moving towards shore (Kleckner and McCleave 1985; Jessop 2006). Glass eels grow into elvers which are small (50-70 mm), pigmented, and sexually undifferentiated eels, found in coastal and freshwater habitats (Jessop 2006; COSEWIC 2006). Elver up-river migrations occur between late April and August, with timing influenced by location, temperature, water flow, and tidal cycles (COSEWIC 2006). Elvers can move up river for many miles, though some remain in estuarine and coastal waters (Jessop 2006).

The yellow eel stage comprises the main growth period of American Eel, and at this stage sexual differentiation occurs (Jessop 2006; COSEWIC 2006). This stage can last for over 30 years in some environments (Jessop 2006). Yellow eels sampled in insular

Newfoundland begin maturation between nine and 18 years of age (Gray and Andrews 1971; Bouillon and Haedrich 1985).

Growth rates of eels are affected by habitat and competition. Similar to other populations (e.g. southern Gulf of St. Lawrence) American Eel in western Newfoundland experience decreased growth rates with increasing time spent in freshwater (Jessop et al. 2009; Hudson 1974; Lamson et al. 2009). However, in insular Newfoundland, Gray and Andrews (1971) found slower growth of young eels (< 6 years of age) that developed in brackish water when compared to freshwater. Bouillon and Haedrich (1985) proposed that higher growth rates occur in larger watersheds due to a decreased elver density which reduced intraspecific competition. Jessop (2010) reported a general trend in increased female growth rates (adjusted for degree days) with increasing latitude north of 44ºN and concluded that females have increased body size at lower temperatures (i.e., follow the temperature-size rule). Males, however, do not follow the same trend.

Sexual differentiation may occur at a critical size rather than age (Oliveira 1999), with reports for American Eel indicating a minimum size of 150 mm total length for differentiation to occur (Dolan and Power 1977), with sex determined by the time an eel reaches 270 mm (Oliveria and McCleave 2000). Sex ratios may be influenced by population density (males more common at higher densities; Krueger and Oliveira 1999), as well as river size (larger rivers tend to produce a higher number of females) and habitat quality (the proportion of males tends to be higher in areas of relatively poor habitat) (Jessop 2006).

Throughout much of their distribution in Canada, more than 95% of sexually differentiated eels are female (COSEWIC 2006). Sex ratios in insular Newfoundland have also been shown to be female-biased (Gray 1969; Gray and Andrews 1971, Bouillon and Haedrich 1985; Jessop et al. 2009; R. Gallant, pers. comm.).

In preparation for migration, several physiological changes occur during the transition from a yellow to silver eel including, change in color (Gray and Andrews 1971; Scott and Crossman 1973), and degeneration of the digestive tract, enlargement of pectoral fins changes in eye diameter, and a decrease in the gonado-somatic index (Durif et al. 2005). Fecundity increases with body size, and estimates of egg production range from two million for a 450 mm female to 20 million for a 1130 mm female (Jessop 2006).

Size at maturation varies geographically and with sex (Jessop 2006, 2010). Males tend to have a relatively smaller size and age at migration, compared to their female counterparts (Oliveira 1999; Jessop 2010). Gray and Andrews (1971) reported an average age of 12 years and average total length of 694 mm for silver eels migrating from fresh waters of insular Newfoundland. Jessop et al. (2009) collected silver eels from an estuarine cove (n=3 females) with total length of 500 to 600 mm and ages 9 to 22 years. Silver eels collected from a freshwater area had lengths of 329 to 929 mm and ages 4 to 32 years (n= 3 males, 50 females).

Migration to the Sargasso Sea from Canadian growth habitats can range between 2000 km (southern Nova Scotia) to 4500 km (western Lake Ontario), depending on the point of departure (COSEWIC 2006). A geographic difference in time of departure as well as stage of maturity upon departure likely contributes to a synchronous arrival of mature adults to the Sargasso Sea (Jessop 2006; COSEWIC 2006). From insular Newfoundland waters (west coast), migration of silver eels was recorded between August and October (Gray and Andrews 1971). Spawning behaviour is largely unknown, as no mature adults have ever been caught in the Sargasso Sea (Jessop 2006), though peak spawning is believed to occur in February and March (McCleave 2008). Adults are presumed to die after spawning (Jessop 2006).

Eels consume a variety of prey items including invertebrates (insects and their larvae, crayfish, snails, and worms), plants, and to a lesser extent fishes (Jessop 2006). Eels prefer to feed on fresh fish, although they will feed on fish caught in nets (Jessop 2006). Stomachs of eels sampled from insular Newfoundland freshwater habitats contained adult dragonflies, dragonfly nymphs, adult mayflies, adult hemipterans, beetle pupae, adult beetles, dipteran larvae, adult dipterans, stonefly nymphs, freshwater snails, freshwater clams, salmonid eggs, salmonids, and eels, while those sampled from brackish waters contained clams, shrimp, gammarids, brittle stars, adult dragonflies, fish eggs, sticklebacks, and eels (Gray 1969).

Smaller eels are likely predated by a variety of larger fish species, including large eels (Facey et al. 1987). Predators of larger eels may include fish-eating birds (Facey et al. 1987), such as Great Black-backed Gulls (*Larus* marinus Seymour 1974).

Several parasites have been identified for American Eel throughout its range. Hanek and Threlfall (1970) found that 58% of eels sampled from marine and fresh water locations in Newfoundland and in Labrador were infected with metazoan parasites, including trematodes, cestodes, nematodes, ancanthocephalans, and copepods. The exotic swimbladder nematode parasite *Anguillicola crassus* has been identified as a potential future threat to American Eel components in Canadian waters (COSEWIC 2006).

Adult American Eel cease feeding and their stomachs degenerate prior to migration (Durif et al. 2005; Jessop 2006). Stomachs of migrating (silver) eels sampled in insular Newfoundland were empty and shrunken (Gray and Andrews 1971).

HABITAT

American Eel are found in a variety of habitats including streams, rivers, and muddy or silt-bottomed lakes during their freshwater stage, as well as oceanic waters, coastal bays and estuaries (Scott and Crossman 1973; Scott and Scott 1988; Jessop 2006; COSEWIC 2006). Individuals during the continental stage occasionally migrate between fresh, salt and brackish water habitats and have varying degrees of residence time in each (Fletcher and Anderson 1972; Clarke et al. 2007; Jessop 2010). During winter,

eels burrow under the mud and entering a state of torpor (or complete inactivity) at temperatures below 5ºC (Walsh et al. 1983), although they may occasionally be active during this period (COSEWIC 2006).

In insular Newfoundland, American Eel are found in brackish, freshwater and marine habitats (Clarke et al. 2007). Seasonal patterns described by Fletcher and Anderson (1972) generalize annual movements from freshwater to estuaries and coastal bays to feed during spring, then either a return during the fall to overwinter (juvenile and immature adults), or a southward migration to the spawning grounds (silver eels). High quality growth (i.e. feeding) habitat within the province has been associated with the Barachois Ponds, common on the south coast of Newfoundland, as well as estuarine habitats throughout the province (Gray and Andrews 1971; Clarke et al. 2007).

Continental phase eels appear highly plastic in habitat use. Preferences were not detected with respect to habitat type, cover, substrate, water temperature, or predator density in streams surveyed by Smoger et al. (1995). Several studies in Newfoundland have found lower densities of eels with increasing distance upriver from the sea (Gray and Andrews 1971; Clarke et al. 2007), though this may reflect density dependence rather than habitat preference (J. Casselman, pers. comm.).

Eels are extremely mobile and may access habitats that appear unavailable to them, using small watercourses or moving through wet grasses (Scott and Scott 1988). Small eels (<100 mm total length) are able to climb and may succeed in passing over vertical barriers (Legault 1988).

Habitat availability may be reduced by factors such as habitat deterioration, barriers to upstream migration (larger eels), and barriers (i.e. turbines) to downstream migration that can result in mortality (COSEWIC 2006). Suitable habitat within the province remains largely available, although there are some rivers with small scale hydroelectric structures [e.g. the Avalon Peninsula (1990s), Rattling Brook (1960) Cat Arm (1980s), Rose Blanche (1990s)] (Clarke et al. 2007) that may impede movements.

Given the plasticity of habitat preferences and the variety of habitat types occupied at one or multiple life stages, habitat critical for the long-term survival of American Eel in the province is hard to define or quantify. Clarke et al. (2007) describe the American Eel as occurring “throughout the region in all accessible areas of the island as well as southern Labrador”.

DISTRIBUTION

Global

Throughout its distribution (Figure 2), American Eel are treated as a single population that spawns in one location in the Sargasso Sea (COSEWIC 2006). American Eel can be found in freshwater habitats, coastal waters, and in the open ocean in North America, from Hamilton Inlet-Lake Melville, Labrador in the north to the Gulf of Mexico,

Panama, and the West Indies in the south (Jessop 2006). Small populations have also been found in southwest Greenland and off the northern coast of South America (Jessop 2006). Inland, this species extends into the Great Lakes and the Mississippi River (Jessop 2006).

National

The range of American Eel in Canada encompasses all accessible freshwater, estuaries, and coastal marine waters connected to the Atlantic Ocean, including the provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland and Labrador. The natural limit of their inland distribution in the Great Lakes region is Niagara Falls (COSEWIC 2006).

Provincial

American Eel are widespread in Newfoundland (Figure 3), consistent with the extensive availability of suitable and accessible habitats (Clarke et al. 2007). Fletcher and Anderson (1972) report American Eel captures from 17 locations throughout insular Newfoundland including the Avalon Peninsula, eastern Newfoundland, central Newfoundland, the south-west coast and Great Northern Peninsula, as well as in south-eastern Labrador. Several studies have further documented their presence in specific locations within these regions (e.g. Gray 1969; Hanek and Threlfall 1970; Gray and Andrews 1970, 1971; Hudson 1974; Bouillon 1982; Bouillon and Haedrich 1985; Jessop et al. 2009). Eels may also stray beyond the traditionally described range for this species; eels have occasionally been documented in the English River, north of Hamilton Inlet-Lake Melville in Labrador (D. Reddin, pers. comm.).

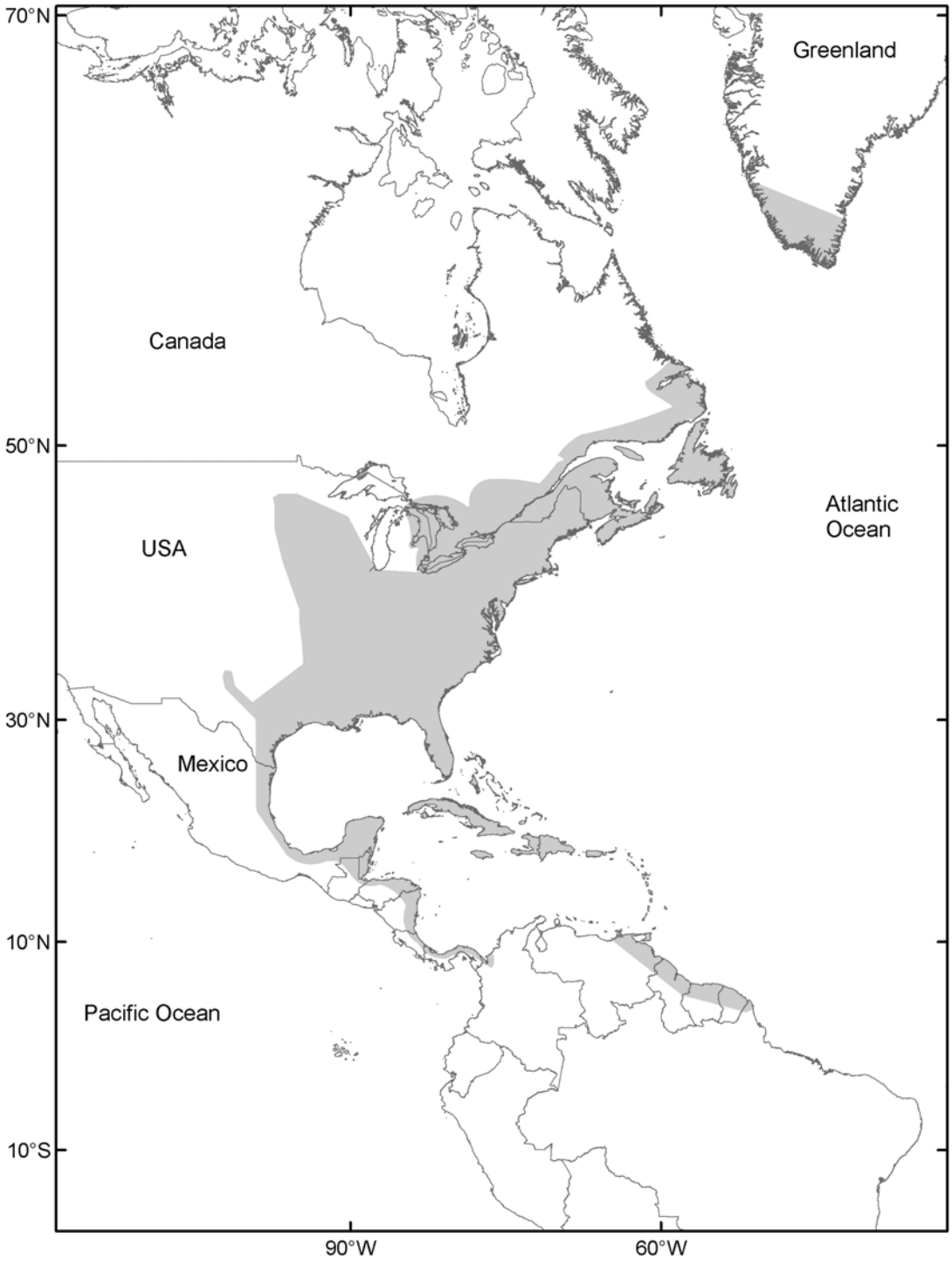

Figure 2. Non-breeding Distribution of American Eel (prepared by the Atlantic Canada Conservation Data Centre, adapted from COSEWIC 2006 and Jessop 2006).

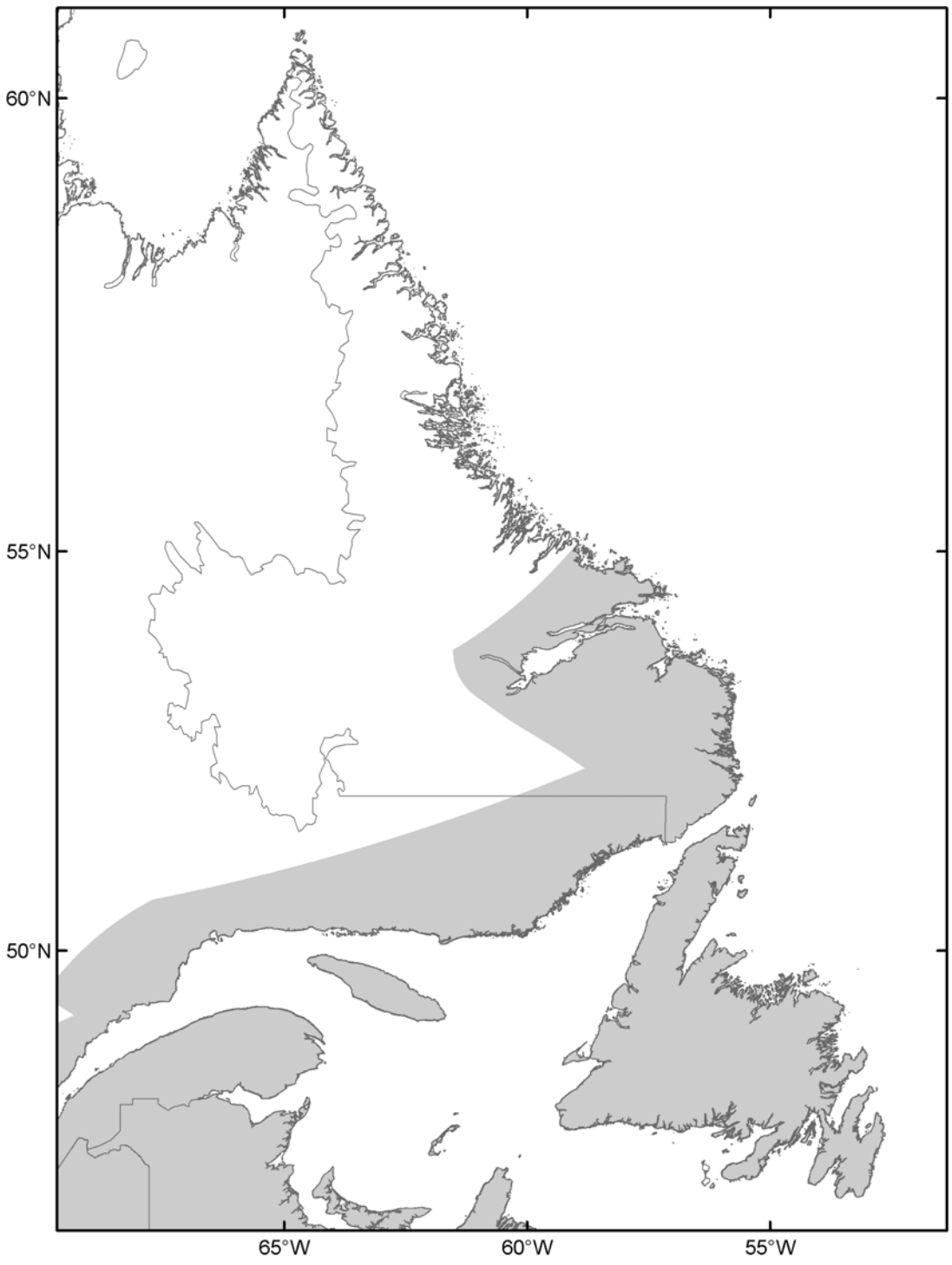

Figure 3. Range of Occurrence of American Eel in Newfoundland and Labrador (prepared by the Atlantic Canada Conservation Data Centre, adapted from COSEWIC 2006 and Jessop 2006).

ABUNDANCE AND POPULATION TRENDS

There are several challenges to effectively estimating American Eel population sizes in Newfoundland and Labrador, including the large range for this species (MacGregor et al. 2008) and that there are only a few fisheries independent data series available for areas outside the Upper St. Lawrence-Lake Ontario region (Clarke et al. 2007). Additionally, the size of the adult stock within a river does not necessarily correlate with the future rate of return of elvers (Jessop 2006). MacGregor et al. (2008) suggested that calculating the relative contribution to the spawning stock by geographic area or region should be considered, however techniques for this calculation are not yet defined.

Despite the challenges in population estimation, declines have been documented for eels over the past three decades throughout this species' range, particularly during the past decade (MacGregor et al. 2008). Due to these declines, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006) assessed this species as a "Species of Special Concern", with a decision to list this species under the Federal Species at Risk Act pending. The US Fish and Wildlife Service (USFWS) has not listed this species under the US Endangered Species Act (USFWS 2007).

Current abundance in the Upper St. Lawrence River-Lake Ontario region is approximately only 2-3% of the mid-1980s levels (DFO 2010). Declines have also been observed in four of five areas assessed (i.e. with sufficient data series) from the lower St. Lawrence River and Gulf of St. Lawrence regions (COSEWIC 2006). These declines may have had significant impact on total reproductive output, as they historically formed a substantial proportion of the breeding population (COSEWIC 2006). While recent trends (since 2003-2004) indicate an increase in numbers returning to some rivers in the Upper St. Lawrence (DFO 2010), numbers remain lower than historic levels and the observed positive trends are too short to confirm whether they are actually increasing (COSEWIC 2006).

In New Brunswick, indices of abundance indicate that the average abundance in the 2000s is higher than that of the 1980s, based on electrofishing surveys on the Miramichi and Restigouche Rivers, and fishery-dependant surveys in the southern Gulf of St. Lawrence (DFO 2010). There are no long-term data series for Nova Scotia / DFO Maritimes Region, though available data indicate decreasing trends or annual variability (i.e., no trend) in abundance in some rivers (DFO 2010).

Within the province of Newfoundland and Labrador, fisheries independent data are available only from quantitative electrofishing surveys conducted in Northeast Brook (drainage 21 km^2) and Miller's Pond (0.07 km^2) on the Avalon Peninsula from 1984-1994, and in the Highlands River (drainage 183 km^2) on the southwest coast from 1980-1981 and 1993-1999 (Clarke et al. 2007; DFO 2010). For each of these areas, abundances were lower in the 1990s compared to available data from the 1980s. In the case of Northeast Brook, catches were significantly lower post-1992 (Clarke et al. 2007). Recent data collected at Western Arm Brook and Conner River salmonid

counting fences show variable eel counts between 1986 and 2010 (DFO 2010). Fisheries independent data from Labrador are limited. For example, the only survey mentioned in the COSEWIC Assessment and Status Report, is that performed by Clarke et al. (2004). They documented only three eels over a six year period from 1999-2005, in the English River watershed. All three eels were captured in 2004 and were believed to be rare in this watershed. Based on the limited available indices, the abundance of eels in Newfoundland and Labrador has been interpreted as “variable but may have stabilized in recent years” (DFO 2010).

In addition to fisheries independent data, fisheries dependant data, including DFO logbook and landings data associated with the commercial fishery, are available for the period from 1990-2008. Catch per Unit Effort (CUE) provides an index of relative abundance over time and can be calculated from logbook data. Landings data, though generally influenced by external factors (e.g. regulations, price per kilogram, alternative opportunities in fishing/other employment, gear efficiencies, etc.), may not be a valid proxy for eel abundance (de Lafontaine et al. 2010). When combined with CUE, landings data can provide additional insight on the status of the fishery.

Commercial logbook data indicates that CUE has remained relatively constant [calculated as *lbs of eel per gear-day* (t=0.132, p=0.897, R2=0.001) and *total number of eels per gear day* (t=1.870, p=0.088, R2=0.241)] (Figure 4). During the same period, annual landings for the province of Newfoundland and Labrador decreased significantly (t=-4.929, $p<0.05$, $R^2=0.618$). Concurrent with this, the total number of active fish harvesters participating in the fishery (Figure 5) has also decreased (t=-2.953, $p=0.014$, $R^2=0.466$), while the total number of gear-days per active harvester reported in commercial logbooks has increased (t=-2.186, $p=0.045$, $R^2=0.242$). Thus, while the same level of success has been observed over time by individual (active) fish harvesters, the total “take” from Newfoundland and Labrador waters has decreased.

Seasonal market prices and annual landings also provide insight on the status of the fishery. During the mid-1990s, average price per pound of eel increased throughout Canada, while annual harvest decreased (J. Casselman, pers. comm.). Between 1993 and 1997 in Newfoundland and Labrador, during a time when landings decreased by approximately 40%, price per pound increased from $1.89/lb to $2.82 (Figure 5). However, it is difficult to determine whether this relates to a decrease in eel abundance or reflects an out-migration of commercial fish harvesters following the closure of the commercial cod and salmon fisheries beginning in the early 1990s. During similar increases in market value in later years (i.e. 2002-2007), concurrent increases in landings were also generally reported (Figure 5).

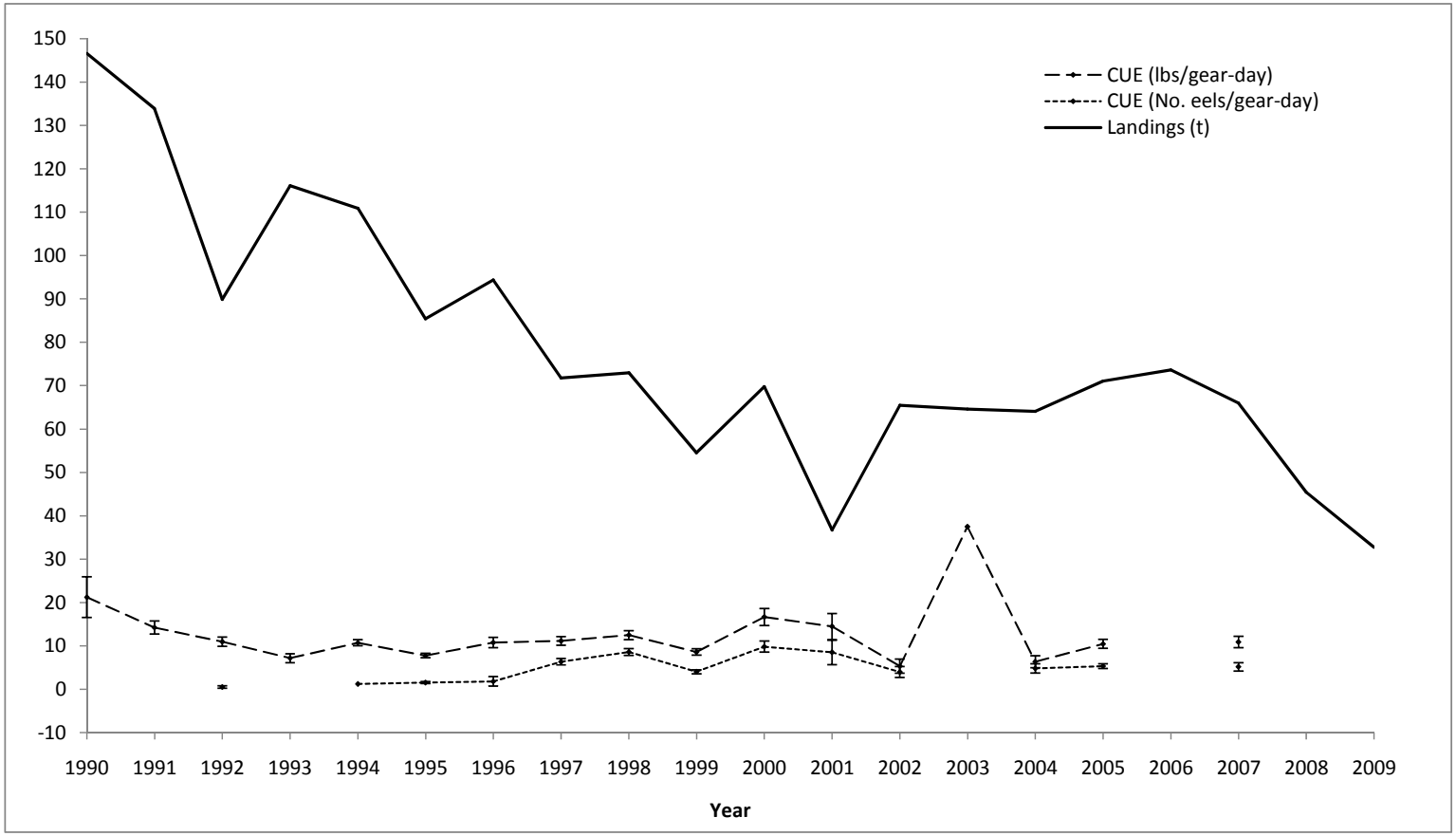

Figure 4. American Eel Landings and Catch per Unit Effort (CUE), 1990-2008. CUE is reported as both pounds per gear-day (large dashed line) and number of eels per gear day (small dashed line); bars represent 95% confidence intervals. Annual landings encompass all of Newfoundland and Labrador. CUE is calculated based on logbook entries; logbooks were not mandatory from 2003-2005 inclusive. The confidence interval for 2003 was omitted due to a small sample size (n=2) as well as a single relatively high landing reported by one harvester; the reported landing of influence was not unusual compared to other years. Data provided by DFO.

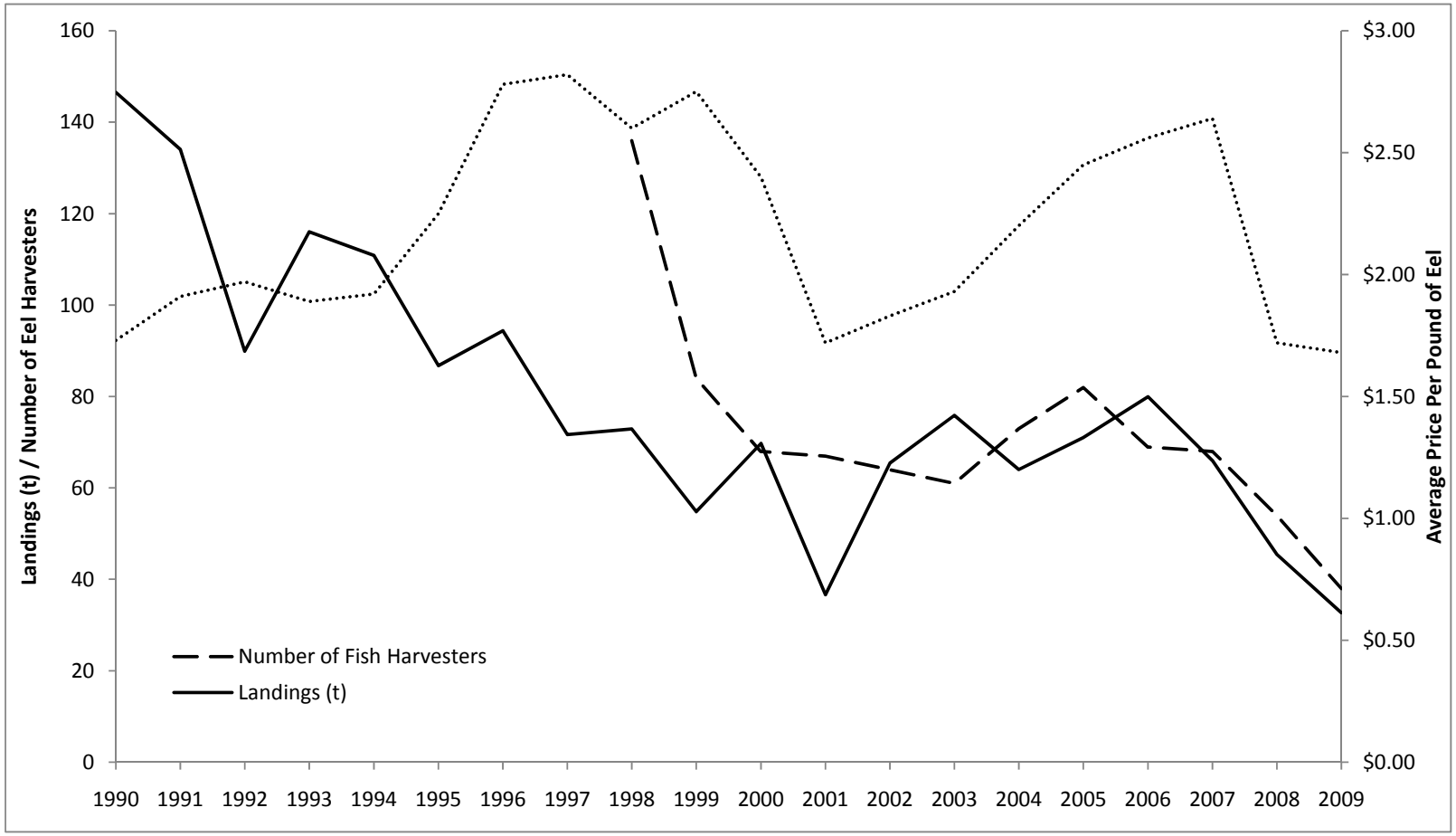

Figure 5. Total Landings (solid line), Price per Pound (dotted line) and Number of Active Fish Harvesters (dashed line) for the American Eel Fishery in Newfoundland and Labrador, 1990-2009. Annual landings encompass all of Newfoundland and Labrador; number of fish harvesters is based on purchase slip data. Data provided by DFO.

Logbook data analyzed to date provide little evidence to support a claim that the American Eel component in Newfoundland and Labrador has either increased or decreased during the period 1990-2009, though caution is expressed in the interpretation of this data. The following caveats apply:

1. Although logbook reporting for commercial catches of American Eel is considered mandatory in Newfoundland and Labrador, it is typically not enforced and thus compliance is generally low.
2. Logbooks were not mandatory in 2003, 2004, and 2005. During this time, sample sizes were small.
3. Reported landings and number of active fish harvesters derived from logbook entries differ considerably from those derived from purchase slip data.
4. Harvesters may prefer not to reveal some information, may purposely supply inaccurate information, or may be unable to accurately estimate some quantities (Fabrizio and Richards 1996).
5. Total landed weight and the total number of eels were reported as estimates by individual fish harvesters and therefore subjective. These variables could not be verified using purchase slip data.
6. Total weight of eels and the total number of eels captured was inconsistently reported. There were 25,448 logbook entries reporting total weight and 9,723 reporting total eels.
7. The data does not provide information on relative exploitation rates of yellow versus silver eels, nor does it reflect any changes in mesh/hoop size of gear over time.
8. Data analysis was limited to harvesters reporting the use of fyke nets and/or eel pots. Approximately 15,000 logbook entries were eliminated from the analysis.
9. Due to limitations associated with the data in terms of time series available, an assessment of regional trends (e.g. Avalon Peninsula, south coast) for all reporting fish harvesters could not be completed. Indications of an increase or decrease in CUE on a regional scale would have allowed inferences regarding abundance; eel abundance would be expected to decrease in more northern regions (e.g. northeast coast) during years of overall low abundance and vice versa (J. Casselman, pers. comm.). That is, the geographic extent of their distribution in any given year is related to overall eel abundance.

While it is impossible to entirely validate logbook data, there is a general tendency for information provided by fish harvesters to veer in the same direction over time (i.e. harvesters are generally consistent in the over or under reporting of information) (J. Casselman, pers. comm.). Thus, information derived from commercial logbooks is

considered a useful tool to investigate long-term trends in fisheries data (J. Casselman, pers. comm.).

FISHERY

Fisheries exist throughout the range of American Eel and throughout nearly all life stages (MacGregor et al. 2008). Eels are fished commercially, recreationally and by aboriginal peoples in many areas of eastern Canada. Elver and silver eel fisheries operate at narrower seasonal time scales compared to yellow eels and as such, fisheries that target yellow eels may have a high cumulative mortality even if yearly mortality rate is low (COSEWIC 2006).

Within the province, harvest of American Eel encompasses commercial, recreational, and aboriginal fisheries which target yellow and silver eels. The harvest of elvers has met with limited success (DFO, pers. comm.). Most of the commercial fishing effort between 1990 and 2007 (based on commercial logbook data) has been concentrated at the mouths of rivers, although coastal harvesting occurs in some areas (Figure 6) (DFO, pers. comm.). Current commercial licences are limited to the island portion of the province (DFO, pers. comm.).

Variable commercial landings have been reported since first documented in 1961, with peak landings reported in 1990-1991 (Figure 7). This was followed by a general decline in landings over approximately the next 18 years (Figure 7). Smaller peaks in landed value were also reported in 1963, 1972 and 1980.

Market prices are believed to be driving the commercial fishery in Newfoundland and Labrador (DFO, pers. comm.). Prior to 1987, fish harvesters received between $0.30-0.40/lb (Knight 1997). Prices then increased to an average of around $1.80/lb over the next few years, coinciding with an increase in harvest in the late 1980s. Prices peaked at $2.88/lb in 1996, with an average annual (1987-1995) landed value of $390,000 (Knight 1997). Average price per pound in 2009 was approximately $1.68. Some eel harvesters speculate that recent market prices for eels have dropped due to a flooded overseas market (R. Gallant, pers. comm.).

In 2009, 154 commercial eel licences were issued in the Newfoundland and Labrador region, of which only 40 licensed fishermen reported sales (DFO, pers. comm.). The majority of reported landings came from NAFO Division 4R, particularly in the area between Cape Ray and Cape St. George (DFO, pers. comm.).

The recreational fishery in the province consists mainly of winter harvesting (spearing) through the ice. There are 38 recreational eel licences issued in the NL Region, all within the Bay St. George/Port aux Port Bay area (DFO, pers. comm.). The recreational eel licence is a limited entry licence and no new licences are being issued (DFO, pers. comm.).

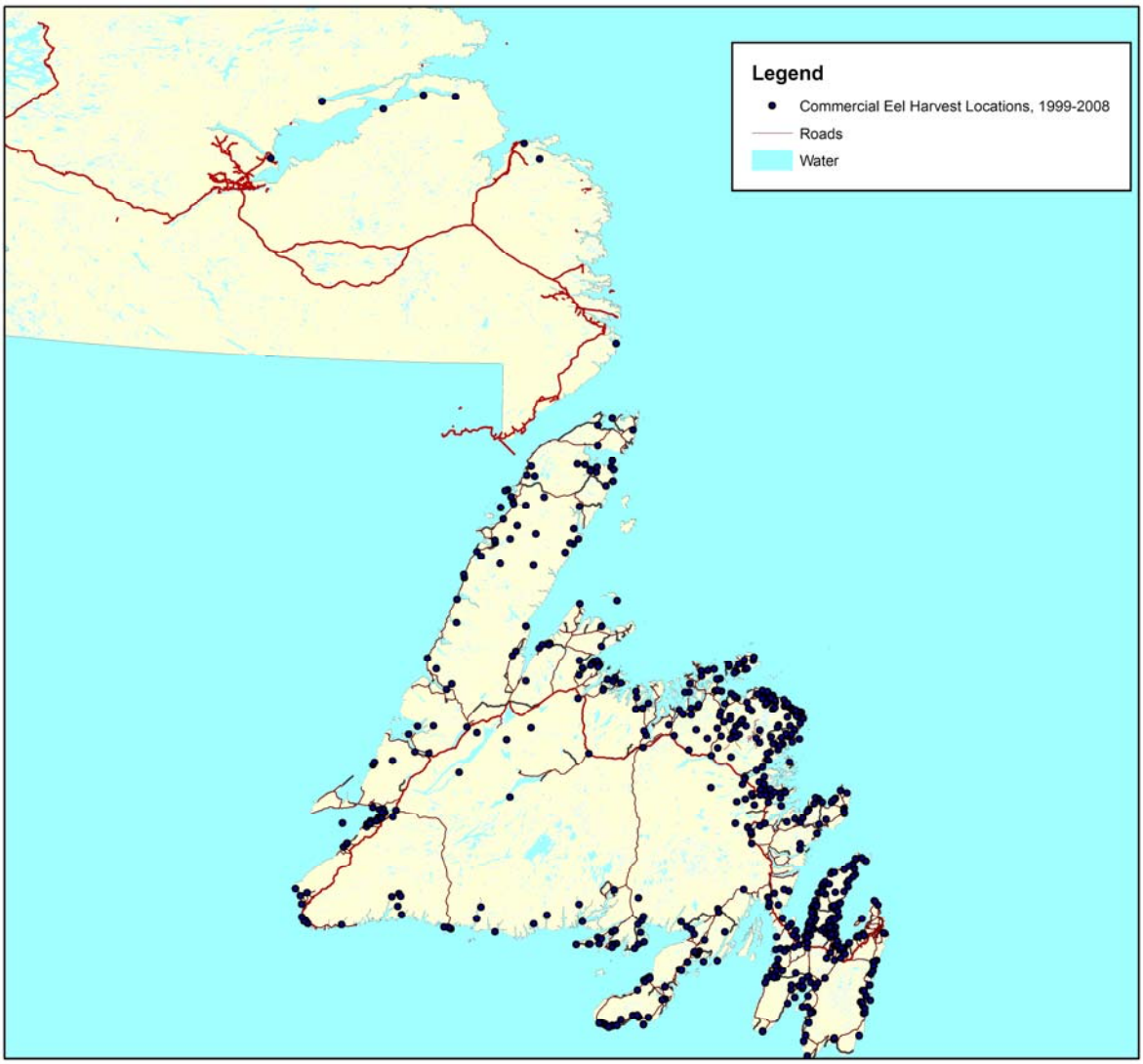

Figure 6. Historic Distribution of the Commercial Eel Fishery in Newfoundland and Labrador, 1990-2007. This map was produced based on data provide by Fisheries and Oceans Canada collected from commercial logbook returns.

Two aboriginal groups participate in the commercial and/or recreational eel fishery. They are the Federation of Newfoundland Indians and the Miawpukek First Nation. Only the latter is a reserve recognized by the federal government; this fishery operates in the vicinity of Conne River through the issuance of a Federal communal fishing licence (DFO, pers. comm.).

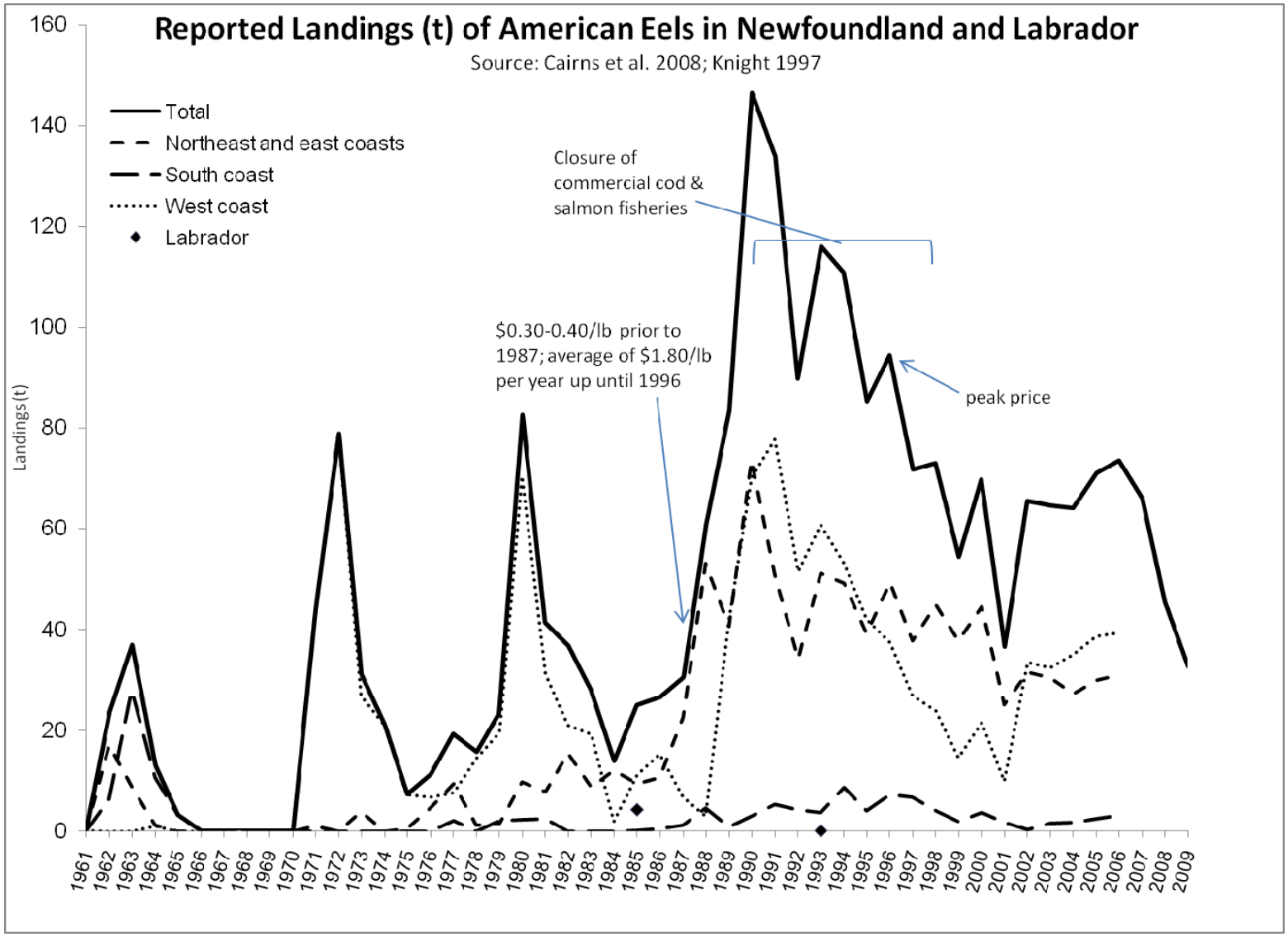

Figure 7. Total Reported Landings (tons) of American Eel in Newfoundland and Labrador and Reported Landings (tons) for Different Regions from 1961-2007. Data is based on information summarized in Cairns et al. (2008) and includes information from Knight 1997.

TRADITIONAL AND LOCAL ECOLOGICAL KNOWLEDGE

Aboriginal people throughout the Canadian range of the American Eel have traditionally fished eel for food. The fishery for American Eel was traditionally important to the Mi'kmaq communities in western Newfoundland because it is one of the few fish that can be harvested year-round and easily preserved (R. Gallant, pers. comm.). There is a need to collect more traditional and local ecological knowledge as outlined in the Goals, Objectives and Actions section.

The Mi'kmaq Alsumk Mowimsikik Koqoey Association (MAMKA), representing the Mi'kmaq people and communities of the Federation of Newfoundland Indians and the Miawpukek First Nation in aquatic resource and oceans management issues, has been actively involved American Eel research in insular Newfoundland. Proposed and/or ongoing projects included an American Eel Fyke Net Study, American Eel Elver Study, and an American Eel Population and Estimate and Tagging Study (MAMKA 2009). A sentinel eel fishery is also being considered to provide information on eel movements, beyond that which is currently provided by the commercial fishery (R. Gallant, pers. comm.).

EXISTING PROTECTION AND MANAGEMENT

The American Eel is currently protected under the Newfoundland and Labrador *Endangered Species Act* (Vulnerable) as well as corresponding Acts under other provincial government regulations [e.g. Ontario (Endangered) and New Brunswick (Special Concern)]. In this province, the designation of a species as Vulnerable requires the release of a Management Plan within three years of the species' listing. The Minister may also make orders or regulations to protect Vulnerable species and their habitat.

Management of American Eel in the province of Newfoundland and Labrador falls under the jurisdiction of the Department of Fisheries and Oceans. An overview of current management practices related to the commercial eel fishery is provided below (Clarke et al. 2007; DFO 2010; DFO pers. comm.):

- Eel fishing seasons and minimum length requirements are established under the Newfoundland and Labrador Fishery Regulations (SOR/78-443) and are modified through Variation Orders as required.
- The fishing season was reduced by one month in 1998. Commercial fishing seasons run from June 1 (Coastal eel pot and fyke net fishery), July 1 (Inland eel pot fishery) or August 1 (Inland fyke net fishery) until October 31 each year.
- The minimum retention size for eels is 20 cm in NAFO Division 4R and sub-Division 3Pn; in NAFO Divisions 3L, 3K and 3Ps the minimum retention size is 30 cm.

- Licencees can harvest only from rivers traditionally fished and only in locations identified on their licence.
- A maximum gear amount for each commercial licence holder is issued with each licence. Only fyke nets and/or eel pots are permitted.
- A gear reduction program was implemented in 1997 to standardize the number of gear units across the province (25 eel pots and 5 fyke nets).
- Commercial eel licences have not been issued since 1998 with an approximate 50% reduction in licence holders between 1998 and 2004. In 2004, the number of eel licences was reduced from 316 to 165.
- New recreational licences have not been issued since 1999.
- By-catch exclusion devices are mandatory. This enhances escapement of small eels as well as juvenile salmon and trout.
- If fishery closures are implemented on scheduled salmon rivers during low water and high temperature conditions, the use of fyke nets for commercial eel harvest must cease.
- A mandatory logbook program was initiated by DFO in 1991 and ran until 2001, and was reintroduced in 2005.

MANAGEMENT GOALS, OBJECTIVES AND ACTIONS

The overall goal for management of species at risk is to ensure the long-term persistence of species as self-sustaining viable populations throughout their current, and when possible, historical ranges. While the province does not have direct management responsibilities for American Eel, it can contribute to management by identifying knowledge gaps, facilitating directed studies within the province, and sharing information with other management agencies. The actions included in this management plan may be implemented by the province, Fisheries and Oceans Canada or a combination thereof. The following details the goals, objectives, and actions needed to fulfill this purpose, all of which are summarized in Table 1. The following three goals have been identified as important to the long-term persistence of the American Eel in Newfoundland and Labrador:

> **Goal 1.** Complete research to close gaps in our understanding of American Eel population trends and demographics.
>
> **Goal 2.** Assess the extent of existing and potential threats and develop mitigation strategies to address them.
>
> **Goal 3.** Collect traditional and local knowledge and increase interaction and knowledge-sharing among jurisdictions, stakeholders, and traditional knowledge holders with respect to American Eel management.

GOAL 1. COMPLETE RESEARCH TO CLOSE GAPS IN OUR UNDERSTANDING OF AMERICAN EEL POPULATION TRENDS AND DEMOGRAPHICS.

A major limiting factor to analyzing trends in abundance of American Eel is a general lack of fisheries-independent data, and a lack of time series data to analyze trends. Additionally, much of the biological data available has been collected in freshwater. Nevertheless a large portion of the fishery may occur in coastal bays and estuaries in some regions (Lamson et al. 2009). The province can contribute to the Federal management of American Eel by identifying knowledge gaps and facilitating directed studies within the province.

Objective 1. Assess abundance and trends in American Eel in Newfoundland and Labrador using historical and newly collected information.

An estimate of the number of mature individuals and any trends, fluctuations, percent declines or estimates of fragmentation for components of the population in this province are unknown, along with any estimates of spatial distribution or trends (COSEWIC 2006). In the absence of such data, it is difficult to set appropriate goals for effective management.

American Eel is a long-lived species with an estimated generation time ranging from 9-22 years in Newfoundland and Labrador, depending on the environment (i.e. fresh

versus salt/brackish waters). Estimates of abundance require a long-term data series and will include multiple year classes. Analysis of data should investigate trends in and/or relationships between the following:

- catch per unit effort (CUE)
- mean size (weight, length);
- proportion of silver, yellow, and elver staged eels;
- age (is the population ageing?);
- sex ratios;
- recruitment;
- estimates of escapement (the “number of silver eels that survive fisheries, turbines and other continental mortality factors to reach the open sea on their way to the spawning grounds” (COSEWIC 2006));
- parasites, particularly monitoring for the nematode *Anguillicola crassus* (an introduced swim bladder parasite that is spreading northward in North America).

Potential relationships between commercial CUE, estimates of fishing mortality, and results of fisheries independent sampling should also be considered. The province encourages DFO to continue collection of commercial logbook data, harvest data and seasonal market prices. This information can provide insight on the response of eels to exploitation and help ensure both the long-term production and economic benefit of the resource (Fabrizio and Richards 1996). To encourage accurate logbook reporting, logbooks should be relevant to both fishers and scientists, should involve a single system for both personal record keeping and reporting, the offering of incentives should be considered, feedback should be provided to fish harvesters in a timely fashion, and confidentiality should be a priority (Fabrizio and Richards 1996).

Action 1: Collect historical and recent data on American Eel in the province including published and unpublished research, government reports, student theses, commercial and individual logbook data, DFO’s Acid Rain database, counting fence data, and management practices.

Action 2: Collect information from local and traditional knowledge holders.

Action 3: Compile collected information into a database.

Action 4: Use compiled information to develop baseline and trend data whenever possible.

Objective 2. Design systematic fisheries-independent research monitoring programs.

Fisheries and Oceans Canada has previously conducted electrofishing surveys in Highlands River from 1979-1999 and Northeast Brook from 1984-1998. Building on

these efforts by targeting these areas and using similar methodology and timing will allow an index of abundance to be established. Incorporation of a glass eel/elver index survey should also be evaluated (J. Casselman, pers. comm.) to provide information on eel recruitment. In this regard, plankton nets, “eel collectors,” or elver traps can be used to sample glass eels and elvers (Jessop 2003; Sullivan et al. 2009).

Additional areas of interest should be added to these baseline surveys to increase within-river habitats sampled as well as the number of regions represented (J. Casselman, pers. comm.). Regional trends in data (i.e. the extent of occurrence in any given year) can be used to make inferences regarding annual abundance. Specifically, in years where there is a decrease in the glass eel population, glass eels are generally not found or are present in low numbers along the northeast coast of Newfoundland (J. Casselman, pers. comm.). Similarly, eels typically migrate shorter distances upstream during years of low abundance (J. Casselman, pers. comm.).

Data collected should include life history stage, length, weight, age, sex, maturation, and parasites, as well as date, time of day, effort (hours), area surveyed, water conditions, habitat, and other factors. Environmental parameters that may influence timing of migration, eel mortality, and other biological factors (e.g. temperature, acidity; Jessop 2003) should also be documented.

Timing of survey efforts is important in order to monitor specific components of the population. Sampling in July will allow measurement of the entire population by avoiding migration periods (DFO, pers. comm.). Surveys conducted during upstream or downstream migration will allow estimation of recruitment and spawner abundance, respectively. Knowledge about different components of the population can be used to assess population health and develop population models.

All data collected during monitoring should be combined with other sources of historic and current data, including any incidental captures and/or observations from other studies ongoing within the Department. Partnerships with interested organizations and/or aboriginal groups such as MAMKA, who is actively engaged in research programs dedicated to American Eel, should be encouraged.

Action 1: Collect information on methods used to monitor American Eel populations and important variables to consider.

Action 2: Assess methods used to monitor American Eel and determine methods most appropriate for the province.

Objective 3. Implement systematic fisheries-independent research monitoring programs.

Action 1: Implement appropriate monitoring programs for adult eels and glass eels in concert with partner organizations (e.g. fishers, DFO, aboriginal organizations).

Action 2: Incorporate newly collected data into a database.

Action 3: Complete analyses of spatial and population trends using newly collected monitoring data.

GOAL 2. ASSESS THE EXTENT OF EXISTING AND POTENTIAL THREATS AND DEVELOP MITIGATION STRATEGIES TO ADDRESS IMPORTANT THREATS.

Significant amounts of American Eel habitat in North America have been lost and numerous anthropogenic sources of mortality exist (MacGregor et al. 2008). Limiting factors and threats identified include habitat loss and fragmentation due to blockage and/or impedance of upstream passage, turbine mortality on silver eels during downstream passage, overexploitation of pre-spawning components (i.e. the entire fishery), chemical and biological contamination, introduced parasites, eel stocking, and the unregulated commercial harvest of Sargassum (*Sargassum* spp.) in the spawning zone (Beak International Incorporated 2001; COSEWIC 2006). Natural limiting factors include climate change and resultant effects on larval transport.

Objective 1. Assess threats to American Eel habitat and populations in the province.

It is not known how important habitat loss/fragmentation, turbine mortality, the fishery, chemical and biological contamination, introduced parasites, eel stocking, harvest of Sargassum, and climate change are in the management of American eel. Clarke et al. (2007) noted habitat destruction or exclusion of habitat through development as an immediate threat to American Eel in this province. Despite this, the province is believed to support an abundance of suitable habitat, much of which remains unexploited and relatively pristine (Clarke et al. 2007).

Action 1: Identify the location and impact of hydroelectric development on eel movement and mortality rates.

Action 2: Assess the impact of the fishery on eel populations in the province.

Action 3: Assess the occurrence and relative importance of other threats identified by COSEWIC (2006) including biological contamination, introduced parasites, and eel stocking.

Objective 2. Develop mitigation strategies to protect against future harm.

Mitigation for eels during the construction of hydroelectric structures is well-established in many regions. Mitigation for hydroelectric developments might include assessment of development structures and associated mitigation projects such as the requirement for an eel ladder and/or turbine size and structure requirements to enhance migration.

Mitigation for fishing will involve a management regime that allows continuation of commercial, subsistence, and recreational fisheries in a manner that protects stocks over the long-term. The province encourages consideration of an increase in the minimum retention size for American Eel to 30 cm (or greater) throughout the entire province, consistent with existing and/or recent increases in minimum size restrictions in

other DFO Regions (53 cm in the Gulf Region and 30-35 cm in the Maritimes Region) and with the federal objective of achieving a 50% reduction in anthropogenic mortality relative to the average mortality from 1997-2002 (DFO 2010).

Action 1. Develop best practices for hydroelectric development to protect eels and eel migration routes as necessary.

Action 2. Determine and evaluate potential mitigative measures for any other threats that are identified as significant for provincial populations of the American Eel.

GOAL 3. INCREASE INTERACTION AND KNOWLEDGE SHARING AMONG JURISDICTIONS, STAKEHOLDERS AND TRADITIONAL KNOWLEDGE HOLDERS WITH RESPECT TO AMERICAN EEL MANAGEMENT.

Primary management authority for fisheries in the province rests with the Federal Government. Currently, research conducted by the Department of Environment and Conservation is compiled and submitted to the Canadian Science Advisory Secretariat (CSAS) of DFO. CSAS then coordinates the peer review and subsequent publication of such documents. Through this process and subsequent annual meetings, the Department is able to provide recommendations regarding management of inland fish species in the province. To this end, any information collected and complied by the Department regarding American Eel, particularly information on trends and any recommendations for management stemming from these results, should be submitted through this process.

Additionally, there are many individuals and organizations interested in the management and harvest of eels. Providing them with information collected or reports created as a result of American Eel research and monitoring would help to keep all affected parties informed of trends in distribution, abundance, and other relevant information.

Objective 1. Collect information on traditional and historical use and importance of American Eel in the province through partnerships with interest groups, management agencies, and the public.

Action 1: Contact aboriginal organizations to collect information on the historical and traditional harvest and use of American Eel.

Action 2: Contact fishers to collect information on the historical harvest of American Eel.

Action 3: Contact any other organizations with information on the historical and/or traditional use and harvest of American Eel in Newfoundland and Labrador.

Action 4: Encourage partnerships for research and monitoring of the American Eel in Newfoundland and Labrador.

MANAGEMENT ACTION IMPLEMENTATION SCHEDULE

Table 1. Implementation schedule of the management actions required to meet management objectives for the American Eel in Newfoundland and Labrador during the next five years (2011-2015).

Management Actions	Implementation schedule				
	2011	2012	2013	2014	2015
Population monitoring and trends					
Collect historical and recent data (including traditional and local knowledge)	X	X	X	X	X
Compile collected information in a database	X	X	X	X	X
Develop baseline and trends information				X	X
Collect information on methods for monitoring eel					
Determine best methods for monitoring eel in the province	X	X	X		
Implement monitoring programs for adult and glass eels				X	X
Regularly update database as new information becomes available	X	X	X	X	X
Complete analyses of spatial and population trends					X
Threat identification and mitigation					
Identify the location and impact of hydroelectric development	X	X	X		
Assess the impact of the eel fishery on the provincial population					X
Assess the occurrence and importance of other identified threats	X	X	X	X	X
Develop best practices for hydroelectric development as necessary				X	X
Determine appropriate mitigative measures for other identified threats					X
Knowledge collection and sharing					
Collect information on historical and traditional harvest of eels	X	X	X		
Develop a database identifying parties interested in eel management	X	X			
Encourage partnerships for research and monitoring initiatives			X	X	X

LITERATURE CITED

Avise, J.C., G.S. Helfman, N.C. Saunders, and L.S. Hales. 1986. Mitochondrial DNA differentiation and life history pattern in the North Atlantic eels. Proceedings of the National Academy of Sciences of the USA 83: 4350-4354.

Avise, J.C., W.S. Nelson, J. Arnold, R.K. Koehn, G.C. Williams and V. Thorsteinsson. 1990. The evolutionary genetic status of Icelandic eels. Evolution 44:1254-1262.

Beak International Incorporated. 2001. The decline of American Eel (*Anguilla rostrata*) in the Lake Ontario/St. Lawrence River ecosystem: A modeling approach to identification of data gaps and research priorities. Report prepared for the Lake Ontario Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan. March 2001. 70 pp.

Bouillon, D.R. 1982. Growth and size of the mature (silver) American Eel (*Anguilla rostrata*) in two areas of Newfoundland. B.Sc. honors thesis, April 1982. Memorial University of Newfoundland, St. John's, NL.

Bouillon, D.R. and R.L. Haedrich. 1985. Growth of silver eels (*Anguilla rostrata*) in two areas of Newfoundland. Journal of the Northwest Atlantic Fisheries Society 6: 95-100.

Cairns, D. K., V. Tremblay, F. Caron, J.M. Casselman, G. Verreault, B.M. Jessop, Y. de Lafontaine, R.G. Bradford, R. Verdon, P. Dumont, Y. Mailhot, J. Zhu, A. Mathers, K. Oliveira, K. Benhalima, J. Dietrich, J.A. Hallett, and M. Lagacé. 2008. American Eel abundance indicators in Canada. Can. Data Rep. Fish. Aquat. Sci. No. 1207. 78 pp.

Casselman, J.M., PhD. Senior scientist emeritus and adjunct professor, Department of Biology, Queen's University, Kingston, Ontario. pers. comm.

Clarke, K.D., R.J. Gibson and D.A. Scruton. 2007. A review of the habitat associations and distribution of the American Eel within Newfoundland and Labrador. Presentation at the Canadian Conference For Fisheries Research, January 2007.

Clarke, K. D., C. J. Pennell, D. G. Reddin and D. A. Scruton. 2004. Spatial segregation of three anadromous salmonids in a northern Labrador (Canada) river during the spawning and over wintering periods. Pages 151-159 in M.T. Spedicato, G. Lembo, and G. Marmulla (eds.). *Aquatic telemetry: advances and applications*. FAO/COISPA, Rome. 296 pp.

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, ON. 71 pp.

de Lafontaine, Y., P. Gagnon and B. Côté. 2010. Abundance and individual size of American Eel (*Anguilla rostrata*) in the St. Lawrence River over the past four decades. Hodrobiologica 647: 185-198.

DFO 2010. Status of American Eel and progress on achieving management goals. DFO Canadian Science Advisory Secretariat, Scientific Advisory Report, Report # 2010/062.

DFO, pers. comm. September 16, 2010 meeting with D. Ball (Resource Manager) G. Veinott (Research Scientist) and K. Clarke (Ecological Sciences), Department of Fisheries and Oceans Canada (DFO), St. John's, NL.

Dolan, J.A. and G. Power. 1977. Sex ratio of American Eel, *Anguilla rostrata*, from the Matamek River System, Quebec, with remarks on problems in sexual identification. Journal of Fisheries Research Board of Canada 34: 294-299.

Durif, C., S. Dufour and P. Elie. 2005. The silvering process of *Anguilla anguilla*: a new classification from the yellow resident to the silver migrating stage.

Fabrizio, M.C. and R.A. Richards. 1996. Commercial Fisheries Surveys. Pages 625-650 in B.R. Murphy and D.W. Willis (eds.). *Fisheries Techniques* (2nd ed.). American Fisheries Society, Maryland, USA.

Facey, D.E.., and M. J. Van Den Avyle. 1987. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic), American Eel. Report prepared for Coastal Ecology Group, U.S. Army Corps of Engineers, and U.S. Department of the Interior, Fish and Wildlife Service, USA, August 1987. Biological Report 82(11.74) TR EL-82-4.

Fletcher, G.L. and T. Anderson. 1972. A preliminary survey of the distribution of the American Eel (*Anguilla rostrata*) in Newfoundland. MSRL Technical Report No. 7. March 1972. Marine Sciences Research Laboratory, St. John's, NL.

Gallant, R., Biologist, Mi'kmaq Alsumk Mowimsikik Koqoey Association (MAMKA), Corner Brook, NL. August 27, 2010.

Gray, R.W. 1969. A contribution to the biology of the American Eel (*Anguilla rostrata* (LeSueur)) in certain areas of Newfoundland. M.Sc. Thesis. Memorial University of Newfoundland, St. John's, NL, Canada

Gray, R.W., and C.W. Andrews. 1970. Sex ratio of the American Eel (*Anguilla rostrata* (LeSueur)) in Newfoundland waters. Canadian Journal of Zoology 48: 483-487.

Gray, R.W., and C.W. Andrews. 1971. Age and growth of the American Eel (*Anguilla rostrata* (LeSueur)) in Newfoundland waters. Canadian Journal of Zoology 49: 121-128.

Hanek, G. and W. Threlfall. 1970. Metozoan parasites of the American Eel (*Anguilla rostrata* (LeSueur)) in Newfoundland and Labrador. Canadian Journal of Zoology 48: 597-600.

Hudson, W.J. 1974. Aspects of the early life history of the American Eel (*Anguilla rostrata* (Lesueur)) in Newfoundland. Ph.D. thesis. Memorial University of Newfoundland, St. John's, NL, Canada.

Jessop, B. M. 2003. The run size and biological characteristics of American Eel elvers in the East River, Chester, Nova Scotia, 2000. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2444. 42 p. + iv.

Jessop, B.M. 2006. Underwater world: American Eel. Communications Directorate, Fisheries and Oceans Canada, Ottawa, ON.

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

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

Kleckner, R.C., and J.D. McCleave. 1985. Spatial and temporal distribution of American Eel larvae in relation to North Atlantic Ocean current systems. Dana 4: 67-92.

Knight, L. 1997. The Newfoundland eel fishery: A fisheries management perspective past and present. Report prepared for the Department and Fisheries Oceans Canada, Newfoundland Region. St. Jon's, NL. 6 pp. + Appendices.

Krueger, W.H. and K. Oliveira. 1999. Evidence for environmental sex determination in the American Eel, *Anguilla rostrata*. Environmental Biology of Fishes 55: 381-389.

Lamson, H.M., D.K., Cairns, J.-C. Shiao, Y. Iizuka and W.-N. Tzeng. 2009. American Eel, *Anguilla rostrata*, growth in fresh and salt water: implications for conservation and aquaculture. Fisheries Management and Ecology 16: 306-314.

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

MacGregor, R., A. Mathers, P. Thompson, J. M. Casselman, J. M. Dettmers, St. LaPan, T. C. Pratt and B. Allen. 2008. Declines of American Eel in North America: Complexities associated with bi-national management. American Fisheries Society Symposium 62: 1-25.

MAMKA. 2009. MAMKA Quarterly, November 2009. Published by the Mi'kmaq Alsumk Mowimsikik Koqoey Association, Corner Brook, NL. Available online: http://www.mamka.ca/MAMKA/Newsletters.html

McCleave, J.D. 2008. Contrasts between spawning times of Anguilla species estimated from larval sampling at sea and from otolith analysis of recruiting glass eels. Marine Biology 155:249-262.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life. Available online: http://www.natureserve.org/explorer/. Accessed: December 2011.

Oliveira, K. 1999. Life history characteristics and strategies of the American eel, *Anguilla rostrata*. Canadian Journal of Fisheries and Aquatic Sciences 56: 795-802.

Oliveira, K., and J.D. McCleave. 2000. Variation in population and life history traits of the American Eel, *Anguilla rostrata*, in four rivers in Maine. Environmental Biology of Fishes 59: 141-151.

Reddin, D. Research Scientist – Atlantic Salmon Population Dynamics, Department of Fisheries and Oceans Canada (DFO), St. John's, NL. pers. comm., January 18, 2011.

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

Scott, W.B and M.G. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. 761 pp.

Seymour, N.R. 1974. Great black-backed gulls feeding on live eel. Can. Field-Nat. 88: 352-353

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

Sullivan, M.C., M. J. Wuenschel and K.W. Able. 2009. Inter and intra-estuary variability in ingress, condition and settlement of the American Eel *Anguilla rostrata*: implications for estimating and underestimating recruitment. Journal of Fish Biology 74: 1949-1969.

USFWS (US Fish and Wildlife Service). 2007. "Endangered Species Act Protection for American Eel Not Needed." News release dated January 30, 2007. Available online: http://www.fws.gov/news/newsreleases/default.cfm

Walsh, P.J., G.D. Foster and T.W. Moon. 1983. The effects of temperature on metabolism of the American Eel *Anguilla rostrata* (LeSueur): compensation in the summer and torpor in the winter. Physiological Zoology 56: 532-540.

Wild Species. 2005. Wild Species 2005: The general status of species in Canada. Available online: http://www.wildspecies.ca/wildspecies2005/GS2005_site_e.pdf. Accessed October 2010.

Wirth, T., and L. Bernatchez. 2003. Decline of North Atlantic eels: a fatal synergy? Proceedings of the Royal Society of London, Series B, Biological Sciences 270 (1516): 681-688.