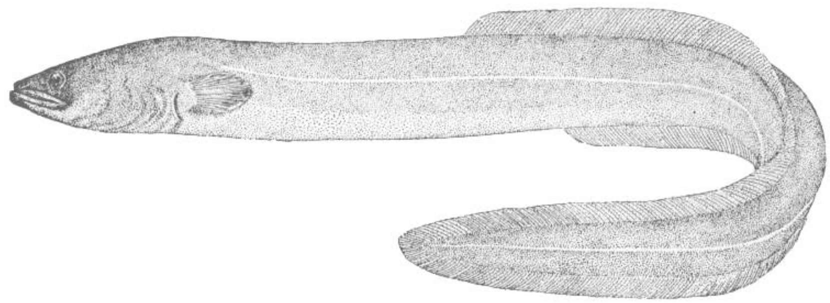
COSEWIC
Assessment and Status Report

on the

American Eel
Anguilla rostrata

in Canada



SPECIAL CONCERN
2006

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

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American eel — (Lesueur 1817). From Scott and Crossman (1973) by permission.

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COSEWIC
Assessment Summary

Assessment Summary – April 2006

Common name
American eel

Scientific name
Anguilla rostrata

Status
Special Concern

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 (no long-term indices are available for Scotia/Fundy, Newfoundland, and Labrador) 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, but time series of elver abundance, although relatively short, do not show evidence of an ongoing decline. 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, including habitat alteration, dams, fishery harvest, oscillations in ocean conditions, acid rain, and contaminants, may continue to impede recovery.

Occurrence
Ontario, Quebec, New Brunswick, Price Edward Island, Nova Scotia, Newfoundland-Labrador, Atlantic Ocean

Status history
Designated Special Concern in April 2006. Assessment based on a new status report.

COSEWIC
Executive Summary

American eel
Anguilla rostrata

Species Information

The American eel, *Anguilla rostrata* LeSueur 1817, is in the order Anguilliformes, family *Anguillidae*. Anguilla eels are termed freshwater eels, although some species (including the American eel) are able to complete their entire life cycle in salt water. Both the American eel and the European eel (*Anguilla anguilla*) spawn in the Sargasso Sea in the southern North Atlantic Ocean. American eels are considered to be panmictic, which means that all members of the species mate randomly as a single breeding population. However, the genetic analysis upon which this conclusion is based does not include samples from the upper St. Lawrence and Lake Ontario.

This report recognizes five zones, termed Freshwater Ecological Areas (FEAs), that are used by eels in Canada. These are 1) Great Lakes-Western St. Lawrence (Ontario and western and central Quebec); 2) Eastern St. Lawrence (eastern Quebec); 3) Maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and the central and southern parts of Quebec's Gaspé Peninsula); 4) Atlantic Islands (Newfoundland); and 5) Eastern Arctic (Labrador).

Distribution

The continental distribution of the American eel ranges from northern South America to Greenland and Iceland. The historic Canadian range includes all accessible fresh water, estuaries and coastal marine waters connected to the Atlantic Ocean, up to the mid-Labrador coast. Continental shelves are used by juvenile eels arriving from the spawning grounds, and by silver eels returning to the spawning grounds. Niagara Falls is the natural distributional limit in the Great Lakes.

Habitat

American eels occupy salt water during their oceanic migrations. During the continental phase, eels occupy all salinity zones, including shallow and sheltered marine waters, estuaries, and freshwater rivers and lakes. Some eels remain in a particular salinity zone during the continental phase, while others move back and forth between fresh and marine waters. Eel densities in medium and large rivers typically diminish with distance from the sea. Maturing eels that descend rivers with hydroelectric dams risk mortality due to turbines. Eels in the continental growth phase are highly plastic in habitat use. They are primarily benthic, using substrate and bottom debris as protection and cover.

American eel habitat receives protection from the Canadian Fisheries Act and other legislation. Some areas of eel habitat have special protection (e.g. Marine Protected Areas), but such areas do not necessarily prohibit exploitation.

Biology

Spawning takes place in the Sargasso Sea. Hatched larvae develop a leaf-like shape and are termed leptocephali. American eel leptocephali drift westward towards the continental shelf, where they metamorphose into small, transparent glass eels, which have the serpentine shape of the adult form. As glass eels move into inshore waters, they develop pigmentation and become elvers. Elver arrival generally occurs in May and early June on the Atlantic coast of the Maritime Provinces, and in summer in the Gulf of St. Lawrence. Some elvers remain in shallow protected salt water, some move into estuaries, and some move into fresh water. Elvers become yellow eels, which have a dark back and a yellowish belly. Sexual differentiation occurs during the yellow phase. Sex determination appears to be controlled by environmental factors. Density appears to be the dominant influence, with high densities promoting the production of males. Eels in the upper St. Lawrence River and Lake Ontario are virtually all females. Females dominate in many locations elsewhere in Canada, but sex ratios are variable in rivers in the Maritime Provinces which flow into the Atlantic Ocean and the Bay of Fundy. Yellow eels in fresh water may continue to migrate for many years. Eels ascending the upper St. Lawrence in recent years are about 12 years old. Eels in brackish and salt water grow more rapidly than those in fresh water. Eels hibernate in mud in winter. Wintering habitat includes all salinity zones. Some, but not all, wintering sites have freshwater upwelling. When yellow eels reach a certain size, their bellies turn silver and they prepare for the spawning migration. In the upper St. Lawrence and Lake Ontario, the size at which silvering occurs is larger than elsewhere. These large eels are highly fecund and may make a major contribution to the species' total reproductive output. Generation time for these eels is about 22 years. Generation time is much shorter in eels reared in salt water (roughly 9 years), because of more rapid growth in this habitat. Because the American eel is a long-lived species, population indicators of any continental stage other than glass eels/elvers typically include numerous year-classes.

Population Sizes and Trends

<u>FEA1 - Great Lakes and Western (Upper) St. Lawrence (Ontario and western and central Quebec)</u>

Juvenile eels have been counted at a fish ladder at the Moses-Saunders dam at Cornwall Ontario since 1974. Mean age of ascending eels rose from 5.6 years in the mid-1970s to 11.9 in the 1990s. Most ascending eels are destined for Lake Ontario. The count index peaked in 1982-1983, and then fell sharply. The index in recent years is about 3 orders of magnitude below its peak level. The decline in Lake Ontario, as indicated by an electrofishing survey and a trawl index in the Bay of Quinte, closely matches the decline of the Moses-Saunders index, when suitable time lags are applied. Eel counts at Moses-Saunders and at passage facilities at the Beauharnois dam on the St. Lawrence River and the Chambly dam on the Richelieu River have shown some increases in recent years. Recruitment to Lake Champlain via the Richelieu River is a small fraction of former levels, despite the restoration of eel passage. The Moses-Saunders index in the last 2 decades is negatively correlated with the North Atlantic Oscillation Index (NAOI), when appropriate time lags are applied. Silver eels caught in the St. Lawrence estuary fishery are principally from FEA1. Eel fisheries have been closed in the upper St. Lawrence River and Lake Ontario and fishing effort has declined in the St. Lawrence estuary. Reported estuary landings decreased from 452 tonnes in 1980 to under 82 tonnes in 2004. Commercial catch per unit effort (CPUE) declined from the beginning of the series in 1985 to the late 1990s. An experimental trap located near Quebec City has showed no consistent trend since the 1970s, but catches in a nearby commercial trap fished with constant effort declined substantially over the same period. The run of silver eels exiting the St. Lawrence was estimated at 488,000 in 1996 and 397,000 in 1997. The exploitation rate on these eels was estimated at 15% in 1996 and 26% in 1997.

<u>FEA2 - Eastern St. Lawrence (eastern Quebec)</u>

Counts of juvenile eels migrating upstream on the Petite Trinité River in the northwestern Gulf of St. Lawrence in 1982-1985 and in 1993-1996 showed no consistent trend with time. An index of year class strength has been derived from counts of juvenile eels migrating upstream in the Sud-Ouest River, which drains into the south shore of the St. Lawrence estuary. The index declined substantially over the time series, which runs from 1999 to 2005. No trend is apparent in electrofishing densities of eels in the Bec-Scie River, Anticosti Island, from 1988 to 1996, but densities in a tributary of the Bec-Scie declined.

<u>FEA3 - Maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and the central and southern parts of Quebec's Gaspé Peninsula)</u>

The only indices of elver arrival in Canada are from two rivers on the Atlantic coast of Nova Scotia. Arrivals fluctuated without trend between 1989 and 2002. Eel densities estimated from electrofishing surveys in the Restigouche River, between New Brunswick and Quebec, showed an isolated peak in 2001 and 2002, but subsequent densities are below the long-term mean. Eel densities estimated from electrofishing in the Miramichi River in eastern New Brunswick are the longest non-fisheries data series for the American eel. Densities varied irregularly in the 1950s and 1960s, peaked in the early 1970s, declined to a minimum in the late 1980s, and have since been increasing.

Eel densities on the Margaree River on Cape Breton Island peaked strongly in the early 1960s, weakly in the 1970s, and subsequently declined to very low levels. A CPUE of the Prince Edward Island (PEI) commercial fyke net fishery has increased between 1996 and 2004.

FEA4 - Newfoundland

Electrofishing survey results for the Northeast Brook on Trepassey Bay suggest a decline from the early 1980s to the mid-1990s. A similar downward trend is found in densities in the Highlands River on Newfoundland's west coast.

FEA5 - Labrador

Eels are found as far north as Hamilton Inlet and Lake Melville. Small numbers have recently been found north of this, in the English River. There are no quantitative abundance series for eels in Labrador.

Canadian Eel Components in the North American Context

Relative contribution of eels reared in FEA1 and elsewhere in Canada to total spawn output of the American eel can be crudely estimated by two methods. The discharge method is based on the assumption that the number of young eels recruiting from the ocean is a direct function of freshwater discharge. This method also takes into account regional variation in fecundity and sex ratio. The discharge method indicates that the St. Lawrence River basin (including the western part of FEA2) contributes 59.2% of the spawn output of the species if the species range is considered to exclude the Mississippi Basin, and 48.8% of the spawn output if range includes the Mississippi. The landings method indicates that FEA1 produces 26.4% of spawn output. Both the discharge and the landings methods rest on unproven assumptions, and their interpretation must consider the major uncertainties inherent in these analyses.

Changes in American eel data series were evaluated between years prior to 1980, and 2000-2005. The interval between these periods represents about three times the approximate generation time of female American eels. Series included reported landings and research survey indices. Percent change between the early and recent periods ranged from -99.5% to +74.8%. All four landings series, and five of the six survey indices, were negative. The sole U.S. series (reported landings) was negative (-67.5%). Landings may be influenced by many factors other than abundance. It is possible that abundance in the 1970s, when much of the early data was collected, was bolstered by favourable conditions of the North Atlantic Oscillation, thereby emphasizing the decline in comparison to recent times.

Rescue Effect

If Canadian eel components collapse, eels whose parents were reared in the United States or elsewhere, may re-colonize Canadian waters. However, the benefits of the rescue effect may be limited if components elsewhere collapse concurrently, particularly if migration is density dependent.

Limiting Factors and Threats

American eels are subject to natural and anthropogenic mortality factors. Changes in ocean current systems may interfere with the ability of leptocephalus larvae to reach continental waters. Estimated disappearance rates due to natural mortality and emigration to the spawning ground range from 15% to 26% per year.

Dams may prevent access to upstream growth habitat, and turbines in hydro dams kill some downstream migrants. There are two large hydro dams on the St. Lawrence River, but eels can bypass these by fish ladders and also by navigation locks. Most major tributaries of the St. Lawrence have impassable hydro dams. The Richelieu River is an exception; the two dams on this system have eel passes and no turbines. There are few dams in rivers flowing into the Gulf of St. Lawrence drainages of New Brunswick and Nova Scotia. There are numerous non-hydro dams on PEI, and there are numerous hydro dams on the Fundy and Atlantic drainages of New Brunswick and Nova Scotia, and in Newfoundland and Labrador. Risk of turbine mortality varies with turbine design and eel size; larger eels have a higher chance of being sliced by blades. Cumulative turbine mortality due to the two dams on the St. Lawrence main stem above Montreal is about 40%. All continental life stages are commercially fished in at least some parts of Canada. Reported Canadian commercial catches decreased in the 1990s. The formerly large yellow eel fishery in Lake Ontario was closed in 2004 due to conservation concerns. Eels are fished in the main stem of the St. Lawrence, and the large silver eel fishery occurs in the estuary. Eels are fished extensively in tidal waters in eastern New Brunswick and on PEI. Elsewhere in the Atlantic Provinces, fisheries may occur in either salt or fresh water, but large areas of eel habitat are unfished. In the 1970s and 1980s, toxic chemicals in the St. Lawrence system impacted eels there. Since that time, concentrations of major toxins have decreased in Lake Ontario. The swim-bladder parasite, *Anguillicola crassus*, has the potential to cause significant damage to eels. It has not yet been detected in Canada but is documented 40 km from the New Brunswick border.

Stocking is a potential way to reduce the sharp decline of eels in FEA1. The net benefit of stocking to total reproductive output depends on several factors which are poorly known, including effects of translocation on sex ratio, ability of translocated eels to find migration routes to the spawning grounds, the survival rates of eels that are stocked relative to the survival rates of the same eels if they had been left in their natural habitat, and the uncertainty whether stocked eels would spawn successfully.

Special Significance of the Species

The American eel has the greatest range of any fish species in North America and has supported major commercial, recreational, and Aboriginal fisheries. Eels were fished by Aboriginals, both in the pre-historic and historic periods. The upper St. Lawrence was a major eel fishing area for Aboriginals. Eels were an important food source for Mi'kmaqs in the Maritime Provinces.

Existing Protection or Other Status Designations

Fishing regulations are established by the Ontario and Quebec governments, and by the Department of Fisheries and Oceans in the Atlantic Provinces. American eels in Canada are not currently listed by the IUCN and have not been assessed by COSEWIC prior to 2006.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5th 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2006)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and it is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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SPECIES INFORMATION

Name and Classification

Class	Actinopterygii
Order	Anguilliformes
Family	*Anguillidae*
Genus	*Anguilla*
Scientific Name[1]	*Anguilla rostrata* (LeSueur,1817)
Common Names[1]	
English	American Eel
French	*Anguille d'Amérique*
Other	
English[2]	Atlantic eel, common eel, freshwater eel, silver eel, yellow-bellied eel, green eel, black eel, bronze eel, elver, whip, and easgann
French	anguille argentée, anguille jaune, anguillette, and civelle
Mi'kmaq[3]	*kat*

Members of the genus *Anguilla* are termed freshwater eels, although some species (including the American eel) are able to complete their life cycle in salt water (Tsukamoto *et al.* 1998; Arai *et al.* 2004; Lamson *et al.* submitted). The American eel is the only North American species of the genus.

Morphological Description

The American eel has an elongated and serpentine body (Figure 1). Its single continuous dorsal fin extends posteriorly from a point about one third of the body length behind the head, around the tail to the vent. The pectoral fin is supported by 7 to 9 radialia (up to 11 in young specimens); the mouth is terminal; the lower jaw slightly longer than the upper; the teeth are small and arranged in several rows on the jaws and palate; a tongue is present; the lips are thick; the lateral line and the palatopterygoid arch are well developed; the gill openings are not confluent; and, the frontal bones are paired (Tesch 1977).

Tesch (1977) described three morphological features which persist through all stages from larvae to maturing eels: the total number of vertebrae (mean 107.2), the number of myomeres (mean 108.2; evaluated at 106.84 by Kleckner and McCleave 1985), and the distance between the origin of the dorsal fin to the anus (mean 9.1% of total length). Other morphological characteristics can only be used comparatively if the individuals are at the same stage of development (e.g. leptocephalus, glass eel, elver, yellow eel, silver eel). Details for each life stage are presented in the Biology section.

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[1]Nelson *et al*. 2004.
[2]Scott and Crossman (1973), Scott and Scott (1988).
[3]Prosper (2001).

Figure 1. The American eel (from www.mnr.gov.on.ca).

Genetic Description

All freshwater eels belong to the genus *Anguilla*. Anguillid eels of the North Atlantic Ocean have been divided into two species based on morphological characters (Ege 1939; Tesch 1977) and molecular genetics (Avise *et al*. 1986; Aoyama *et al*. 2001; Wirth and Bernatchez 2003). The American eel inhabits continental waters on the western side of the Atlantic Ocean, while the European eel (*Anguilla anguilla*) is found in continental waters on the eastern side of the Atlantic. Both species also occupy the Sargasso Sea in the southern North Atlantic and Iceland in the northern North Atlantic. Hybrids between American and European eels have been identified in Iceland (Avise *et al*. 1990). Since these species are close relatives, some information from European eel studies has been applied to the American eel for the purpose of this status report.

Panmixia refers to a breeding system in which all members of a species mate randomly as a single breeding population. In panmictic species, genetic structure shows no geographical heterogeneity. Wirth and Bernatchez (2001) found mild geographic variation in the genetic structure of the European eel, which they interpreted as evidence against panmixia for that species. However, Dannewitz *et al*. (2005) argued that the reported genetic variation is due to temporal shifts and does not constitute evidence against panmixia. Microsatellite and mitochondrial DNA analysis of American eel samples from Gulf of St. Lawrence, the Atlantic coast of Canada, and the eastern seaboard of the U.S. indicate panmixia (Avise *et al*. 1986, Wirth and Bernatchez 2003) (Table 1). In this paper the American eel is considered to be panmictic, although final confirmation of this status requires genetic sampling from all parts of the species' range, including the St. Lawrence River and Lake Ontario.

Because of the American eel's panmictic nature, the word "population" refers to all members of the species. Eels from any subset of the species' range are referred to as a component.

Table 1. Pairwise sample differentiation estimates based on allelic variance at seven microsatellite loci in 21 North Atlantic eel samples (from Wirth and Bernatchez 2003). Bold indicates significant ϴ estimates following Bonferroni corrections (k =210, α =0.05/320 = 0.00024). Samples include eels from two Canadian sites in the Gulf of St. Lawrence: Trinité River and Long Pond, Prince Edward Island.

	samples	Minho	Couesnon	Tiber	Grand-Lieu	Elbe	Severn	Adour	Ölfus	Salses	Arresø	Motala	Imsa	St. John's	Wye	Medomak	Boston	South Edisto	Prince Edward Island	Hudson	Trinité
European eel	Moulony	0.00242	−0.0009	0.0006	0.0007	0.0017	−0.0009	0.0017	0.0011	−0.0001	0.0027	**0.0076**	−0.0008	**0.0195**	**0.0183**	**0.0176**	**0.0190**	**0.0244**	**0.0199**	**0.0124**	**0.0298**
	Minho		−0.0016	−0.0020	0.0005	0.0016	−0.0010	0.0008	−0.0008	0.0007	−0.0002	0.0039	0.0029	**0.0218**	**0.0203**	**0.0169**	**0.0219**	**0.0276**	**0.0206**	**0.0124**	**0.0307**
	Couesnon			0.0001	0.0005	0.0022	−0.0008	0.0006	−0.0011	−0.0005	0.0020	**0.0080**	0.0032	**0.0186**	**0.0145**	**0.0140**	**0.0184**	**0.0244**	**0.0163**	**0.0125**	**0.0263**
	Tiber				−0.0001	0.0046	−0.0002	0.0038	0.0014	0.0031	0.0021	**0.0110**	0.0030	**0.0174**	**0.0159**	**0.0159**	**0.0183**	**0.0234**	**0.0181**	**0.0113**	**0.0252**
	Grand-Lieu					0.0003	−0.0016	0.0002	−0.0009	0.0016	0.0011	**0.0078**	0.0035	**0.0156**	**0.0118**	**0.0127**	**0.0158**	**0.0217**	**0.0145**	**0.0080**	**0.0231**
	Elbe						−0.0002	0.0018	0.0016	0.0044	0.0003	**0.0044**	0.0044	**0.0196**	**0.0163**	**0.0175**	**0.0189**	**0.0254**	**0.0206**	**0.0161**	**0.0267**
	Severn							0.0045	0.0005	0.0011	0.0037	**0.0094**	0.0037	**0.0189**	**0.0196**	**0.0171**	**0.0199**	**0.0262**	**0.0215**	**0.0133**	**0.0290**
	Adour								0.0010	0.0026	−0.0013	0.0053	0.0022	**0.0216**	**0.0170**	**0.0148**	**0.0213**	**0.0271**	**0.0168**	**0.0148**	**0.0253**
	Ölfus									0.0010	0.0035	0.0063	0.0036	**0.0140**	**0.0116**	**0.0096**	**0.0132**	**0.0179**	**0.0134**	**0.0070**	**0.0212**
	Salses-Leucate										0.0036	0.0059	**0.0063**	**0.0217**	**0.0175**	**0.0177**	**0.0200**	**0.0295**	**0.0219**	**0.0153**	**0.0293**
	Arresø											0.0004	0.0030	**0.0216**	**0.0151**	**0.0179**	**0.0199**	**0.0257**	**0.0204**	**0.0153**	**0.0272**
	Motala												0.0078	**0.0360**	**0.0267**	**0.0297**	**0.0308**	**0.0397**	**0.0323**	**0.0215**	**0.0359**
	Imsa													**0.0180**	**0.0153**	**0.0143**	**0.0163**	**0.0186**	**0.0170**	**0.0086**	**0.0211**
American eel	St. John's														0.0037	0.0005	−0.0016	0.0016	−0.0003	0.0020	0.0032
	Wye															0.0034	−0.0008	**0.0073**	0.0022	0.0026	0.0026
	Medomak																−0.0005	0.0033	−0.0002	0.0015	0.0011
	Boston																	0.0018	0.0022	0.0010	0.0016
	South Edisto																		**0.0070**	0.0002	0.0041
	Prince Edward Island																			0.0034	0.0031
	Hudson																				**0.0052**

American eels spawn in the Sargasso Sea (Schmidt 1922). Leptocephali larvae are dispersed widely by ocean currents, including the Florida Current, the Gulf Stream and the North Atlantic Current, to western shores of the Atlantic Ocean. Because American eels are considered to belong to a single panmictic breeding population, they must be managed as a single stock (Castonguay *et al*. 1994a; Haro *et al*. 2000; Casselman 2003).

Designatable Units

Sub-speciation, geographic heterogeneity, range disjunction, or biogeographic distinction have not been demonstrated in the American eel population, and so the consideration of assessment below the species level is not an option. Yet, the panmictic nature of American eel life history implies that factors affecting any life stage, in any geographic area of the range, and in any array of habitats, have the potential to affect the abundance of all life stages of the species throughout the range. Regional factors can affect eels as they disperse towards continental coastlines and during the long growth phase, such that eel components may be in difficulty in some parts of the range while maintaining strong numbers elsewhere.

Geographic trends are evident in American eels in the sizes and trajectories of components, types and magnitude of threats, and contribution to recruitment. In addition, migration in medium and large rivers may be density-dependent, e.g. the size of a component in a given geographic area is dependent on the densities of eels downstream. Therefore, although panmixis precludes assignment of status below the species level, consideration of the status of the species can be aided by developing the discussion in terms of the applicable geographic areas or ecozones. The American eel occupies five freshwater ecological areas (FEAs) in Canada, as defined by COSEWIC. These FEAs are: 1) Great Lakes-Western (Upper) St. Lawrence (Ontario and western and central Quebec); 2) Eastern (Lower) St. Lawrence (eastern Quebec); 3) Maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and the central and southern parts of Quebec's Gaspé Peninsula); 4) Atlantic Islands (Newfoundland); and 5) Eastern Arctic (Labrador). Contrary to the COSEWIC ecological areas system, Anticosti Island is assigned to FEA2 rather than to FEA4. In this report, the part of FEA3 that drains into the Atlantic Ocean and the Bay of Fundy is referred to as Scotia-Fundy.

DISTRIBUTION

Global Range

The American eel is a catadromous species that is widely distributed in fresh waters (streams and lakes), estuaries and coastal marine waters along more than 50 degrees of latitude (from 5° to 63°) of the western North Atlantic Ocean coastline Figure 2), from Venezuela to Greenland and Iceland (Scott and Crossman 1973; Tesch 1977; Helfman *et al*. 1987).

Figure 2. Global range, Lee (1980).

Canadian Range

The historic Canadian range encompasses all accessible fresh water, estuaries and coastal marine waters connected to the Atlantic Ocean of Canada, up to the mid-Labrador coast (Figure 3). Continental shelves are used by juvenile eels arriving from the spawning grounds, and by silver eels returning to the spawning grounds. Eels regularly occur up to Hamilton Inlet-Lake Melville, Labrador (53°15' N; 60°10' W; Scott and Crossman 1973). However, they have also been found further north in Labrador in the English River (Kaipokok Bay: 54°58'N; 59°45'W; K.D. Clarke, DFO, pers. comm.).

Niagara Falls is the natural limit of the American eel's distribution in the Great Lakes. Occurrences reported in the upper Great Lakes watersheds (Lakes Erie, Huron and Superior) are the result of recent dispersal through the Erie and Welland canals (Scott and Crossman 1973). Such records should probably be considered as introductions (Figure 3).

Extent of occurrence (EO) for each FEA was measured according to the COSEWIC definition: the area included in a polygon without concave angles that encompasses the geographic distribution of all known components of a species. In drawing the polygons ocean migration routes and zones occupied by vagrants were not

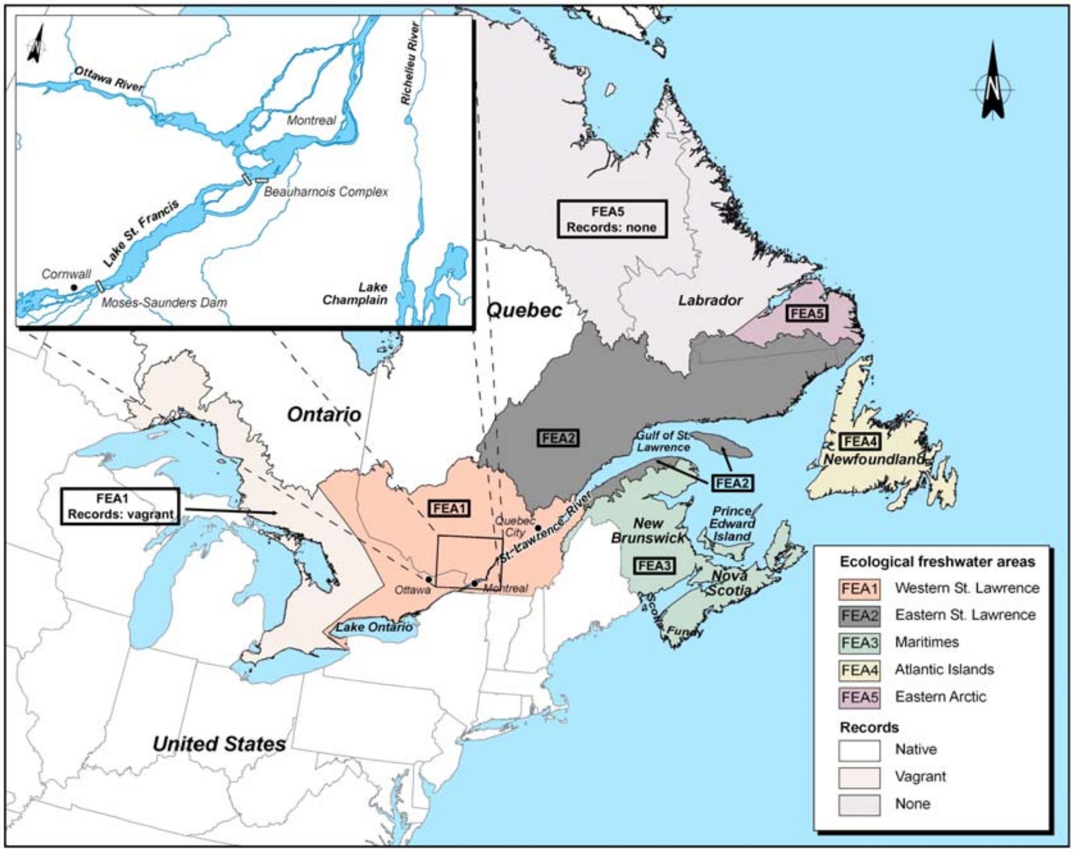

Figure 3. Canadian geographic range of the American eel (records from Mandrak and Crossman 1992).

considered. EO was measured by planimeter from Figure 3. EOs are 391,515 km^2 for FEA1, 546,122 km^2 for FEA2, 292,923 km^2 for FEA3, 177,586 km^2 (10.6%) for FEA 4, and 75,472 km^2 (5.4%) for FEA5. The EO for the Canadian range is 2,065,932 km^2. Area of occupancy (AO) is based on aquatic habitat only. Since the American eel utilizes continental shelves during migration, a buffer of 370 km (200 nautical miles) from shore has been considered. In Lake Ontario, only the area between the shoreline and 10 m of depth has been considered. Such area of occupancy has been calculated by Verreault *et al*. (2004). Areas of occupancy in km2 for FEAs 1 through 5 and for Canada are 97,400, 161,400, 635,200, 627,500, 130,700, 1,653,200 respectively.

HABITAT

Habitat Requirements

The American eel uses a very broad diversity of habitats (Helfman *et al*. 1987). During their oceanic migrations, eels occupy salt water and, in their continental phase, they use all salinity zones. During the continental phase, marine habitat use is limited to shallow protected waters. Survival is affected by environmental conditions in any habitat (oceanic, estuarine, freshwater) occupied during any life cycle phase, and by anthropogenic factors such as hydro-dams, habitat modification and fisheries.

Growing eels are primarily benthic, utilizing substrate (rock, sand, mud) and bottom debris such as snags and submerged vegetation for protection and cover (Scott and Crossman 1973; Tesch 1977).

Eel densities typically diminish with distance from the sea in medium and large rivers (Smith and Saunders 1955; Gray and Andrews 1971; Smogor *et al*. 1995). This pattern, however, may be altered by natural or artificial obstacles. In a component of European eels, White and Knights (1997) reported that barriers to upstream migration had a greater effect on eel densities than distance from the ocean. Ability to overcome obstacles is size-dependent. Small eels (less than 10 cm long) are able to creep up damp vertical barriers (Legault 1988), but larger eels are generally unable to bypass large waterfalls and dams (McCleave 1980; Barbin and Krueger 1994). Hence, larger eels attempting to move upstream require unobstructed passage (Moriarty 1987).

Reduced survival of maturing eels in their seaward migration has been associated with passage through hydroelectric turbines (Desrochers 1995; Normandeau Associates and Skalski 2000), fisheries (Castonguay *et al*. 1994a; Caron *et al*. 2003; Verreault and Dumont 2003), and with obstructions which produce free falls of more than 13 m (Larinier and Travade 1999).

Continental-phase American eels are highly plastic in their habitat use. In streams, eels generally do not show consistent preferences for habitat type, cover, substrate, water temperature, and density of predators (Hawkins 1995; Smogor *et al*. 1995), but there is some association between eel densities and diversity of depth-velocity regimes (Wiley *et al*. 2004). In Prince Edward Island, eels are abundant in freshwater ponds formed by dams but are rare in most freshwater streams (Cairns *et al*. submitted).

Some continental-phase eels are predominantly sedentary but others are predominantly migrant (Feunteun *et al*. 2003). Since otoliths are essentially calcium carbonate in an organic proteinaceous matrix, Casselman (1982) analyzed strontium/calcium ratios in eel otoliths to document migratory stages. Recent investigations using otolith microchemistry (Jessop *et al*. 2002; Cairns *et al*. 2004; Thibault *et al*. 2005; Lamson *et al*. submitted) report three main movement patterns: salt water residency, freshwater residency, and inter-habitat shifting. In the St. Jean River on the Gaspé Peninsula, some freshwater resident eels perform very short intrusions into brackish or salt water (Daverat *et al*., in press). Inter-habitat shifting is more frequent in systems where dams do not hinder movements (Jessop *et al*. 2002; Cairns *et al*. 2004). Catadromy is no longer seen as obligate for eels, but rather is a facultative life history option (Tsukamoto *et al*. 1998; Jessop *et al*. 2002; Morrison *et al*. 2003; Arai *et al*. 2004; Lamson *et al*. submitted). Seasonal local movements associated with wintering may also involve habitat needs in terms of water temperature, oxygen concentration and water quality, but winter habitat requirements are poorly known (Tesch 1977; Feunteun *et al*. 2003).

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

Habitat Trends

Freshwater habitat deterioration, migratory barriers generating habitat loss and fragmentation for upstream migrants, and turbine mortality for downstream migrants, are among the most frequently cited factors proposed to explain the declines of the American eel (Castonguay *et al.* 1994a; Haro *et al.* 2000; Verreault *et al.* 2004). The effects of dams are presented in the Limiting Factors and Threats section, under Habitat modifications and dams. In general, habitat factors have shown relative stability over the past several decades, and changes in these factors do not correspond to the timing of changes in eel populations (Castonguay *et al*. 1994a).

Protection/Ownership

In Canada, American eels occur primarily in publicly owned waters. The species' habitat, including ocean habitat used during migrations, receives protection against alteration and destruction by the Canadian *Fisheries Act*, the Canadian *Environmental Protection Act*, and numerous provincial acts including the Ontario *Environmental Protection Act*, the Ontario *Water Resources Act*, and the Quebec *Environmental Quality Act*. Habitat that lies within National Parks, Provincial Parks, National Wildlife Areas, and Marine Protected Areas may be subject to additional protections through the *National Parks Act*, the *Loi sur les Parcs* in Quebec, the Ontario *Provincial Parks Act* in Ontario and the *Canada Wildlife Act*. However, rules governing parks and conservation areas do not necessarily prohibit exploitation and do not automatically protect eels from other threats (see Limiting Factors and Threats section).

BIOLOGY

Life Cycle, Migratory Behaviour, Growth and Reproduction

The life history of the American eel encompasses oceanic, coastal, estuarine and freshwater environments. Spawning and hatching take place in the Sargasso Sea (Schmidt 1922). Larvae are transported to coastal waters by the Gulf Stream system formed by the Florida Current, the Gulf Stream and the North Atlantic Current. Some arriving juvenile eels migrate up rivers to become resident yellow eels of freshwater habitats; whereas others remain in brackish or salt waters, and still others show inter-habitat movements (Jessop *et al*. 2002; Cairns *et al*. 2004; Thibault *et al*. 2005; Lamson *et al*. submitted). After a number of years (typically 8 to 23; this report) in growth habitats, eels mature into silver eels that migrate back to the spawning grounds. Spawning occurs once; therefore, the American eel is a semelparous species (Helfman *et al*. 1987) and each mortality within continental waters is a pre-spawning mortality. The terminology of eel life history differentiates stages according to migration patterns and morphological characteristics. Life stages are detailed below.

Egg

The egg probably hatches within a week of deposition in the Sargasso Sea. McCleave *et al*. (1987) suggested that hatching peaks in February and may continue until April. Wang and Tzeng (2000) proposed, on the basis of otolith back-calculations, that hatching occurs from March to October and peaks in August. However, Cieri and McCleave (2000) argued that these back-calculated spawning dates do not match collection evidence and may be explained by resorption.

Leptocephalus

The leptocephalus is the larval form. Leptocephali are transparent willow leaf-like, laterally compressed larvae (Figure 4) that are passively transported west and north to coastal waters on the eastern coast of North America, by the surface currents of the Gulf Stream system (Schmidt 1922; Tesch 1977; Kleckner and McCleave 1982). This stochastic larval distribution is completed in 7 to 12 months (Kleckner and McCleave 1985; Wang and Tzeng 2000). Vertical distribution is usually restricted to the upper 350 m of the ocean (Kleckner and McCleave 1982; Castonguay and McCleave 1987). Growth has been evaluated at about 0.21 to 0.38 mm per day (Kleckner and McCleave 1985; Castonguay 1987; Tesch 1998; Wang and Tzeng 2000).

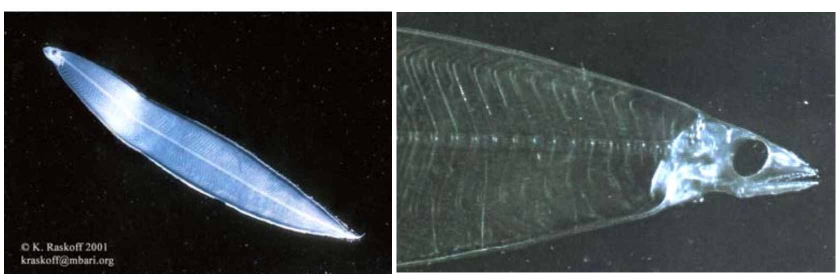

Figure 4. Leptocephalus, larval stage [from kraskoff@mbari.org and P. Parks (OSF)].

Glass Eel

As they enter the continental shelf, leptocephali metamorphose into glass eels (Figure 5), which have the typical elongate and serpentine eel shape (McCleave *et al*. 1987). The term glass eel refers to all developmental stages from the end of metamorphosis of the leptocephalus to pigmentation (Tesch 1977). Metamorphosis occurs when leptocephali are about 55 to 65 mm long (Kleckner and McCleave 1985). Mean age at this metamorphosis has been evaluated at 200 days and estuarine arrival

Figure 5. Glass eels, unpigmented elvers, post-larval stage (from MRNF, Secteur Faune Québec).

at 255 days; giving 55 days between glass eel metamorphosis and estuarine arrival (Wang and Tzeng 2000). During the elver run in the East River (Chester, Nova Scotia), the degree of elver pigmentation increased progressively over the run, and glass eels were rarely found after the end of May (Jessop 2003a). On the north shore of the Gulf of St. Lawrence, in the Petite Trinité River, glass eels occurred in the second half of June and were rare compared to elvers (Dutil *et al*. 1989).

Young eels use selective tidal stream transport to move up estuaries (Kleckner and McCleave 1982). As they enter coastal waters, the animals essentially transform from a pelagic oceanic organism to a benthic continental organism.

Elver

Glass eels become progressively pigmented as they approach the shore; these eels are termed elvers. The melanic pigmentation process (Bertin 1951; Élie *et al*. 1982; Grellier *et al*. 1991) occurs when the young eels are in coastal waters. At this phase of the life cycle, the eel is still sexually undifferentiated. The elver stage lasts about three to twelve months. Elvers that enter fresh water may spend much of this period migrating upstream (Haro and Krueger 1991; Jessop 1998a). Elver influx is linked to increased temperature and reduced flow early in the migration season, and to tidal cycle influence later on (Tesch 1977; Kleckner and McCleave 1982; Martin 1995; Jessop 2003b).

Elver length and arrival date increase from south to north along the Atlantic coast of North America (Vladykov 1966; Haro and Krueger 1988). In Atlantic coastal Nova Scotia, elver migration peaks between late April-early May and late June, although small numbers of elvers may continue to enter rivers until mid-August (Jessop 1998a). Total length averaged 60.14 ± 0.17 mm (50.4-70.5 mm) in 2000 on the East River, Chester, Nova Scotia (Jessop 2003c). On the Murray River (Prince Edward Island), elvers were caught between the end of June and the end of August (Cairns *et al*., submitted). In the Petite Trinité River (north shore of the Gulf of St. Lawrence), most individuals were already pigmented (elvers) in early July but arrived until the end of July (Dutil *et al*. 1989) and averaged 62.4 mm (59-69 mm).

Yellow Eel

The yellow stage is the growth phase of the species. The belly colour varies from yellowish to greenish or olive-brown, with the back remaining dark (Scott and Crossman 1973; Tesch 1977). The skin is thick and tough and may secrete copious amounts of mucous, which acts as a protective cover. Unlike the well-developed scales of most fishes, eel scales are rudimentary and embedded deeply within the skin.

Sexual differentiation occurs during the yellow stage and appears to be strongly influenced by environmental conditions (Krueger and Oliveira 1997; Oliveira 1997; Krueger and Oliveira 1999). Krueger and Oliveira (1999) suggested that density was the primary environmental factor influencing the sex ratio of eels in a river, with high densities promoting the production of males. From life history traits of four rivers of Maine, Oliveira and McCleave (2000) evaluated that sexual differentiation was completed by 270 mm total length.

In most Canadian waters more than 95% of sexually differentiated eels are female (Gray and Andrews 1970; Dolan and Power 1977; Dutil *et al*. 1985; Jessop 1987; Fournier and Caron 2005). In particular, eels in the upper St. Lawrence and Lake Ontario are virtually all female. Males appear to be more common in the Scotia-Fundy region than elsewhere in Canada. In the Saint John River, males were 7.4% of a sample of 970 eels (Ingraham 1999). In stream portions of the East River (Chester, Nova Scotia), more than 55% of yellow eels sampled were classified as males (Jessop *et al*., in press). Eels which had been captured as elvers in the Bay of Fundy and stocked in a lake on the south shore of the St. Lawrence River (FEA2) contained 27.2% males after four years of growth (Verreault *et al*., submitted). Yellow eels may continue to migrate upstream for many years. Female juvenile eels passing the eel ladder at the Moses-Saunders dam near Cornwall (Ontario) in the 1970s and 1980s ranged in age from 3 to 7 years, averaging 5 years (Casselman *et al*. 1997). Eels ascending this ladder in recent years are much older, ranging in age from 10 to 14 years, averaging 12 years (J.M. Casselman, pers. obs.). These eels are headed for Lake Ontario, the largest single growth habitat for the American eel within its distribution range.

In the Sud-Ouest River (south shore of the St. Lawrence River) and the Petite Trinité River (northwestern shore of the Gulf of St. Lawrence), upstream migrations occurred between June and August (Dutil *et al*. 1989; Verreault 2002; Fournier and Caron 2005). At Chambly, Beauharnois and Moses-Saunders dams, migration generally peaks in July and August (Casselman *et al*. 1997; Casselman 2003, Verdon *et al*. 2003; Bernard and Desrochers 2005). A fall peak has also been observed at Moses-Saunders in 2004 and 2005 (J.M. Casselman, pers. obs.). In components that have ready access to brackish or salt waters, eels are reported to move from fresh water to estuaries in the spring, and move back to fresh water in the fall (Medcof 1969; F. Caron, MNRF, Secteur Faune Quebec, pers. obs.).

Home ranges occupied by individual yellow eels vary with habitat type (stream, lake, tidal, creek, marsh, estuary) and movement patterns (freshwater residency, salt water residency, inter-habitat shifting). Home range was estimated to be relatively small (up to 2 ha) in estuarine habitats such as salt marshes (Ford and Mercer 1986) and tidal streams (Bozeman *et al*. 1985; Dutil *et al*. 1988), but in Lake Champlain, LaBar and Facey (1983) reported home ranges up to 65 ha.

Growth patterns are affected by habitat type. Eels utilizing brackish and salt waters grow much more rapidly than those in fresh waters (Jessop *et al*. 2002; Cairns *et al*. 2004; Jessop *et al*. 2004). Variation exists among freshwater habitats as well. Annual growth increments of eels translocated in a watershed originally without eels (see Stocking section) were much lower in rivers (40 mm per year) than in a lake (112 mm per year; Verreault *et al*., submitted).

In Canadian waters, American eels hibernate in mud during the winter. Wintering habitats include fresh waters, brackish estuaries, and bays with full strength salt water (Smith and Saunders 1955; D.K. Cairns, DFO, pers. obs.). Eels in estuaries often concentrate in mud that has freshwater upwelling, but they may also be found in bottoms that have no freshwater influx (D.K. Cairns, DFO, pers. obs.). Eels are reported to enter torpor (complete inactivity) at temperatures below 5°C (Walsh *et al*. 1983), and at less than about 2°C based on aquaculture experiments to minimize weight loss (B.M. Jessop, DFO, pers. comm.). Smith and Saunders (1955) caught two eels in a stream trap in Prince Edward Island in January and February. Eels speared through the ice in a Prince Edward Island estuary in January had stomachs bulging with fresh and undigested silversides (*Menidia menidia*), suggesting recent feeding activity (D.K. Cairns, DFO, pers. obs.). These observations suggest that eels are occasionally active during the normal period of hibernation.

<u>Silver Eel</u>

As the maturation process proceeds, the yellow eel metamorphoses into a silver eel. The silvering metamorphosis results in morphological and physiological modifications that prepare the animal to migrate back to the Sargasso Sea. The eel acquires a greyish colour with a whitish or cream coloration ventrally (Gray and Andrews 1971; Scott and Crossman 1973; Tesch 1977). The digestive tract degenerates (Pankhurst and Sorensen 1984; Durif 2003), the pectoral fins enlarge to improve swimming capacity (Pankhurst 1982a; McGrath *et al*. 2003; Durif 2003), eye diameter expands and visual pigments in the retina adapt to the oceanic environment (Vladykov 1966; Pankhurst 1982b; McGrath *et al*. 2003), the integument thickens (Tesch 1977; Pankhurst and Lythgoe 1982), percentage of somatic lipids increases to supply energy for migrating and spawning (Larsson *et al*. 1990; Tremblay 2004), gonadosomatic index (Verreault 2002; McGrath *et al*. 2003; Tremblay 2004) and oocyte diameter increase (Couillard *et al*. 1997), gonadotropin hormone (GTH-II) production increases (Durif *et al*. 2005), and osmoregulatory physiology changes (Dutil *et al*. 1987).

Distance travelled to reach the Sargasso Sea varies substantially over the geographic range of the American eel. A silver eel from the most distant growth habitat, western Lake Ontario, must migrate more than 4,500 km to reach the spawning grounds, whereas a maturing eel from the closest Canadian growth habitat, southern Nova Scotia, migrates about 2,000 km. Disparities in migration distance generate disparities in the timing of the onset of the migration, probably related to synchronous arrival in the Sargasso Sea, permitting spawning between February (peak) and April (Kleckner *et al*. 1983; Kleckner and McCleave 1985; Helfman *et al*. 1987). Maturing eels begin to descend the Richelieu River in May (Dumont *et al*. 1998). Eels from Lake Ontario begin outmigrating in mid- to late June (McGrath *et al*. 2003). Silver eels from Nova Scotia, which is much closer to the spawning grounds, outmigrate until November (Jessop 1987). Downstream migration occurs primarily at night.

There are large variations in reproductive characteristics of female silver eels across the species' range (Nilo and Fortin 2001). Because the species is panmictic (Avise *et al*. 1986; Wirth and Bernatchez 2003), variations cannot be explained genetically. Eels from northern components show slower growth and greater length, weight, and age at migration (Hurley 1972; Facey and LaBar 1981; Helfman *et al*. 1987). Being less variable within a given component, size, rather than age, appears to be the main cue triggering maturation and migration (Helfman *et al*. 1987; Oliveira 1999; Verreault 2002; Tremblay 2004). Pre-spawning female eels from the St. Lawrence River and its tributaries are generally much larger (means 837-1043 mm; this report) than those from other freshwater rearing sites in Canada (means 650-694 mm; this report) (Table 2).

Table 2. Migration periods, mean length and age of female silver eels exiting Canadian freshwater systems.

Site	FEA[A]	Migration period	n	Length (mm)	Age	Reference
Upper St. Lawrence River St. Francis and St. Lawrence lakes, Moses-Saunders Vicinity of Iroquois dam	1	June–October	200 53 30	915 976 1,001	20 21	Casselman 2003 McGrath *et al.* 2003 Tremblay 2004
Richelieu River	1	June-October	494	1,019		Dumont *et al.* 1998
St. Lawrence estuary	1	September-October	474 4,52 9 30	840 853 837	 20	Couillard *et al.* 1997 Verreault *et al.* 2003 Tremblay 2004
Sud-Ouest River (South shore of the St. Lawrence)	2	August-November	107 30	1,026 1,043	21 23	Verreault 2002 Tremblay 2004
Rivière aux Pins	2		100	600		Couillard *et al.* 1997
Petite Trinité River (North shore of the St. Lawrence)	2	August-October	424 30	650 679	17 20	Fournier and Caron 2005 Tremblay 2004
Long Pond (Prince Edward Island)	3	August-October	30	693	20	Tremblay 2004
Margaree River, Nova Scotia	3	September	319	642		D.K. Cairns, DFO, unpubl.
Topsail and Indian ponds, Salmon River, Burnt Berry Brook, Topsail Barachois (Newfoundland)	4	August-October	92	694	12	Gray and Andrews 1971
LaHave River (Nova Scotia)	3	August-November	346	611	19	Jessop 1987

The overall mean of mean age at spawning migration of female silver eels leaving Canadian freshwater sites is 19.3 years (SD 3.0, range 12-23, Table 2). Age of silver eels from brackish and saltwater habitat is poorly known because such eels are difficult to sample as they leave for the spawning grounds. Silver eels leaving Long Pond, a freshwater pond on Prince Edward Island, had a mean length of 693 mm (Table 2). If eels from the same geographic area have similar sizes at silvering, the age of silvering of eels reared in salt water can be estimated from growth trajectories of resident salt water eels. Eels from salt water bays a few km from Long Pond, whose exclusive use of salt water habitat was confirmed by strontium-calcium analysis, showed an annual growth of 55.8 mm/year (Lamson submitted). Given this growth rate these salt water residents would reach 693 mm at about age 7. Eel growth rate increases sharply with salinity (Lamson submitted), so the phenomenon of eels silvering much younger in marine than fresh water is probably widespread and general.

Eel ages are conventionally scored as being 0 during the year of continental arrival. Hence generation time is calculated as age at silvering + 2, to account for the time of migration from and to the spawning grounds. Because American eels are a long-lived species, population indicators of any continental stage other than glass eels/elvers typically include numerous year-classes.

American eel fecundity increases with body size (Wenner and Musick 1974; Barbin and McCleave 1997; Tremblay 2004). The large body size of female silver eels from the St. Lawrence River system (Table 2) means that these eels are much more fecund than those from elsewhere in Canada. In five components within the St. Lawrence River and Gulf, Tremblay (2004) found that absolute fecundity ranges from 3.4 to 22 million eggs for body lengths ranging from 53.2 to 111.0 cm and body weight ranging from 260 to 3,340 g. Large-bodied eels average about 6.5 million oocytes / kg while small-bodied eels have more than 10 million oocytes / kg.

Because of their large size, high fecundity, and exclusively female composition, silver eels exiting the upper St. Lawrence and Lake Ontario have the highest potential egg production per exiting migrant of any American eel component.

Male silver eels are more common in components south of the St. Lawrence River and Gulf, including the Scotia-Fundy region and the east coast of the United States. According to Oliveira *et al*. (2001), the proportion of male silver eels seems to be inversely related to the amount of lacustrine habitat. In a small Nova Scotian river (East River, Chester), Jessop *et al*. (2002) reported that 56.5% of silver eels (n=62) were males. In the Annaquatucket River (Rhode Island), sex ratios of silver eels ranged from 77% males in 1977 to 94% males in 1991 (Krueger and Oliveira 1997). Since males become silver eels at much smaller sizes than females, sex of silver eels can usually be evaluated by size alone. Winn *et al*. (1975) used a length threshold of 400 mm to identify females. Male silver eels from the Annaquatucket River have a mean length of 337.3 ± 0.4 mm (n = 2,998) and a mean age of 10.9 ± 0.1 years (n = 853) (Oliveira 1999). Compared to female silver eels, males have a more constrained size and age at migration. Unlike females which have large body sizes to increase fecundity, males appear to migrate back to the Sargasso Sea at the minimum size necessary to survive the spawning migration (Helfman *et al*. 1987).

Nutrition

Leptocephalus

Little is known about the food habits of leptocephali. Recent studies on other eel species (Otake *et al*. 1993; Mochioka and Iwamizu 1996) suggest that leptocephali do not feed on zooplankton but rather consume detrital particles such as marine snow and fecal pellets or particles such as discarded houses of larvacean tunicates.

Glass Eel and Elver

Based on laboratory experiments on European glass eels, Lecomte-Finiger (1983) reported that they were morphologically and physiologically unable to feed. However, Tesch (1977) found that elvers at a later stage of pigmentation, stage VIA4 (Élie *et al.* 1982), were feeding. Stomach examination of elvers caught during their upstream migration in the Petite Trinité River on the north shore of the Gulf of St. Lawrence revealed that elvers fed primarily on insect larvae (Dutil *et al.* 1989).

Yellow Eel

The yellow eel is essentially a nocturnal benthic omnivore. Prey includes fishes, molluscs, crustaceans, insect larvae, surface-dwelling insects, worms and plants. The eel prefers small prey animals which can easily be attacked (Tesch 1977). Food type varies with body size (Ogden 1970, cited in Tesch 1977). Stomachs of eels less than 40 cm and captured in streams contained mainly aquatic insect larvae, whereas larger eels fed predominantly on fishes and crayfishes. In Lake Champlain, food sources were mainly fish (38%), decapods (30%) and insects (10%). Insect abundance decreased in larger eels (Facey and LaBar 1981). The eel diet adapts to seasonal changes and the immediate environment. Feeding activity decreases or stops during the winter, and food intake ceases as eels physiologically prepare for the spawning migration.

POPULATION SIZE AND TRENDS

Studies on eel densities and sizes of components in Canada are limited. Types of available data vary among FEAs. Reported landings are available for all FEAs (see Limiting Factors and Threats section). All the data presented are compiled in Cairns *et al*. (unpubl. ms.). Spawning escapement in the American eel is considered to be 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.

FEA1 - Great Lakes and Western St. Lawrence (Ontario and western and central Quebec)

The number of eels in FEA1 (Figure 6) declined greatly from the mid-1980s through the 1990s (Castonguay *et al*. 1994a; Casselman *et al*. 1997; Casselman 2003). Commercial catches in Ontario declined sharply despite increased price per kg and fishing effort (Casselman 2003). Eel abundance has been severely reduced in Lake Champlain, the Ottawa and Richelieu river basins, the upper St. Lawrence River and Lake Ontario. Early declines have also been documented in three major tributaries on the US side of Lake Ontario: Oswego River (including Oneida Lake), Genesee River and Black River. Eel exclusion from these tributaries is due essentially to migration barriers. Rising commercial catches in the Quebec portion of Lake St. Francis are in contrast to the overall trend FEA1. However, harvest in Lake St. Francis is quite small compared with that in other sections of the system (Casselman 2003) and might be associated with closure of the Ontario fisheries (J.M. Casselman, pers. obs.).

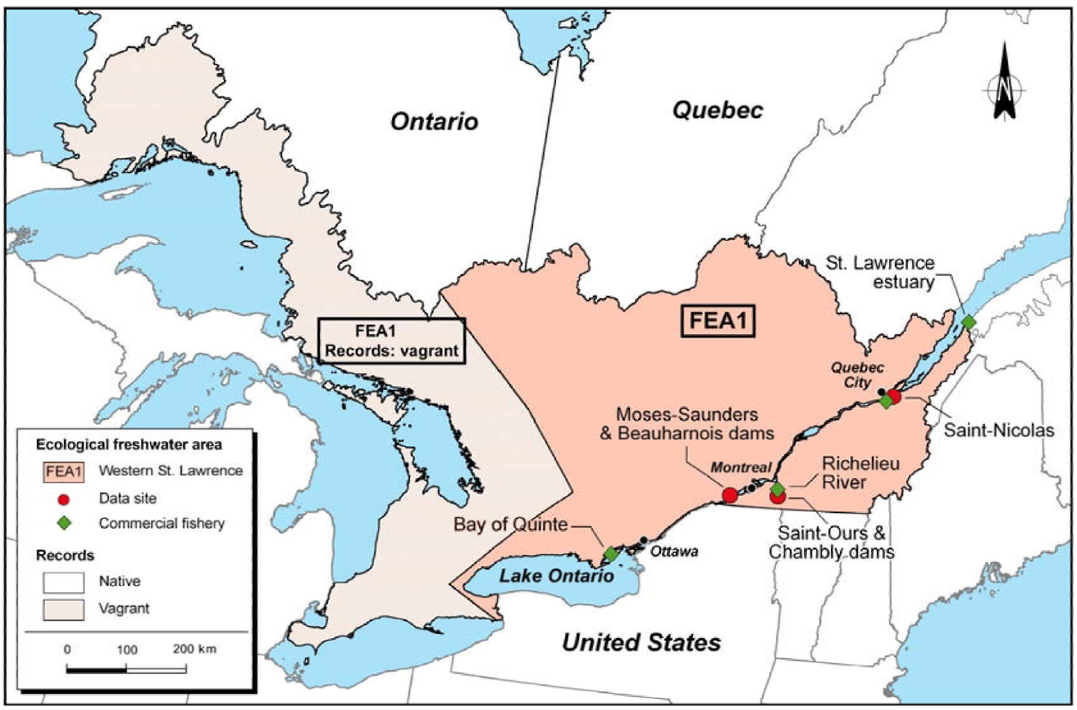

Figure 6. Data sites and commercial fisheries within the ecological freshwater area FEA1, Great Lakes - Western St. Lawrence (records from Mandrak and Crossman 1992).

Indices of Juvenile Abundance

The longest-term data set on yellow eel recruitment in FEA1 is for upstream migrants ascending, during peak migration (31 days), the eel ladder at the Moses-Saunders dam (Castonguay *et a*l. 1994a; Casselman *et al*. 1997; Casselman 2003). This ladder was first installed in 1974. Eels ascending the ladder had a mean age of about 6 in 1975 (Liew 1976), but mean age increased to about 12 in the 1990s

(Casselman 2003). After a peak in 1982-1983, ladder counts dropped sharply and fell to record low levels in the late 1990s (Figure 7; Casselman 2003). The few eels that ascended the ladder in the 1990s were much larger and older (mean 493 ± 17 mm; 11.9 ± 1.1 years) than typical recruits before the decline (mean 363 mm ± 15 mm; 5.6 ± 0.1 years) (Casselman 2003). The number of juvenile eels climbing the eel ladder has declined from more than one million per year in the early 1980s to fewer than 4,000 annually (less than 60 eels per day) in most years since 1998 (J.M. Casselman, pers. obs.). The index showed upward movement in 2005, with a mean summer peak of 227 eels per day. Over the past 20 years (approximately one generation time for the St. Lawrence River-Lake Ontario component), recruitment at the eel ladder has fallen by three orders of magnitude (Casselman 2003) to approximately 0.2% of its level in the early 1980s, and recruitment of young juveniles is now at minimal levels (J.M. Casselman, pers. obs.).

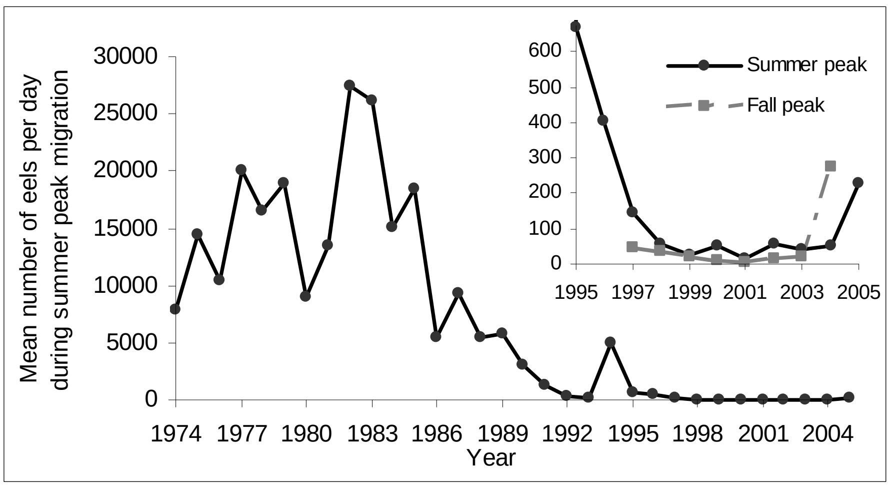

Figure 7. Number of eels ascending the eel ladder per day at the Moses-Saunders dam in the upper St. Lawrence River at Cornwall, Ontario, during the 31 day summer peak migration period between 1974 and 2005 (from J.M. Casselman, OMNR). The insert shows mean daily summer and fall peak (31 days) counts between 1995 and 2005. In 2004, the fall peak (n = 274 per day) surpassed the mid-summer peak for the first time. However, these were not young eels but were larger individuals. Counts for 1996 are predictions from correlations between catch and eel ladder abundance

Young eels ascending climbing facilities on the west side of the Beauharnois dam were monitored in 1994-1995 and 1998-2005 (Bernard and Desrochers 2005). Counts dropped from 24,721 in 1994 to 5,441 in 1998, and then rose to 51,694 in 2005. The increasing trend in Beauharnois counts corresponds to the modest recent increases in the Moses-Saunders index of approximately 11,000 in 2004 and 2005 (J.M. Casselman, Queen's University, pers. obs.). The rising numbers at Beauharnois beginning in 1998 also correspond to a decrease in mean eel size, suggesting a declining mean age of eels that arrive at the dam. Despite the recent increases, the number of eels counted through the west Beaharnois facility is still far short of the number needed to restore the annual passage that occurred at Moses-Saunders in the 1980s (ca. 1 million per year). However, eels also move upstream from Beauharnois via the navigation locks, and the number using this route is unknown.

Upstream movements of yellow eels has been monitored at the Chambly dam on the Richelieu River since 1998 (Bernard and Desrochers 2005). Numbers were high in the first two years the ladder operated, presumably because of pent-up demand by eels that had previously been unable to migrate. Since 2000 there have been irregular increases, with 2,177 eels counted upstream in 2005. Numbers of eels ascending the Chambly ladder are insufficient to restore historical abundance levels in upstream waters. The efficiency of this ladder is 60%. The former commercial fishery in the Richelieu River (efficiency of 66%) harvested a mean of 34,000 kg (or approx. 23,000 individuals) of silver eels annually between 1920 and 1980.

Indices of Yellow Eel Abundance

Catch per unit effort (CPUE) in the trawl fishery for yellow eels in the Bay of Quinte (Lake Ontario), the commercial electrofishing index, and total reported landings for Ontario have declined in parallel with the Moses-Saunders recruitment index (Figures 8 and 7; Casselman 2003). The most recent electrofishing catches in eastern Lake Ontario are 0.5% of what they were in the late 1980s (J.M. Casselman, pers. obs.).

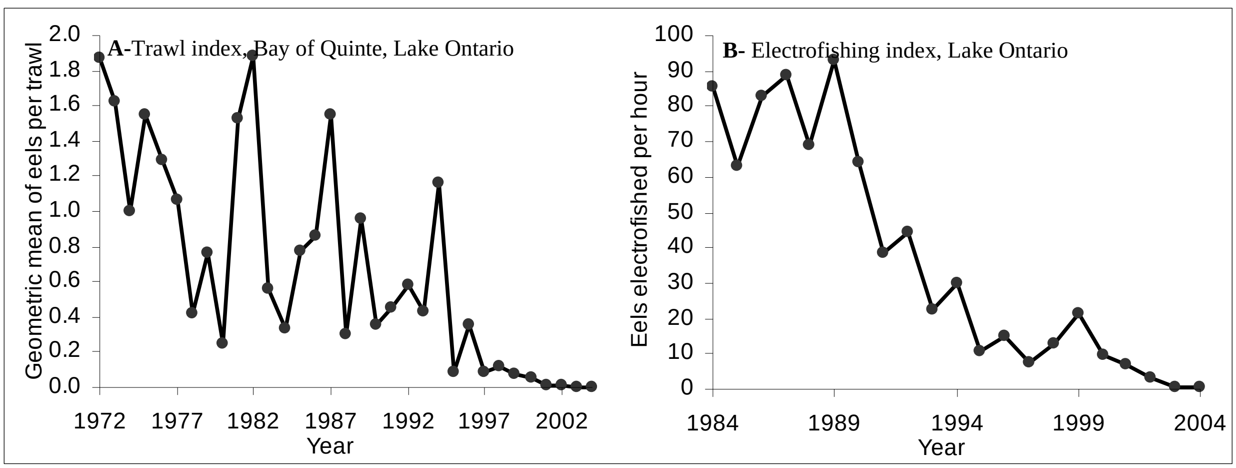

Figure 8. Fisheries independent indices of abundance of yellow eels in FEA1 (from J.M. Casselman, OMNR): (A) bottom trawl CPUE from Bay of Quinte, Lake Ontario (1972-2004); (B) electrofishing CPUE from eastern Lake Ontario (1984-2004).

North Atlantic Oscillation Index (NAOI)

The North Atlantic Oscillation Index (NAOI, National Center for Atmospheric Research 2005) describes the ratio of atmospheric pressures in the Azores and Iceland. The NAOI is linked to a wide variety of biological processes in the North Atlantic Ocean (e.g. Jonsson and Jonsson 2004). Eel recruitment in the past two decades to the upper St. Lawrence River and Lake Ontario is highly significantly negatively correlated with the NAOI when the appropriate age lags are taken into consideration (mean age of eels reaching the Moses-Saunders ladder is 9 years; ICES 2001, Casselman submitted; Figure 9). The standard procedure for examining the NAOI uses a fast Fourier transformed mean (Knights 2003). This provides an index of residuals, which can be compared with recruitment residuals. There is also a highly significant correlation between the NAOI and the lagged recruitment index of the European eel at Den Oever in the Netherlands (Knights 2003). Prior to the mid-1970s, lagged recruitment indices from both sites (and species) were relatively stable and were uncorrelated with the NAOI. After that period, strongly negative correlations appear (ICES 2001). However, short-term indices of early life stages or indices closer to the source of recruitment showed no apparent trends or correlations with the NAOI (Casselman, submitted).

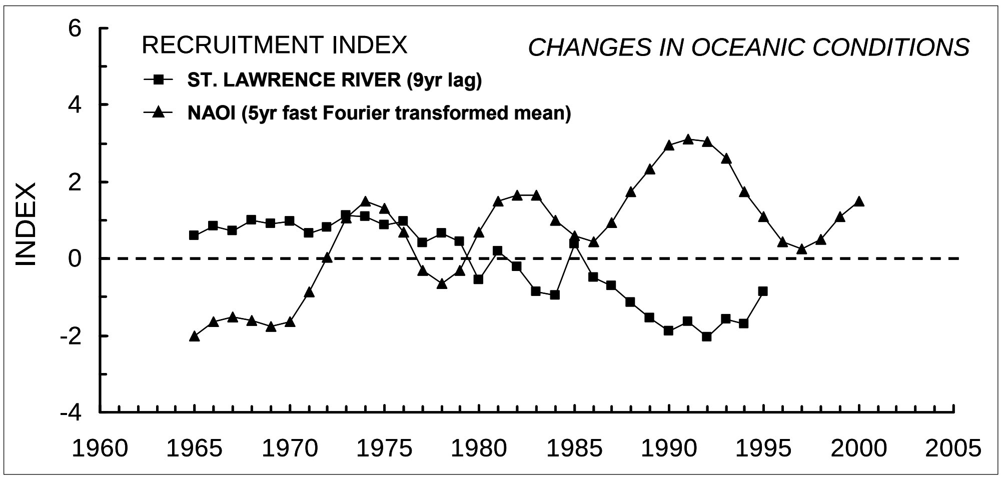

Figure 9. NAOI correlation with the recruitment index of the eel ladder with a 9 year lag (from J.M. Casselman, OMNR).

Indices of Spawning Escapement

Quebec silver eel landings from the Richelieu River and the St. Lawrence estuary are considered under FEA1 since catches are composed principally of out-migrating females from lakes and rivers located upstream (Verreault *et al*. 2003; Verdon *et al*. 2003). Annual landings show dramatic declines since the 1980s (Figures 10 and 11). From 72.9 tonnes caught in 1981, the Richelieu River fishery collapsed in 1997 with a total catch of less than 5 tonnes and was closed in 1998 (Dumont *et al*. 1997; Verdon *et al*. 2003). In the Richelieu River, the decline has been partly related to the reconstruction of two old cribwork dams in the 1960s. No passage facilities for eels were provided, so upstream migration to Lake Champlain was impeded (Verdon *et al*. 2003). Between 1987 and 1997, average eel weight increased by 50%, which reflected an aging component that was not supplemented by recruits (Verdon *et al*. 2003). In the St. Lawrence estuary, total catch declined from 452 tonnes in 1980 to less than 82 tonnes in 2004 (Figure 10). Fishing effort in this area was relatively constant until 1996, and thereafter declined. Catch and effort have been recorded by two commercial fishermen in the estuary since 1985. CPUEs, calculated as eels harvested per m of net, decreased from 1985 to the late 1990s (Figure 10). CPUEs subsequently showed no consistent trend at the same time that effort decreased.

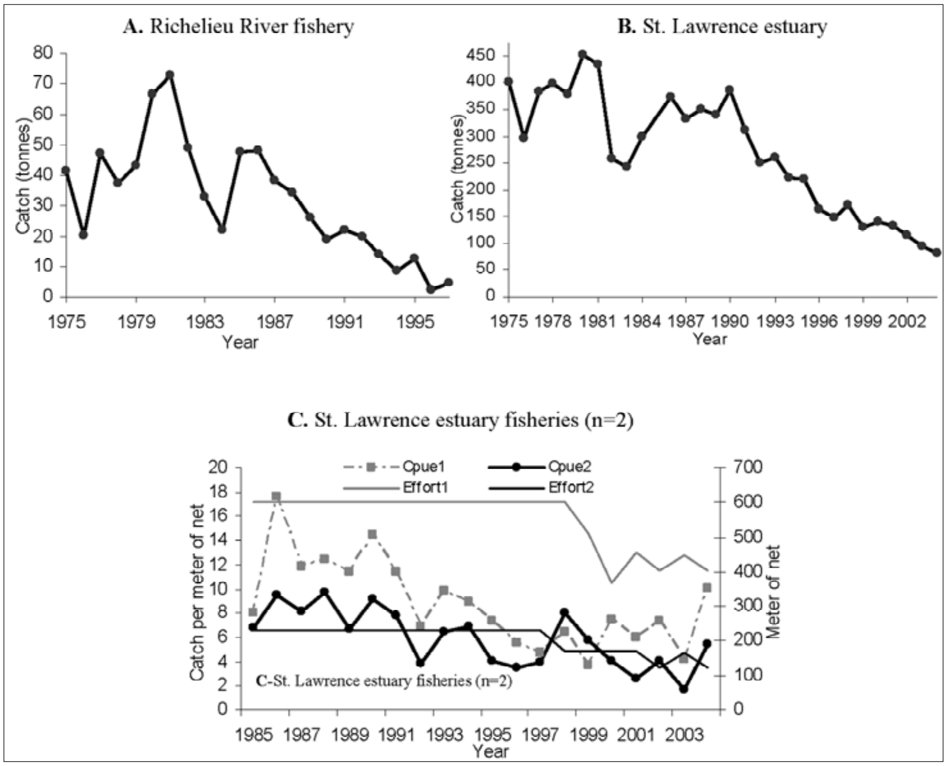

Figure 10. Commercial indicators of silver eels within FEA1 (from Caron *et al.*, submitted): (A) reported catch of silver eels in the Richelieu River (1975-1997); (B) reported catch of silver eels in the St. Lawrence estuary (1975-1984; 1986-2004); (C) CPUE and effort from two fisheries in the St. Lawrence estuary (1985-2004; from G. Verreault, MNRF, Secteur Faune Québec).

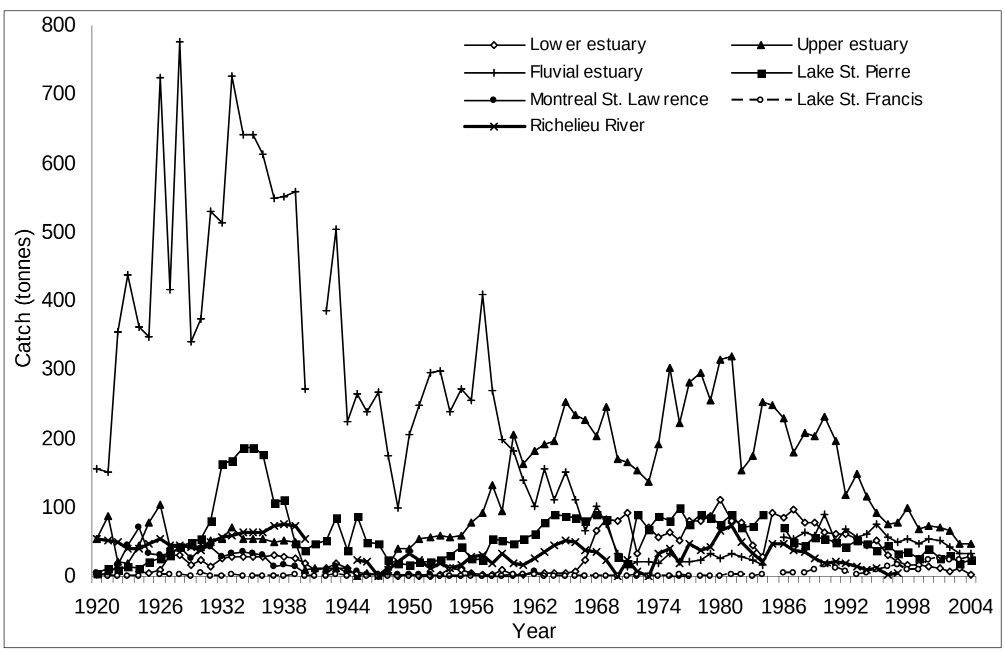

Figure 11. Declared commercial catch of American eels in the St. Lawrence River (1920-2004) by sector in Quebec (from Caron *et al.*, submitted).

A fisheries-independent abundance index is provided by catches of eels at the Saint-Nicolas experimental trap fishery, near Quebec City, between 1971 and 2004 (Castonguay *et al*. 1994b; de Lafontaine *et al*., submitted). Most eels caught in the fall (1 September-1 November) are silver eels, although colour has not been systematically recorded. Fall catches showed intermittent high peaks in the 1970s (Figure 12). Fall catches were relatively stable between the late 1970s and the late 1990s. Fall catches in the late 1990s and early 2000s again showed intermittent peaks. September-October catches in a commercial trap (fixed gears), fished with relatively constant effort 1 km upstream from the experimental trap, declined substantially between the mid-1970s and the late 1990s (Figure 12). Mean weight of eels in the experimental trap has been increasing since measurements began in the mid-1990s (de Lafontaine *et al*., submitted), which suggests that mean age of eels taken in this gear is increasing.

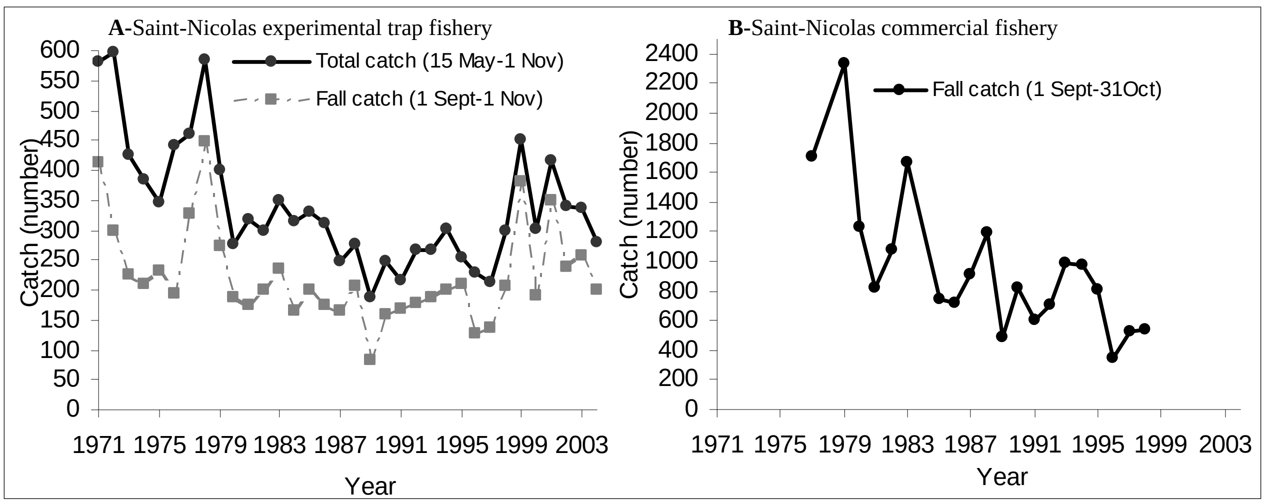

Figure 12. Total catches of eels recorded at Saint-Nicolas, near Quebec City (from de Lafontaine *et al.*, submitted) (A) experimental trap fishery (1971-2004); (B) commercial fishery 1 km upstream (1977-1998). The beginning date of the commercial fishery varied among years but the fall catch was always entirely covered.

Spawning escapement and fishing mortality on silver eels originating in FEA1 was estimated in 1996 and 1997 by means of mark-recapture experiments in the St. Lawrence estuary (Caron *et al*. 2003). Migrants upstream of Quebec City were estimated to number 488,000 in 1996 and 397,000 in 1997. Since exploitation rate by the commercial fishery in the estuary was estimated to be 19% in 1996 and 24% in 1997, total spawning escapement was estimated to be 396,000 in 1996 and 302,000 in 1997. Based on these data, Verreault and Dumont (2003) estimated silver eel departures from the upper St. Lawrence River – Lake Ontario from a model based on eel passage, commercial landings, percentage of migrating eels in the commercial catch, and turbine survival rate. Departures were estimated to be 525,000 in 1996 and 424,000 eels in 1997.

FEA2 - Eastern St. Lawrence (eastern Quebec)

In FEA2 (Figure 13), indices of juvenile abundance and spawning escapement are available for two small unexploited watersheds (200 km²): Petite Trinité and Sud-Ouest rivers (Verreault 2002; Verreault *et al*. 2004; Fournier and Caron 2005). Juvenile abundance data are also available from the Bec-Scie River on Anticosti Island.

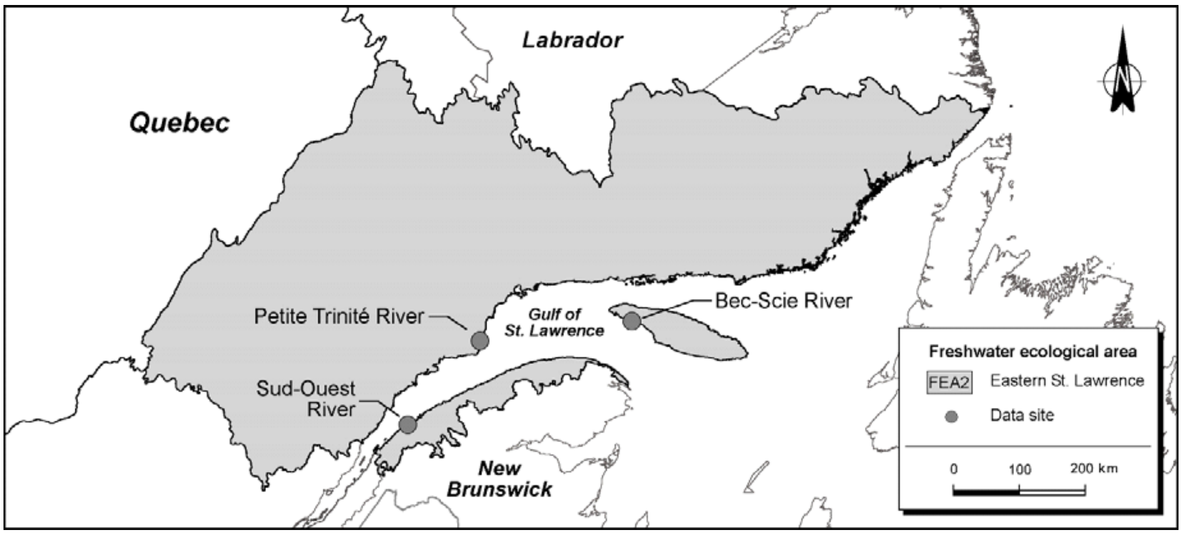

Figure 13. Data sites within the ecological freshwater area FEA2, Eastern St. Lawrence.

Indices of Juvenile Abundance

Sampling sites on the Petite Trinité River and on the Sud-Ouest River are both about 4 km from the river mouth. On the Petite Trinité River, on the north shore of the Gulf of St. Lawrence, elver counts at a waterfall were evaluated three times per night every four nights between mid-June and mid-August from 1982 to 1985 and from 1993 to 1996 (Raymond and Caron 1997). From 1999 to 2001, eel ascents have been estimated at the same site with a capture-recapture method using the Petersen estimator (Figure 14). Annual abundance of elvers (total length less than 120 mm) has been estimated at 14,000, 20,000, and 18,000, respectively (Fournier and Caron 2005). The second of these methods is much more efficient than the first, so the data collected by the two methods cannot be compared. Electrofishing data collected on the Petite Trinité River in 2001 reported a mean density of 4.05 eels per 100 m² in the principal course of the river compared to 1.09 eels per 100 m² in the upper part and in the tributaries. In lake habitat, estimates varied from 0 to 77.1 eels per ha for a mean density varying from 31.7 to 33.0 eels per ha, depending on the estimator used. Eels were aged from 2 to 28 years with a mean of 10.8 years, a mean length of 421 mm and a mean weight of 173 g (Fournier and Caron 2005).

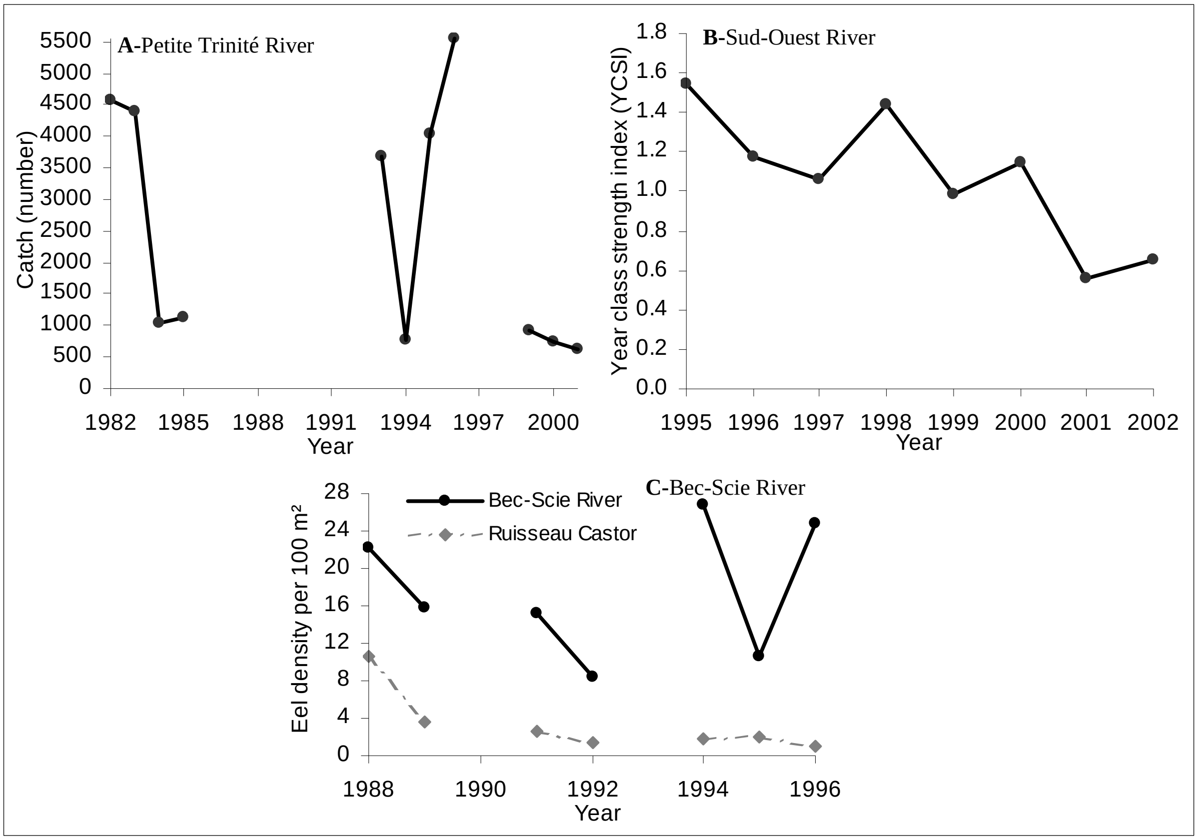

Figure 14. Indices of juvenile abundance for FEA2: (A) Number of eels caught in the Petite Trinité River (1982-2001, from Fournier and Caron 2005); (B) Year class strength index (YCSI) based on juvenile captures during upstream migration in the Sud-Ouest River (1995-2002, from G. Verreault, MNRF, Secteur Faune Québec); (C) Eels per 100 m² from electrofishing surveys conducted in the Bec-Scie River, Anticosti Island (1988-1996).

On the Sud-Ouest River on the south shore of the St. Lawrence estuary, a year-class strength index (YCSI) has been derived from juvenile upstream migration captures from 1999 to 2005 (Figure 14; Verreault, unpublished data). These preliminary data demonstrate a decline of YCSI through time (from 1.55 in 1995 to 0.66 in 2002).

Electrofishing data are also available for the Bec-Scie River, located in southwest Anticosti Island. The drainage area watershed is 131 km^2. Surveys were directed on Atlantic salmon (Salmo salar) from 1988 to 1993 but were continued specifically for eels between 1994 and 1996. Electrofishing was conducted using three sweeps in 16 sites, each 100 m^2 (Raymond and Caron 1997). Mean density within 100 m^2 of river was estimated at 17.7 ± 7.1 eels (Figure 14). The lowest density was in 1992 (8.4 eels/100 m^2) while the highest occurred the year after with 26.8 eels/100 m^2. No trend is apparent in the main course of the river, but densities in one of its tributaries (Ruisseau Castor) showed a downward trend since 1988 (1988: 10.7 eels/100 m^2; 1996: 1.1 eels/100 m^2).

Recent studies of the American eel in the St. Jean River and Estuary in the eastern Gaspé Peninsula, Quebec (Thibault *et al*. 2005, F. Caron unpubl.) have shown eels present in substantial numbers, and with a range of ages. This suggests that recruitment to the area is continuing, although no time series of abundance is available.

Since there is no fishing in the Petite Trinité and Sud-Ouest rivers, estimates of outmigrating silver eels correspond to spawning escapement. On the north shore of the St. Lawrence, maximum spawning escapement in the Petite Trinité River, with a freshwater habitat area of 14.3 km², was estimated at 103.4 kg/year/km². In the Sud-Ouest River, with a freshwater habitat area of 8.7 km², maximum spawning escapement was estimated at 86.8 kg/year/km².

FEA3 - Maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and the central and southern parts of Quebec's Gaspé Peninsula) [Figure 15].

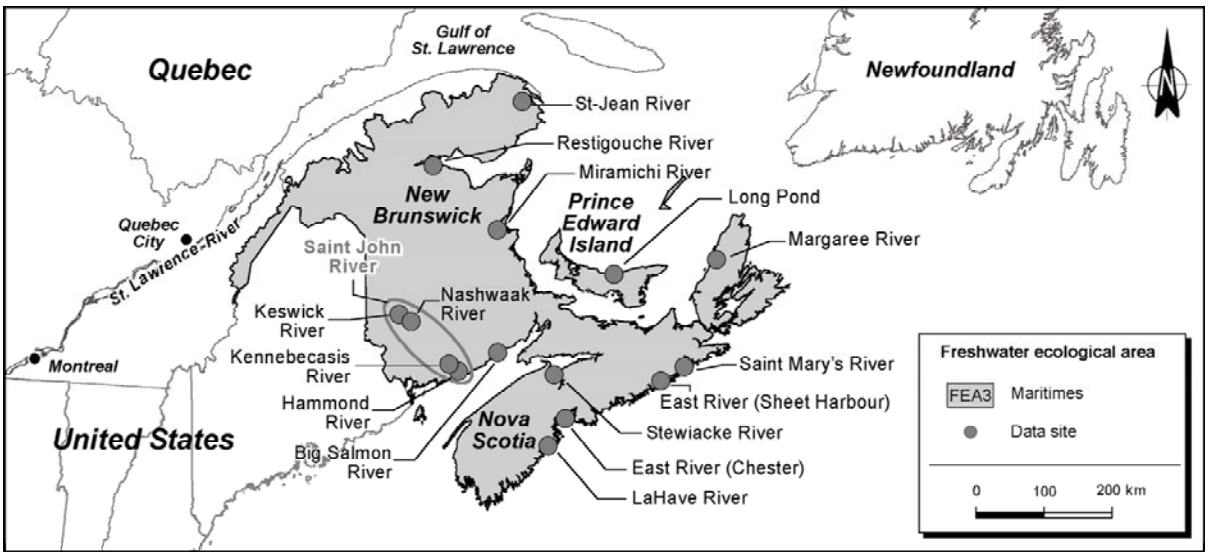

Figure 15. Data sites within the ecological freshwater area FEA3, Maritimes.

<u>Indices of Recruitment</u>

Estimates of elver influx into rivers are available for two Nova Scotian sites. The East River, Sheet Harbour, abundance series is the longest elver series available for the species. Annual recruitment varied without trend from 0.1 to 0.5 million elvers between 1989 and 1999 (Figure 16; Jessop 2003a). In the East River, Chester, the total run of elvers peaked at 1.7 million in 2002. Since the overlap periods of the two series are strongly correlated, a combined index of 13 years can be interpreted. Elver recruitment showed inter-annual variability but no indication of decline between 1989 and 2002.

In 1989, the first two licences were issued to fish experimentally for American eel elvers in the lower reaches of rivers draining into the Bay of Fundy in Nova Scotia and New Brunswick. In 1996, seven commercial licences were issued (Jessop 1998b). Within a geographic region, the elver catch depends on elver abundance, fishing effort, and elver catchability (availability, fishing efficiency depending on gear types) and the distribution of elvers through the run. Elver CPUE (kg caught per hour fished) rose from 1996 to peak in 2000, and subsequently declined (Figure 16).

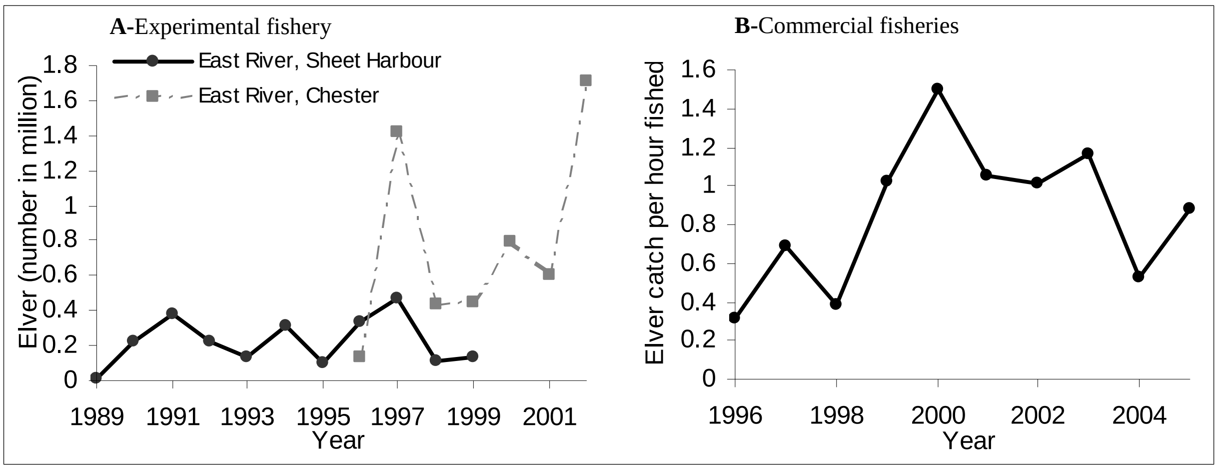

Figure 16. (A) Elver counts in two Nova Scotian rivers (from R. Bradford, DFO): East River, Sheet Harbour (1989-1999) and East River, Chester (1996-2002); (B) CPUE from commercial elver licences (1996-2005, 2005 being incomplete).

Indices of Juvenile Abundance

The longest fisheries-independent abundance indicators for the American eel come from electrofishing surveys for salmonids conducted in the Restigouche, Miramichi and Margaree rivers in the Maritime Provinces. Surveys were conducted in sites closed by barrier nets and open unbarriered sites. Densities were estimated by the depletion method where possible, or by mean ratios of counts to total populations derived from sites where the depletion method was applied. Densities in recent years are generally below the long-term mean. Mean densities (eels per 100 m^{-2}) in the Restigouche River peaked in 2001 and 2002, but densities recorded in previous and subsequent years were below the long-term mean (Figure 17; Cairns *et al*., submitted). In the Miramichi River, eel densities varied irregularly in the 1950s and 1960s, peaked in the early 1970s, and then declined to a minimum by the late 1980s. Densities have since shown a modest recovery but remain well below the long-term mean (Cairns *et al*. submitted). Eel densities measured by electrofishing in the Miramichi River (Figure 17) show similar trends to landings in the southern Gulf of St. Lawrence since the 1970s (Figure 18). Densities in the Margaree River peaked in the early 1960s, showed a lesser peak in the 1970s and subsequently declined to very low levels (Figure 17).

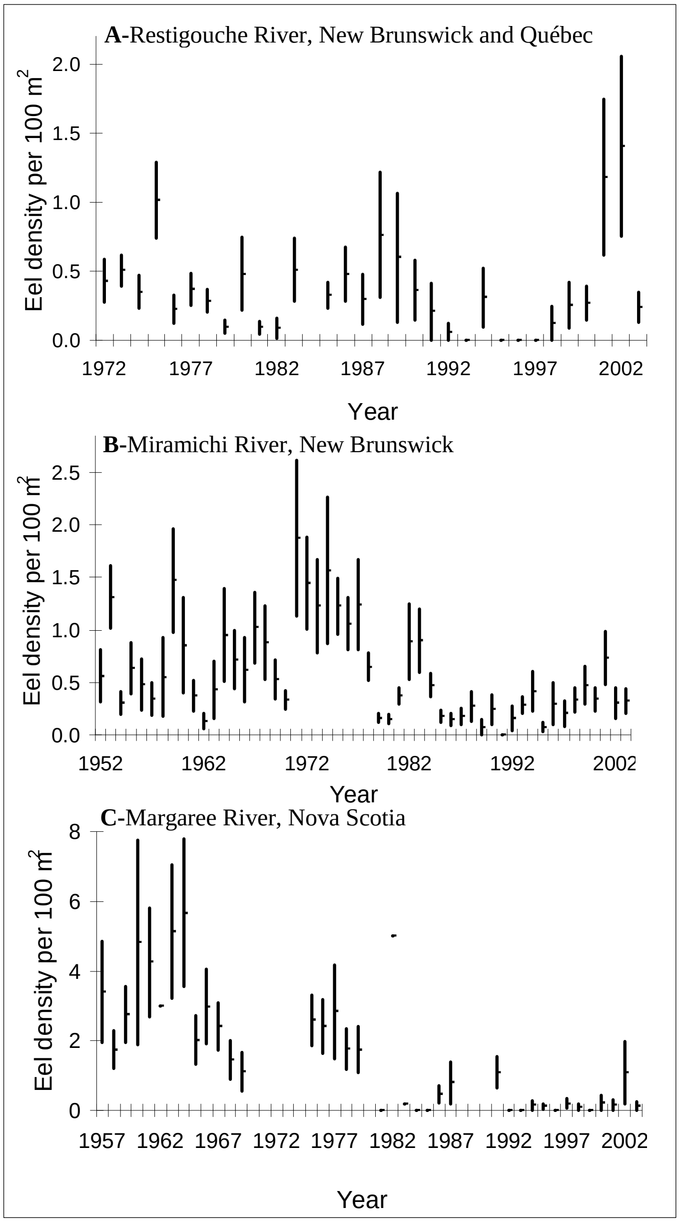

Figure 17. Mean number of eels (± SE) per 100 m² in three rivers in the southern Gulf of St. Lawrence, estimated from electrofishing surveys (from D.K. Cairns, DFO): (A) Restigouche River (1972-2003); (B) Miramichi River (1952-2003); (C) Margaree River (1957-2003).

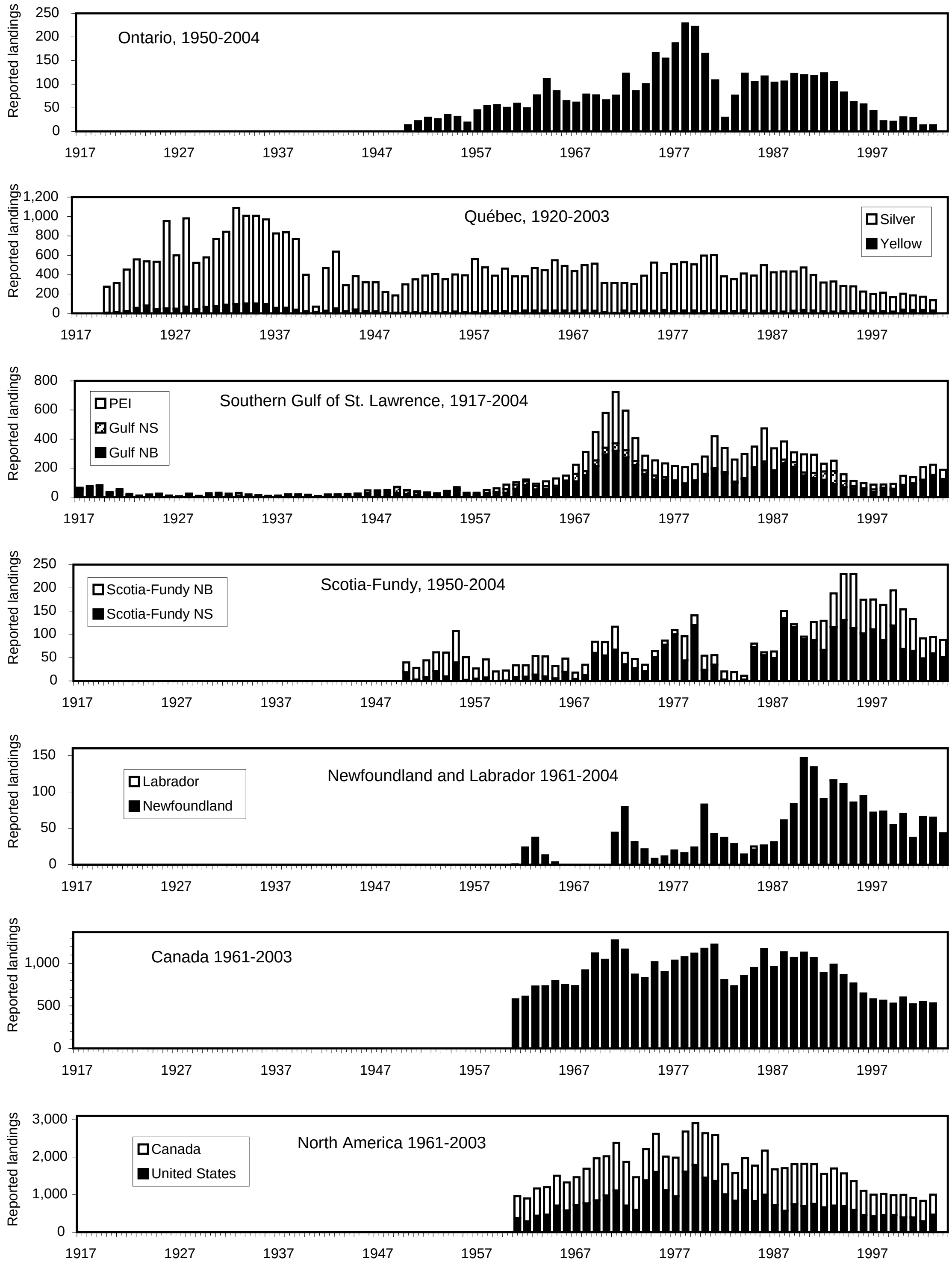

Figure 18. Reported landings in tonnes of American eels in Ontario (Casselman 2003, updated by J.M. Casselman, OMNR), Quebec (Caron *et al.*, submitted), Southern Gulf of St. Lawrence (D.K. Cairns, DFO), Scotia-Fundy (R. Bradford, DFO), Newfoundland (M. O'Connell, DFO), Canada, and North America. Many factors affect landings; for specific explanations, see original sources.

Electrofishing indices are available for several rivers in the Scotia-Fundy region (Figure 19). The Hammond, Kennebecasis, Nashwaak and Keswick rivers are located in the lower Saint John River watershed (Figure 15). Most early surveys were done with barriered (closed) sites and most recent surveys were done at open sites. Results obtained from these two methods cannot be directly compared. Results may also have been affected by inconsistent reporting of eel bycatch. In general, there are no consistent temporal trends within a single method (barrier or open) in New Brunswick sites. In the three Nova Scotia sites, the electrofishing series has declined since the late 1990s.

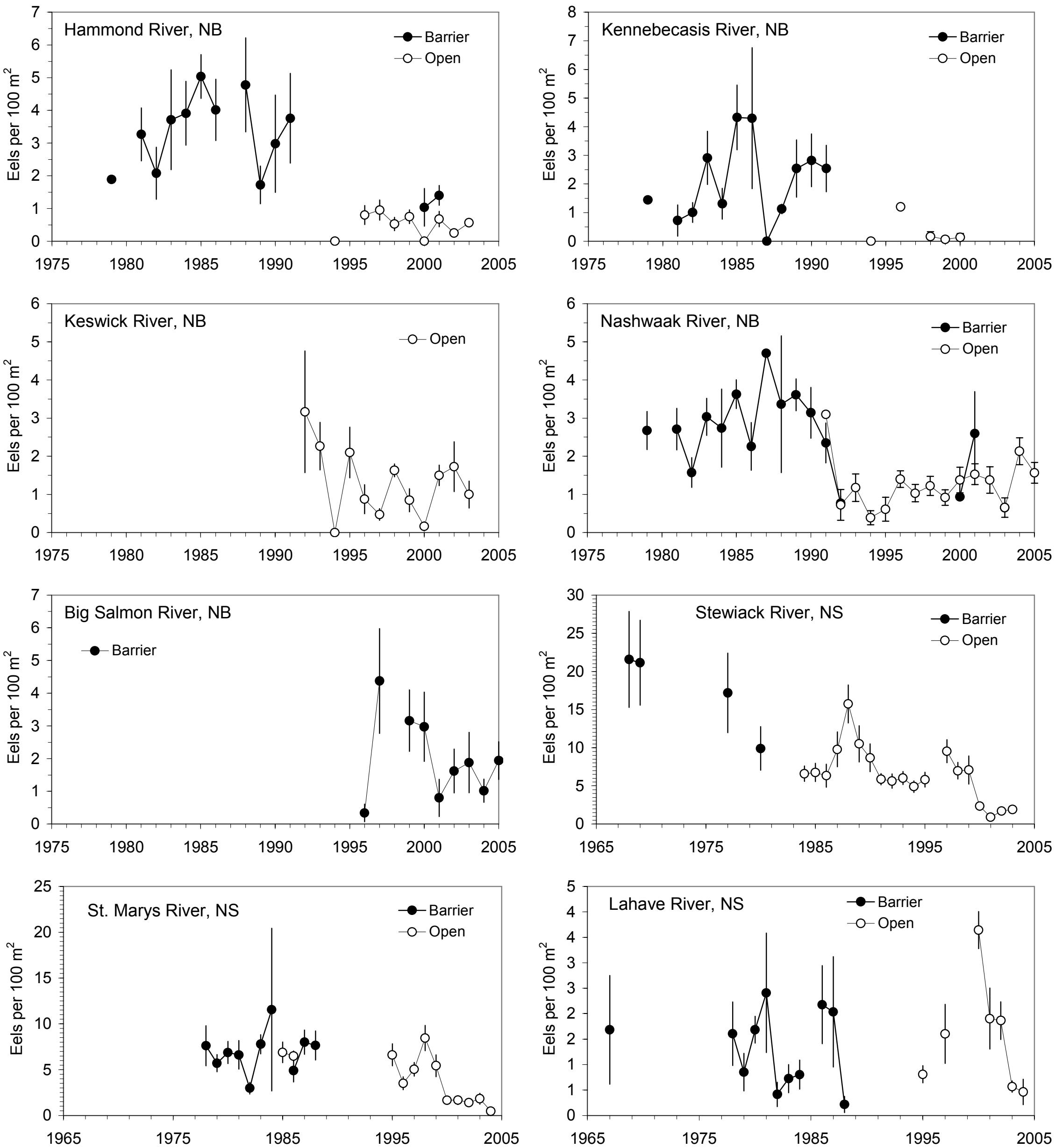

Figure 19. Arithmetic annual mean (± standard error) of American eels per 100 m^2 in the first sweep of electrofishing surveys in barriered and open sites in New Brunswick and Nova Scotia rivers that flow into the Bay of Fundy and the Atlantic Ocean.

Indices of Yellow Eel Abundance

Most eels harvested in the Maritime Provinces are yellow eels. The only commercial fishery allowed on Prince Edward Island is a fyke net fishery. A logbook program that has operated since 1996 gathers information on effort and landings. Three to seven commercial eel fishers volunteer each year to participate in the program. For each day of the fishing season, number of fyke nets in the water, total catch of sublegal (under 50.8 cm; mean age 4.9 ± 1.2 years) and legal eels are recorded (D.K. Cairns, DFO, pers. obs.).

CPUE of sublegal eels peaked in 1999, declined, and has since risen, whereas CPUE of legal sized eels in the Prince Edward Island fyke net fishery has increased between 1996 and 2004 (Figure 20). The rise in CPUE corresponds to recent rising trends in reported landings in Gulf New Brunswick and Prince Edward Island (Figure 18).

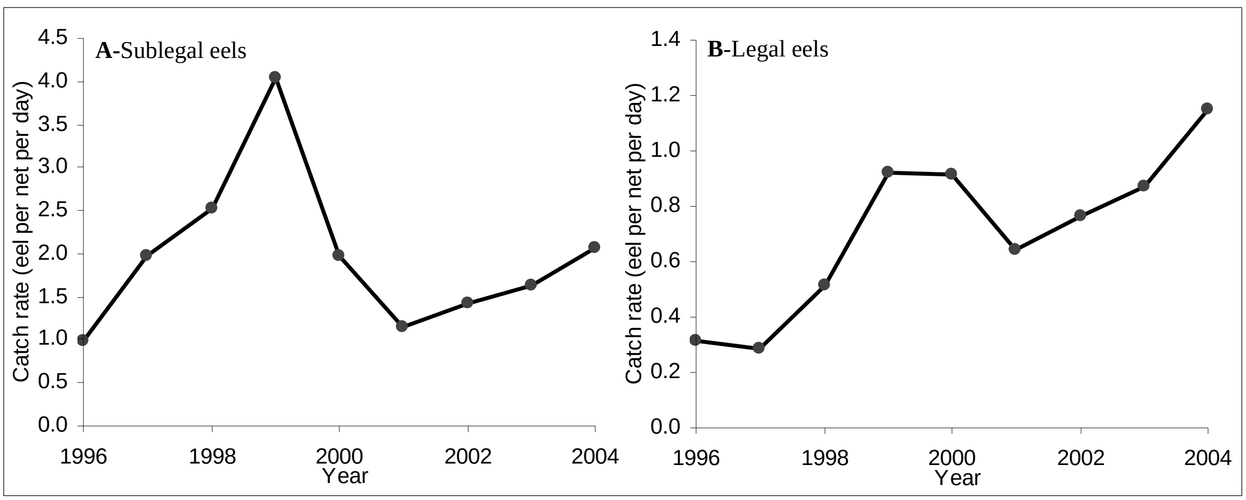

Figure 20. CPUE of: (A) sublegal; and (B) legal American eels by commercial fyke net fishers on Prince Edward Island (1996-2004; from D.K. Cairns, DFO).

FEA4 - Atlantic Islands (Newfoundland) [Figure 21]

Indices of Juvenile Abundance

Available data series from the eel components of Newfoundland are limited to electrofishing surveys conducted for salmonids on two rivers, Northeast Brook and the Highlands River. These sites have no commercial eel fisheries; therefore these data should not be influenced by any local harvesting. The methods used in both rivers are considered consistent through time (K.D. Clarke, DFO, pers. comm.). Methods employed varied but the longest data set is based on five electrofishing stations located on the main stem. Each station was isolated with barrier nets and depletion electrofishing was conducted with a minimum of 3 sweeps. American eel abundance was relatively stable within Northeast Brook from 1984 to 1990 (Figure 22). With the exception of 1986, which had low eel abundance, average catches of eels ranged from a low of 4.5 per station to a high of 8 per station. Data post-1990, with the exception of 1992, suggest lower overall abundance of eels in the electrofishing stations. Average eel catches in this period, excluding 1992, ranged from 1 to 2.8 eels per station. For the Highlands River, data are discontinuous with only two sampling years in the early 1980s but concur with the trends observed in Northeast Brook (Figure 22).

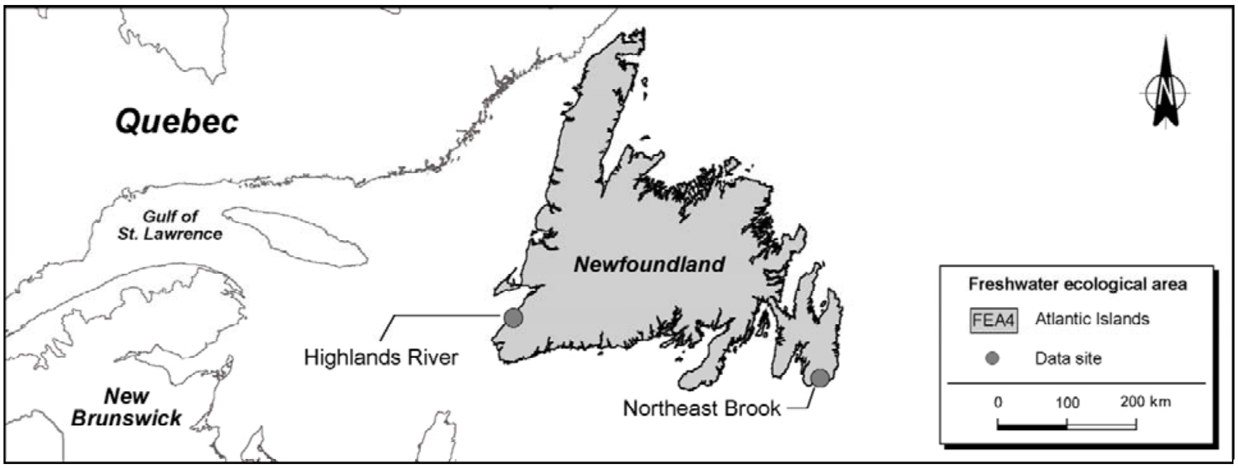

Figure 21. Data sites within the ecological freshwater area FEA4, Atlantic Islands.

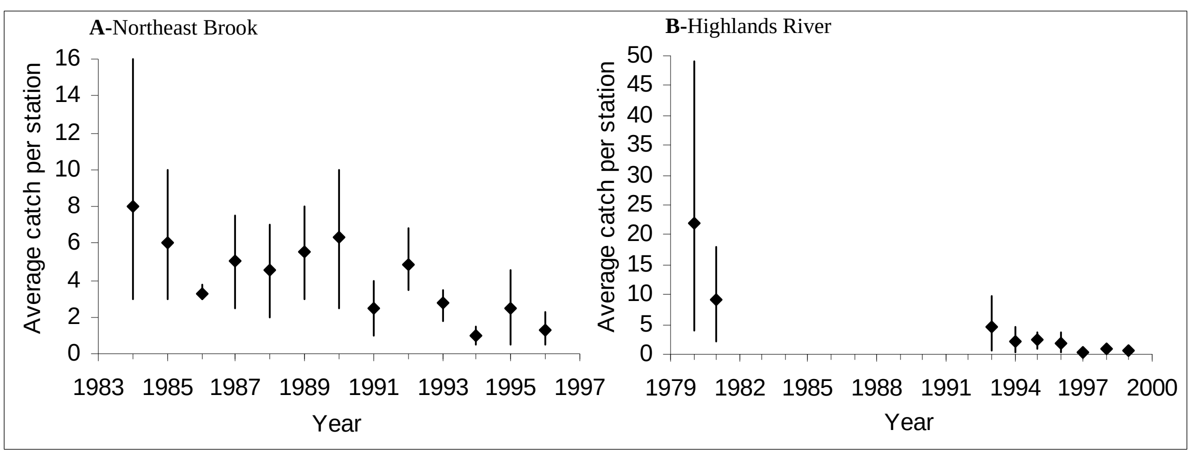

Figure 22. Mean number of eels caught (± 95% confidence intervals) per 100 m² in two rivers of Newfoundland, estimated from electrofishing surveys (from K.D. Clarke, DFO): (A) NorthEast Brook (1984-1996); and, (B) Highlands River (1980-1981; 1993-1999).

FEA5 - Eastern Arctic (Labrador)

Data regarding eels in Labrador are scarce. Electrofishing and fyke net studies have been conducted throughout the English River watershed over the past six years (1999-2005). This watershed flows in an easterly direction into Kaipokok Bay. The lower portion of the catchment is dominated by English River Pond (Clarke *et al.* 2004). The only eels captured since 1999 (n = 3) were in the lower main stem of the system in 2004. This section of the river is characterized by braided channels, created by islands, with a predominance of cobble/gravel substrate (Clarke *et al.* 2004). Given this, while eels certainly can and do inhabit this area, they would appear to be rare (K. Clarke, DFO, pers. comm.). These captures extend the known Canadian distribution of the species further north (Figures 3 and 23).

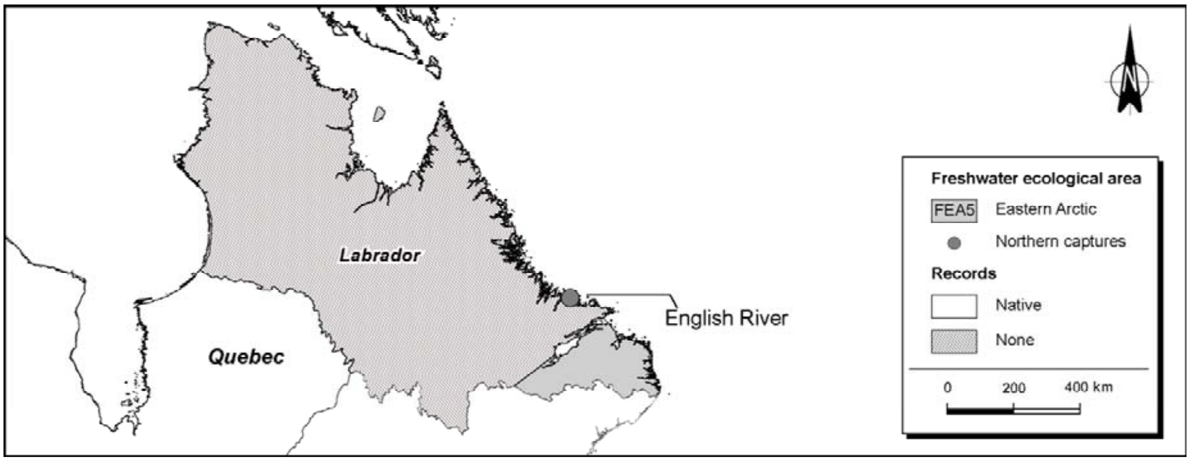

Figure 23. Northern eel captures in Canada within the ecological freshwater area FEA5, Eastern Arctic.

Canadian Eel Components in the North American Context

The collapse of the American eel in the upper St. Lawrence River and Lake Ontario prompts questions about the relative importance of this component to the species as a whole. Specifically, it would be useful to know, for the period prior to the St. Lawrence - Lake Ontario collapse, what proportion of the total number of American eel eggs released on the spawning grounds were from eels that had used the upper St. Lawrence and Lake Ontario as rearing habitat. It would also be useful to know the relative contribution of all Canadian eel components to total egg release on the spawning grounds.

There is no rigorous way to calculate these proportions. However, two methods are available to give a first approximation. One is based on river discharge (Castonguay 1994a) and the other is based on commercial landings.

Contribution of the St. Lawrence Eel Component - Discharge Method

Laboratory studies have demonstrated attraction by glass eels to low salinities and to natural organic chemicals that are contained in river discharge (Miles 1968, Tosi *et al*. 1988, Sola 1995). Given the acute chemo-sensitivity of eels, it seems likely that young eels coming in from the ocean use chemical features of river discharge plumes to locate rivers. Since rivers with larger discharge produce larger plumes, it is plausible that the number of young eels attracted to a river is a function of its discharge. The discharge method assumes that the number of young eels recruiting to river systems is a linear function of water discharge at the river's mouth.

Studies on the European eel have shown that some glass eels caught off the coastline prefer to remain in salt water, when given a choice of salinities (Édeline and Élie 2004). These are presumably the eels that colonize salt water bays and the lower parts of estuaries. However, even eels that prefer salt water need a mechanism to find the coast, because open marine waters are not suitable growth habitat. It is plausible that such eels locate the coastline by chemically detecting river discharge plumes, and the greater the discharge, the more eels will be attracted. Hence we expand the basic assumption of the discharge method to say that recruitment of young eels to a continental area is a linear function of the total river discharge of that area.

The discharge method assumes that recruitment is unrelated to the amount of accessible upstream habitat, because young eels attracted to a river mouth have no way of knowing what proportion of habitat in the system is accessible. The method further assumes that cumulative survivorship between recruitment to continental habitat and return to the spawning grounds does not vary among regions.

The availability of numerous historical reports of American eels in the Mississippi drainage basin suggests that the Mississippi basin was once a significant part of the species' historical range (Casselman 2003). However, this may no longer be the case. The discharge method was therefore applied under two differing assumptions; first, that the American eel's range excludes the Mississippi basin, and second, that the American eel's range includes the Mississippi basin.

Table 3 shows estimated total discharges for major eel rearing areas in North America. The discharge value for the St. Lawrence River is from Baie Comeau. Water flowing past this point includes discharge from tributaries in the western part of FEA2. The Baie Comeau discharge is used because this location is near the river's mouth, and hence represents the attraction water that draws glass eels and elvers into the St. Lawrence River system. Thus in the discharge analysis the St. Lawrence River basin includes FEA1, the western part of FEA2 which drains into the St. Lawrence estuary, and US drainage into the St. Lawrence.

Spawn output depends on number of eels, sex ratio, and fecundity. The number of silver eels produced, relative to production in the US eastern seaboard, is shown in Table 3. For this purpose production in the US eastern seaboard is arbitrarily set at 1,000 eels. Relative production for each region is calculated by comparing that region's discharge to the discharge of the US eastern seaboard. For example, mean discharge of the St. Lawrence basin is 16,800 m^3 sec^{-1} and mean discharge of the US eastern seaboard is 11,186 m3 sec-1. Number of silver eels produced by the St. Lawrence, relative to production of the US eastern seaboard, is 1000 x 16,800/11,186 = 1,502.

Table 3. Relative contribution of American eel rearing regions to total egg production, based on the assumption that the number of silver eels produced is proportional to mean freshwater discharge.

Region	Mean discharge $(m^3 \cdot sec^{-1})$[A]	Percent of silver eels that are female[B]	Range excludes Mississippi Basin[C]				Range includes Mississippi Basin			
			Relative no. of silver eels produced[D]		Relative no. of eggs produced (millions)[E]	Percent of total egg production	Relative no. of silver eels produced[D]		Relative no. of eggs produced (millions)[E]	Percent of total egg production
			Total	Females			Total	Females		
St. Lawrence River basin (includes FEA1, western FEA2, and US drainage to the St. Lawrence)	16,800	100	1,502	1,502	20,025	67.2	1,502	1,502	20,025	60.3
Central and eastern FEA2, FEA3, FEA4, FEA5	13,180	97.8	1,178	1,152	7,721	25.9	1,178	1,152	7,721	23.3
Canada						93.1				83.6
US eastern seaboard	11,186	65.5	1,000	655	2,058	6.9	1,000	655	2,058	6.2
Mississippi basin	18,434	65.5	0	0	0	0.0	1,648	1,079	3,391	10.2
Total excluding Mississippi	44,078				29,804	100				
Total including Mississippi	62,512								33,195	100.0

A) Data sources: St. Lawrence Basin - discharge at Baie Comeau, Anonymous 1996; area of central and eastern FEA2, FEA3, FEA4, and FEA5 measured by planimeter from Fig. 2 (699,645 km^2) x mean discharge per unit drainage area of New Brunswick rivers (0.023 $m^3/s/km^2$, Caissie submitted); U.S. eastern seaboard, Sutcliffe *et al*. 1976; Mississippi basin, Anonymous 2006.

B) From the regional means of sex ratio data compiled by Nilo and Fortin (2001). Percent female in the Mississippi Basin, where no data are available, is assumed to be the same as the US eastern seaboard.

C) The Mississippi Basin is considered to include the Missouri basin

D) Silver eel production is relative to production of the U.S. eastern seaboard, which is arbitrarily set at 1,000.

E) Fecundity for the St. Lawrence is the mean of two mean measurements of eels from FEA1 (14.5, 13.3 million) and one from western FEA2 (13.3 million) (Tremblay 2004). Fecundity elsewhere in Canada is the mean of two measurements from the Gulf of St. Lawrence (6.5 and 6.9 million, Tremblay 2004). Fecundity in the U.S. (3.1 million) is from the length-fecundity relation of Barbin and McCleave (1997) applied to the mean length of female silver eels in the U.S. eastern seaboard (585 mm) as compiled by Nilo and Fortin 2001.

The relative number of silver eels produced is multiplied by the proportion of silver eels that are female in the various regions to produce the relative number of female silver eels. Eels from the St. Lawrence River system are virtually all female. Based on mean regional values from the sex-ratio compilation of Nilo and Fortin (2001), 97.8% of silver eels in FEA2, FEA3, FEA4, and FEA5 are female and 65.5% of silver eels in the U.S. eastern seaboard are female (Table 3).

The relative number of eggs produced is determined by multiplying the relative number of female silver eels by mean fecundities. Fecundities of FEA1 eels, measured at two locations, and fecundities from the Sud-Ouest River, which flows into the south side of the St. Lawrence Estuary in FEA2, are derived from large eels whose size is typical of the St. Lawrence system (Tremblay 2004). The mean of these values is taken as the St. Lawrence River fecundity (Table 3). Silver eels measured in two north shore tributaries in FEA2 are typical of sizes found in Prince Edward Island, Nova Scotia, and Newfoundland (Table 2). The great majority of FEA2 is on the north shore of the St. Lawrence Estuary and Gulf (Figure 3). Hence fecundity in central and eastern FEA2, FEA3, FEA4, and FEA5 is assumed to be the mean of two fecundity measurements in the Gulf of St. Lawrence (Tremblay 2004). Fecundity for the U.S. is derived from the fecundity-length relation of Barbin and McCleave (1997), applied to the mean length of female silver eels in the U.S. eastern seaboard as compiled by Nilo and Fortin (2001).

The discharge method estimates that the St. Lawrence River basin contributes 67.2% of the spawn output of the species if the species' range is considered to exclude the Mississippi Basin, and 60.3% of the spawn output if range includes the Mississippi (Table 3).

There are a number of factors which limit the confidence that can be placed in this result. These are summarized below.

The assumption that recruitment of young eels from the sea is a direct function of discharge is based on the premise that young eels in the ocean can access all continental rearing areas with equal ease. Continental rearing areas that are close to the spawning grounds and that directly face the Atlantic Ocean (e.g. the US eastern seaboard) require only a short and direct trip from the spawning ground. Habitats that drain into semi-enclosed gulfs which are distant from the spawning ground (e.g. the St. Lawrence and Mississippi basins) require a long and circuitous trip. It is unlikely that a linear relation between discharge and recruitment applies across habitats which differ so greatly in their distance and routing from the spawning ground. European glass eel influx is intense in the central part of the species' continental range, but is much lighter toward the edge of the species' range (Dekker 2000, Knights 2003). On a smaller scale, Jessop (1998b) found that discharge did not explain elver run size in two rivers on the Atlantic coast of Nova Scotia.

If the pool of recruiting eels available to colonize the St. Lawrence River is diminished by the long and circuitous route, then the discharge method will overestimate the relative importance of the St. Lawrence River to the species' egg production. The potential error can be illustrated by assuming that St. Lawrence River recruitment is only 50% of what it would be if recruitment is linearly related to discharge. Under this scenario, the St. Lawrence would produce 50.6% of total eggs if range is assumed to exclude the Mississippi basin, and 43.2% of total eggs if the Mississippi is included. If St. Lawrence recruitment is 25% of what it would be if recruitment is linearly related to discharge, St. Lawrence egg production would be 33.9% of the total when Mississippi is excluded, and 27.5% of total when the Mississippi is included in the species' range.

Low salinity and natural organic chemicals appear to attract young eels coming in from the sea (Miles 1968, Tosi *et al*. 1988, Sola 1995). However, the relative importance of these two types of attractants is not known. Miles (1968) showed that attractiveness to eels of natural organic chemicals varied among Nova Scotia rivers. If natural organic chemicals are the main attractant for eels at sea, variability in the natural chemical properties of river plumes may invalidate the assumed linear relation between discharge and recruitment.

The discharge method assumes that cumulative natural mortality is similar across all regions. Eels that rear in fresh water take much longer to reach the silver stage than those that do so in brackish or salt water (Lamson *et al*. submitted). If natural mortality on an annual basis is similar across habitats, then cumulative mortality to the silver stage would be much greater in fresh habitats. Alternately, eels in salt water might be trading faster growth rates against higher mortality, so that cumulative mortality between the habitat types is similar. Rearing habitat in the St. Lawrence and Mississippi basins is fresh. Rearing habitat in other regions is a mix of fresh and marine. Hence any difference between cumulative mortality with respect to salinity of rearing habitat would lead to error in the estimate of the relative egg production of the St. Lawrence River basin.

Silver eels escaping from continental waters must travel to the Sargasso Sea in order to spawn. Differential survival rates on this journey would introduce error in the estimates of relative egg production. Silver eels leaving the St. Lawrence River might have lower survival rates than those of the US eastern seaboard because of the longer distance they must travel. On the other hand, St. Lawrence River eels might have higher survival rates because they are large, and large fish typically have lower mortality rates than small fish.

The discharge method assumes that there is no inter-regional variation in the effect that habitat quality and accessibility have on silver eel production. Accessibility can be blocked by natural and artificial obstacles. It is also affected by distance, as eel density in a system typically declines with distance from the river mouth (Moriarty 1987). The assumption that habitat effects are similar across regions seems unlikely. In particular, production in the St. Lawrence River basin, a long system with obstacles on its mainstem and tributaries and no marine habitat, may be more affected by habitat issues than production in regions that include readily-accessible marine habitat. The discharge method also ignores the effects of commercial fisheries on silver eel production. Commercial fishing effort varies geographically, and substantial areas in both Canada and the US are unexploited.

Reliability of the analysis is affected by limited data on sex ratio and fecundity. Eel sex ratios may be biased because of under-representation of males due to size selectivity of gear. Fecundity data from the Gulf of St. Lawrence are used for US waters, because no published fecundities are available there.

Contribution of the St. Lawrence Eel Component – Landings Method

The second method is based on commercial landings. The chain of assumptions is as follows. Fisheries exploitation rates are assumed to be similar among regions, so landings are a linear function of standing stock biomass. Production of silver eels, by weight, is assumed to be a linear function of standing stock biomass. Since the relation between fecundity and body weight is roughly linear, egg production is taken to be a linear function of weight of silver eels produced. Male silver eels are generally less numerous than females (Table 3), and they are much smaller (e.g. mean weight of silver males on Prince Edward Island is 11% of the mean weight of silver females; D.K. Cairns, DFO, unpubl.). Hence male eels are generally a small fraction of total eel biomass. For this reason total weight of silver eels produced is assumed to be the same as weight of female silver eels produced. Since each parameter in the chain is assumed to be linearly related to the next, landings are assumed to be linearly related to egg production.

The period from 1970 to 1989, prior to the collapse in the Lake Ontario component, is used to calculate landings (Table 4). The landings method indicates that FEA1 produces 26.4% of spawn output (Table 4). Based on relative size of landings, 5.9% of spawn output is from Ontario and 20.6% is from Quebec.

Table 4. Relative contribution of American eel rearing regions to total egg production, based on the assumption that production of eggs is proportional to mean landings for 1970-1989.

Region	Mean annual landings (t), 1970-1989	Percent of total egg production
Ontario portion of FEA1	123	5.9
Quebec portion of FEA1	431	20.6
FEA1 total	554	26.4
FEA2, FEA3, FEA4, FEA5	466	22.2
Canada	1,019	48.7
US eastern seaboard	1,076	51.3
Total	2,096	100.0

Factors which reduce confidence in this analysis are listed below.

It is unlikely that exploitation rate by commercial eel fisheries was uniform across regions during the period covered (1970-1989). Eel exploitation in North America is geographically heterogeneous. FEA2 and FEA5, which have no or virtually no exploitation, are grouped with FEA3 and FEA4, where exploitation varies geographically. The landings method assumes that overall exploiation rate of these areas combined is similar to local area exploitation rate. No exploitation rates, even for local areas, are available for 1970-1989. Exploitation rates have recently been estimated for Prince Edward Island, the Maryland portion of Chesapeake Bay, and the

St. Lawrence estuary (ICES 2001, Caron *et al*. 2003), but data are insufficient to estimate exploitation rates over broad geographic areas. It is plausible that overall exploitation rate in FEA1 is higher than the rate elsewhere, because all eels produced in FEA1 are subject to commercial fisheries during their exit to the spawning grounds, whereas other regions contain areas where no exploitation occurs. If exploitation rate in the St. Lawrence is higher than elsewhere, the landings method will overestimate standing stock biomass relative to landings. This could lead to an overestimate of the relative importance of St. Lawrence eels to the species' spawn output.

The landings method estimates that egg production from eels reared in the Mississippi is zero, because there are no landings there. If the Mississippi produces eels which spawn in the Sargasso Sea, the landings method will overestimate percent contribution to total egg output from other areas, including FEA1.

The landings method treats all exploitation as equal. Eels grow and are subject to natural mortality before becoming silver eels. Growth and mortality schedules, which vary among regions, may impact the way exploitation affects silver eel production, leading to error in estimates of the relative importance of egg production.

The landings method treats Ontario and Quebec as discrete units. However, a substantial portion of eels landed in Quebec completed their yellow (growth) phase in Ontario waters, and all or nearly all eels landed in Ontario spent their early years in Quebec waters.

In sum, both the discharge and the landings methods suggest that the St. Lawrence River basin has contributed a substantial portion of total spawn output by the American eel. However, both methods are subject to large uncertainties. The discharge method's assumption of a linear discharge-recruitment relation is particularly problematic. Some sources of uncertainty suggest that it is more probable that the methods overestimate, rather than underestimate, the contribution of the St. Lawrence River basin to total spawn output.

Changes in Eel Abundance

COSEWIC uses change of abundance over three generations as a criterion for species classification. Mean generation time of female American eels reared in Canadian freshwaters is approximately 22 years. Mean generation time for female American eels reared in salt water is poorly known, but is probably roughly nine years, based on an estimate for Prince Edward Island marine habitats. Using these mean generation times, and considering 2006 as "present," three generations ago encompasses the period 1940-1979.

Table 5 compares means of American eel data series for the period of three generations ago (prior to 1980) to recent means. Series include scientific indices and landings data. Nine Canadian and one US data series are available for comparisons over three generations. Three of the Canadian series are landings, three are from research electrofishing, and three are from non-electrofishing research surveys. The single US series is landings.

Table 5. Mean values of American eel data series.

Parameter	1950s to 1970s		1980s		1990s		2000s		Percent change to 2000s		
	Years	Value	Years	Value	Years	Value	Years	Value	From 1950s-1970s	From 1980s	From 1990s
Landings, Ontario (t) (FEA1)	1970-1979	140	1980-1989	105	1990-1999	75	2000-2005	14	-90.1	-86.7	-81.4
Silver eel landings, Quebec (t) (FEA1)	1970-1979	387	1980-1989	429	1990-1999	264	2000-2003	140	-63.9	-67.4	-47.1
Landings; FEA3, FEA4, FEA5 (t)[A]	1970-1979	481	1980-1989	450	1990-1999	438	2000-2003	355	-26.2	-21.1	-18.9
Landings, US (t)	1970-1979	1,186	1980-1989	966	1990-1999	593	2000-2003	386	-67.5	-60.0	-34.9
Moses-Saunders peak ladder index (FEA1)	1974-1979	14,690	1980-1989	13,557	1990-1999	1,113	2000-2005	74	-99.5	-99.5	-93.3
Bay of Quinte trawl index (FEA1)	1972-1979	1.20	1980-1989	0.90	1990-1999	0.37	2000-2004	0.01	-98.8	-98.4	-96.2
Lake Ontario electrofishing			1984-1989	80	1990-1999	27	2000-2004	4		-94.8	-84.5
Beauharnois west passage					1994-1999	14,482	2000-2005	26,249			81.3
St. Nicholas fall captures (FEA1)	1971-1979	291	1980-1989	179	1990-1999	195	2000-2004	247	-15.1	37.8	26.6
PEI commercial CPUE					1996-1999	0.47	2000-2005	0.83			75.2
Restigouche electrofishing densities (FEA3)	1972-1979	0.41	1980-1989	0.40	1990-1999	0.13	2000-2004	0.72	74.8	78.0	444.5
Miramichi electrofishing densities (FEA3)	1952-1979	0.82	1980-1989	0.36	1990-1999	0.25	2000-2004	0.47	-43.0	29.1	89.1
Margaree electrofishing densities (FEA3)	1957-1979	2.89	1981-1987	0.92	1991-1999	0.18	2000-2004	0.35	-87.9	-62.1	91.2
Keswick open electrofishing counts (FEA3)					1992-1999	1.42	2000-2003	1.10			-22.7
Naswaak open electrofishing counts (FEA3)					1991-1999	1.18	2000-2005	1.44			22.5
Stewiacke open electrofishing counts (FEA3)			1984-1989	9.29	1990-1999	6.72	2000-2003	1.71		-81.6	-74.5

A) There is no eel fishery in FEA2

Percent change between the period before 1980 and the 2000s ranged from -99.5 to +74.8 (Table 5). All of the four landings series showed negative change. Five of the six survey indices were negative. Comparisons from the 1980s to the 2000s, and from the 1990s to the 2000s, show mixed results. Nine of 12 series showed negative change from the 1980s to the 2000s, and nine of 16 series showed negative change from the 1990s to the 2000s.

Several factors limit the reliability of these series to indicate changes in American eel populations. Fisheries landings are an indicator of minimum biomass, because landings can never exceed biomass. Beyond that, landings are generally poor indicators of abundance, because they are subject to changes in fishing methods, regulations, and markets. North American eel fisheries have been affected since 1970 by market factors, including competition in the European market from the advent of large-scale aquaculture production, and by tightened regulations. Nevertheless, the value of eels in both Canada and the U.S. has increased 6-to-10-fold in inflation-corrected dollars (J.M. Casselman, Queen's University, unpubl.). In the Atlantic coast of the Maritime Provinces, some eel fishing effort has been channelled into the elver fishery, which produces very small volumes of catch. The only long-term series from the US is landings. It is unclear what portion of the large decline (67.5%) in reported US landings between 1970-1979 and 2000-2003 stems from changes in fishing practices and intensity and what portion stems from changes in abundance.

There appears to be a relation between eel abundance and the North Atlantic Oscillation (Figure 9). Much of the data in the early period is from the 1970s. It is possible that abundance during that time was bolstered by favourable NAOI conditions. If this is the case, then at least part of the decline between the early and the recent periods may be part of a natural cycle.

The most reliable long-term series are the fisheries-independent surveys in the St. Lawrence River system and the southern Gulf of St. Lawrence (Table 5). Changes between early and recent periods for these series vary widely, from very steep declines (>90%) in Ontario, to smaller declines (-15.1%) in the St. Lawrence estuary, to high inter-river variability in the southern Gulf (from -87.9% to +74.8%).

Rescue Effect

If the American eel became extirpated or severely depleted in one or more FEAs in Canada, the possibility of a rescue effect can be addressed in two scenarios:

1. Eels become extirpated or severely depleted in Canada, but there is no substantial change in American components. In this scenario, young eels from the Sargasso Sea, primarily of American parentage, would continue to colonize the whole continental rearing area, including eastern Canada. External components would thus "rescue" the species in Canada. However, egg production in the Sargasso Sea might be substantially reduced due to the lack of Canadian-reared spawners, so total recruitment of young eels to Canada and elsewhere could be much less than normal, and recruitment towards range limits could be reduced if migration is density dependent.

2) Eels become extirpated or severely depleted in both Canada and the United States. In this scenario, egg deposition in the Sargasso Sea would be drastically lowered, and recruitment of young eels would likely fall to low or negligible levels in all rearing areas, including Canada. The rescue effect for eels in Canada would therefore be limited, particularly if migration is density dependent.

Because of panmixis, progeny of eels reared in Canada colonize the full range of the species in random fashion. Therefore, in the case of a population decline that affects both Canada and the United States, reproductive output from Canadian-reared eels would "rescue" United States components as much as reproductive output from United States-reared eels would "rescue" Canadian components.

There are widespread concerns about the conservation status of the American eel in the United States. These concerns have led to the current examination by the United States Fish and Wildlife Service (USFWS) of the American eel as a candidate for listing under the Endangered Species Act (USFWS 2005). Additionally, the USFWS is considering a proposal to list the species in Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Conservation concerns have also prompted the Atlantic States Marine Fisheries Commission to prepare a stock assessment for the species, which is currently underway.

LIMITING FACTORS AND THREATS

Because of its extended lifespan, semelparous reproductive system, and long migrations, the American eel faces a long list of natural and anthropogenic mortality factors.

Natural Limiting Factors

Global climate change is thought to be generating a northward deviation of the Gulf Stream system (Castonguay *et al.* 1994b; Knights 2003), and to be reducing oceanic productivity (Dekker 1998). Weakening currents could interfere with leptocephalus transport and survival either by starvation or by unfavourable transport patterns that extend the duration of oceanic migration (Knights 2003), both leading to reduced recruitment.

Continental-phase eels may die from natural causes, and they may also metamorphose into silver eels and leave for the spawning grounds. These two factors are often difficult to distinguish. The finite instantaneous instream mortality rate (M) for elvers entering the East River (Chester) has been evaluated at 0.0612, based on trap count data (Jessop 2000b). This rate is higher than those reported for European elvers (0.0107 and 0.0233; Berg and Jørgensen 1994 cited in Jessop 2000a) and may be a direct result of the toxic effects of low pH of the river (Jessop 2000a).

Annual disappearance rate estimates include both natural mortality and emigration and are based on the assumption that recruitment is stable through time. On the Sud-Ouest River, Verreault (2002) estimated an annual disappearance rate of 26.4% (instantaneous rate = 0.307) for emigrating eels aged 9 to 17. A population model indicates that 27% of eels that enter Lake Ontario survive to reach the open Gulf of St. Lawrence as pre-spawning silver eels. Abundance of escaping eels declined by 23% annually between 2000 and 2004 (J.M. Casselman, pers. obs.). Estimates show good agreement, given that recruitment during the period has virtually ceased. In the Hudson River, the disappearance rate was estimated at 15% (instantaneous rate = 0.16 ± 0.06), and no significant difference was found between freshwater and brackish water sites (Morrison and Secor 2003). A stochastic life table model estimated a disappearance rate of 22.9% (instantaneous rate = 0.26) per year in an unexploited eel component in Prince Edward Island (ICES 2001).

Anthropogenic Threats

Habitat Modifications and Dams

Dams and other barriers generate habitat loss and fragmentation for upstream migrants, and produce turbine mortality for downstream migrants.

There are two hydro complexes on the main stem of the St. Lawrence River below Lake Ontario. The Moses-Saunders dam was completed in 1959. The Beauharnois complex was begun in the late 1920 and completed in 1961 (Verdon and Desrochers 2003, R. Verdon, Hydro-Québec, pers. comm.). Shipping locks at these two dams offered upstream passage opportunities, but upstream passage has been provided by permanent eel ladders at the Moses-Saunders dam since 1974 and at the Beauharnois dam by a passage facility that operated in 1994-1995 and from 1998 to the present. Ladders have been available to give access to Lake Champlain via the Richelieu River at Chambly since 1997 and at St-Ours since 2001. The Ottawa River is blocked by 12 hydro-dams, none of which is equipped with an eel ladder.

There are few dams on rivers draining into the southern Gulf of St. Lawrence, except on Prince Edward Island, where about 800 low head dams are erected, and where most streams are blocked at one to several places (MacFarlane 1999). Nevertheless, since eels of all stages have the ability to ascend salmonid fish ladders, and small eels are able to ascend low dams that lack any passage facilities (Cairns *et al.* 2004; Lamson *et al.* submitted), eels are generally common in the ponds above these dams. There are numerous hydro-dams in the Scotia-Fundy region, including the Mactaquac dam which blocks the upper part of the Saint John River in New Brunswick. The only monitored eel ladder in the Maritime Provinces is at the Morgan Falls hydro-facility on the LaHave River on the south shore of Nova Scotia. The ladder has operated since 2002 (R. Bradford, pers. comm.).

Verreault *et al.* (2004) examined obstacles to eel recruitment in the St. Lawrence River drainage area in Quebec and Ontario and the United States. In the St. Lawrence River watershed, over 8,000 dams (at least 2.5 m high) prevent, restrict or delay access to more than 12,000 km^2 (Table 6) of freshwater habitat (10 m or less deep; Verreault *et al.* 2004). Hydro-dams (n = 151) were present on many major tributaries in the upper St. Lawrence except on the Richelieu River (FEA1). Based on data analysis from three tributaries in the St. Lawrence River watershed, restricted access could have reduced potential annual escapement substantially, by more than 800,000 eels (Table 6; Verreault *et al.* 2004), primarily highly fecund females (Casselman 2003; Verreault *et al.* 2003; Tremblay 2004). Historically, the Ottawa River habitat would have potentially contributed 255,000 female silver eels annually (Table 6; Verreault *et al.* 2004).

To enhance potential annual production and escapement, these habitats should be made more accessible and downstream migrants should be protected from turbine mortality. The extended potential recruitment to these habitats, however, is unknown and actual carrying capacity is unquantified.

Table 6. Surface areas of freshwater growth habitat that is upstream of restrictive dams in the St. Lawrence watershed, and estimated potential annual escapement (modified from Verreault *et al*. 2004).

Site (subwatershed)	Estimated growth habitat above dams (km^2)	Potential annual unutilized production
Upper St. Lawrence River - Lake Ontario	5,800	399,700 [A]
Ottawa River	3,700	255,000
Richelieu River - Lake Champlain	1,200	82,700 [B]
Others	1,400	99,200
All	12,100	836,600

A: Access re-opened in 1974 at Moses-Saunders Dam and in 2002 at Beauharnois Dam; B: Access re-opened between 1997 (Chambly Dam) and 2001 (St-Ours Dam)

Silver eels descending rivers equipped with hydro-dams may be killed or injured as they pass through turbines. Turbine mortality is positively correlated to eel length and inversely proportional to blade spacing. It also varies with turbine type (Francis, Kaplan and propeller), turbine size, and operating conditions such as flow and generating efficiency (Montén 1985; Larinier and Dartiguelongue 1989; Travade and Larinier 1992). Since eels of the upper St. Lawrence River – Lake Ontario system (FEA1) are the longest in North America (Verreault *et al*. 2003), they are at greatest risk of turbine mortality. Mortality rate of emigrating eels with mean length of 88 cm has been estimated at 16% for a Francis turbine and at 24% for a propeller turbine at the Beauharnois dam (Desrochers 1995). Eels with a mean length of 102 cm passing a propeller turbine in the Moses-Saunders dam suffered an estimated mortality of 26.4% (Normandeau Associates and Skalski 2000). Migrants leaving Lake Ontario encounter both of these dams during their spawning migration, and are subjected to an accumulated turbine mortality of 40% (Verreault and Dumont 2003). This additive turbine mortality at Moses-Saunders dam and Beauharnois dam contributes to almost 75% of the anthropogenic mortality during downstream migration and reduces the annual spawning escapement by 40%. This analysis refers to the St. Lawrence system above the Beauharnois dam only. Turbine mortality figures should be regarded as a minima because undetected sublethal injuries could further reduce the number of females that reach and successfully spawn in the Sargasso Sea (Couillard *et al*. 1997).

In the southern Gulf of St. Lawrence few dams are used for water power, and turbine mortality is not a significant issue. Numerous rivers in Scotia-Fundy region, Newfoundland, and Labrador are dammed but no data are available on number of dams or amount of habitat loss.

Fisheries

All eel fisheries target pre-spawners (Richkus and Whalen 1999). All continental stages are subject to commercial exploitation in Canada, but the stages that are exploited vary geographically, and much of the Canadian range is unfished. Fisheries for elvers and silver eels occur during narrow time windows. The yellow eel stage may last many years, so fisheries that target this stage may produce high cumulative mortality even if fishing mortality rate per year is low.

Fishery landings have limited value as indicators of abundance. Landings may be influenced by regulations, price per kg, alternative opportunities in fishing and other employment, and by changing gear efficiencies.

Total annual harvest data from commercial fisheries in Canada are presented in Figure 18 and detailed harvest for Quebec fisheries by sector is presented in Figure 11. Canadian commercial catches decreased substantially in the 1990s despite an increase in price per kg (Casselman 2003). The unreported eel catch is believed less than 5% in Lake Ontario and 8% in the St. Lawrence estuarine fishery (ICES 2001). In the Scotia-Fundy region, reported landings are closely correlated with effort and are not considered to reflect abundance (R. Bradford, pers. comm.).

Fishing mortality rate is poorly known for yellow and silver American eels. Instantaneous fishing mortality on mostly yellow eels in exploited waters of Prince Edward Island was estimated at 0.5 per year (ICES 2001). The great majority of eels taken in this fishery are yellow, and are exposed to fishing mortality over several years. Assuming no density dependence in survival rates, the model estimated that fishing in exploited Prince Edward Island waters reduced spawner escapement by 90% below what it would have been in the absence of fishing. In the St. Lawrence estuary silver eel fishery, mark-recapture experiments yielded estimates of exploitation rates of 19% in 1996 and 24% in 1997 (Caron *et al.* 2003).

Eel fishing effort is unevenly distributed within the Canadian range of the American eel. In some regions, there are intensive fisheries while in other regions eels are unexploited. The stage targeted by fisheries (glass eel, elver, yellow eel, silver eel) also varies geographically. In Ontario, the major yellow eel fishery in Lake Ontario and the upper St. Lawrence River was closed in 2004. In Quebec, there are major fisheries in the upper St. Lawrence River and estuary targeting mainly silver eels (> 75%; Caron *et al.*, submitted). Eels originating in FEA2 are not exploited since Quebec fisheries target eels from FEA1. In the southern Gulf of St. Lawrence (FEA3), commercial fisheries target yellow eels in tidal waters. Yellow eels are fished extensively in coastal waters and estuaries of the Gulf New Brunswick and Prince Edward Island. There is little eel fishing effort in the Gulf of Nova Scotia, and none in most fresh waters of the southern Gulf of St. Lawrence. Winter recreational spear fisheries also contribute to anthropogenic mortality of yellow eels in the Southern Gulf of St. Lawrence. In the Scotia-Fundy region, eel fishing occurs in both fresh and marine waters, but many rivers and coastal habitats are unfished. The only documented elver fishery in Canada occurs in Scotia-Fundy. In Newfoundland (FEA4) and Labrador (FEA5), yellow and silver eels are fished principally in rivers, but there are many rivers which are not exploited. Landings for Labrador have been reported only in 1985 (4.3 tonnes) and in 1993 (0.1 tonne), and it is unknown whether this irregular pattern is related to abundance; however, landings are not large. Although seven exploratory elver licences were issued in 2004 in Newfoundland, fishing and effort data are not available.

Yellow and silver eel catches in FEA1 (Figure 18) have steadily declined since the early 1980s under relatively constant fishing effort before 1996. As a result of dramatic resource declines, commercial eel fisheries were closed in the Richelieu River in 1998 and in Lake Ontario and in Ontario waters of the upper St. Lawrence River in 2004. Between 1950 and 1999, catches from the estuarine fishery in the lower St. Lawrence River (FEA1 origin) were almost fivefold greater and more consistent than catches in the commercial harvest in Ontario (Casselman 2003).

Lake St. Francis is located between Moses-Saunders dam and Beauharnois dam. Catches in Lake St. Francis are now a significant part of total harvest in FEA1 (Figure 11). Harvest (in Quebec waters only) rose from 5.2 tonnes in 1988 to 29.0 tonnes in 2004, in contrast to the general abundance trend in FEA1. This fishery was opened in 1986 and relies on a consistent fishing effort. Favourable access infrastructure developed at the Beauharnois dam since 1994 by means of a trap and by a permanent ladder since 2002, could have had contributed to a rising trend in total catch (P. Dumont, MNRF, Secteur Faune Québec, pers. comm.).

Reported commercial catches in the southern Gulf of St. Lawrence (FEA3) were low from the beginning of the time series in 1917 to the 1960s, when catches increased following the introduction of new fishing methods and the development of markets (Figure 18). Therefore, catch trends prior to 1970 are probably unrelated to abundance. After a peak around 1970, reported catches dipped, peaked again in the late 1980s, dipped again, and have gradually increased since the late 1990s. Heavy exploitation of eels over the minimum size (46.0 cm up to 1997, 50.8 cm in 1998 and beyond) could have reduced the size and age distribution (Cairns *et al.* 2004).

The Canadian elver fishery targets arriving glass eels and elvers as they ascend estuaries. Jessop (2000b) estimated that elver fishers took 31 to 52% of arriving elvers in the East River, Chester, Nova Scotia. Some elver fishing sites (including East River, Chester) are located at the mouths of rivers that are impacted by acid rain. These rivers, or substantial portions of these rivers, may be unsuitable for eel growth and survival. Hence, the elvers that are removed by the fishery do not necessarily represent a loss to the reproductive capacity of the species, because many of them would probably die due to low pH if they had not been caught (Jessop 2000a).

There has been a trend towards increasingly restrictive fishing regulations in the last several decades, especially in the Atlantic Provinces, and especially since 2000 (e.g. Cairns *et al*. submitted). Changes include shortening of seasons, increases of minimum size, caps on the number of gears that can be deployed, and freezes on the development of any new fisheries.

<u>Chemical and Biological Contamination</u>

Contaminants may impact eels by reducing survival and impairing reproduction (Castonguay *et al.* 1994a; Hodson *et al.* 1994; Couillard *et al.* 1997). In polluted waters, eels are heavy bioaccumulators since they are long-lived benthic species with a high fat content that accumulates lipophilic contaminants such as PCBs (polychlorinated biphenyls), pesticides (DDT), dioxins and furans. High summer mortalities of silver eels in the freshwater part of the St. Lawrence in the early 1970s were attributed to acute toxicity from environmental contaminant levels (Dutil 1984).

Couillard *et al.* (1997) used the relationship between tissue mirex concentration and body mass to identify the origin of migrating silver eels taken in the St. Lawrence estuary. Those with high loadings were presumed to have come from the upper St. Lawrence River - Lake Ontario area. The authors observed a relationship between chemical contamination and pathological lesions, and suspected a relation between organochlorine contamination and oocyte diameter that may lead to reproductive failure at a later stage of maturation (Couillard *et al.*, unpublished data, cited in Castonguay *et al.* 1994a). PCBs have deleterious effects on eel fertility by impairing egg quality and embryonic development. Since migrating females are fasting (Pankhurst and Sorensen 1984), contaminants recirculate into the blood system, and chemical levels in the eggs could be even higher at hatching, increasing the likelihood of toxicity to the larvae (Hodson *et al.* 1994; Robinet and Feunteun 2002). Above 0.2 pg/TEQ/g[2], production of vital offspring is affected (Anonymous 2005). Van Ginneken *et al.* (2005) observed lower oxygen consumption rates in swimming and resting eels loaded with PCBs in comparison to a control group. Results corroborate the general depressing effect of PCBs on protein synthesis (G. Thillart, Leiden University, pers. comm.).

Contaminant levels in Lake Ontario have decreased significantly from 1970s' levels (Luckey *et al.*, in press), and there is little evidence to suggest that human-related contaminants [PCBs, DDT, mirex, dieldrin (insecticide), dioxins, furans, mercury] are currently impacting natural reproduction and health of Lake Ontario benthos, plankton or fish on a lakewide basis. According to a monitoring program targeting coho salmon, total PCB concentrations have decreased threefold and mirex has reduced twofold since 1970 (Luckey *et al.*, in press). Eels from the St. Lawrence estuary tributaries have been reported to be less contaminated with mirex than those from Lake Ontario (Hodson *et al.* 1994). However, Renaud *et al.* (1995) found greater concentration of mirex during the 1990s than between 1947 and 1950 in polluted tributaries of the St. Lawrence River (St-François and Sainte-Anne rivers). Therefore, deterioration of habitat quality could affect eel survival throughout its range depending on pollution level.

One of the most important factors influencing contaminant dynamics in Lake Ontario is the increasing proliferation of exotic nuisance species since they alter both fish community composition and food web energy flows (Luckey *et al.*, in press). Thus, subsequent changes to pathways and fate of contaminants have resulted in altered bioaccumulation rates in portions of fish communities as evidenced by recent spikes in contaminant burdens. Alterations to the forage base of fish communities have resulted in diet shifts and in some cases, the consumption of a more contaminated prey, which produces elevated body burdens of contaminants (Luckey *et al.*, in press).

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[2]PCBs units: picogram/ toxicity equivalency factor/ gram

Exotic zebra and quagga mussels have substantially altered water quality and trophic relations in Lake Ontario (Mills 2005). However, the rapid proliferation of these mussels occurred in the early 1990s, well after the major decline in the Moses-Saunders had been completed.

Many rivers in the southern uplands area of Nova Scotia have low pH due to acid precipitation (Marcogliese and Cone 1996). Acidic conditions in these rivers may limit the survivorship of American eels (Jessop 2000a).

Introduced Parasite: Anguillicola crassus

The swim bladder nematode parasite, *Anguillicola crassus*, spread into Europe from shipments of Japanese eels (*Anguilla japonica*) from Asia to aquaculture facilities in Germany in 1982 (KØie 1991, cited in Barse and Secor 1999). In North America, the parasite was originally discovered in a single eel captured in Winyah Bay (South Carolina) in 1995 (Fries *et al.* 1996). Since then, the parasite has been detected in eels in the Hudson River and Chesapeake Bay (Barse and Secor 1999; Morrison and Secor 2003). The following information on *A. crassus* in New England is provided by K. Oliveira, University of Massachusetts, pers. comm. Eels in the Paskamensett River, Massachusetts, showed infestation rates higher than 90%. All rivers in Rhode Island and Massachusetts that were examined had the parasite with some degree of variation in intensity. The parasite has also been documented in Maine waters. It appears that the parasite is at least past mid-coast of Maine and may be as far east as the East Machias River, which is about 40 km from the New Brunswick border.

A significant ($p < 0.05$) positive relationship between mean intensity of infection and eel size was found (Moser *et al.* 2001). Heavy infections can lead to hemorrhagic lesions, swim bladder fibrosis or collapse, skin ulceration, decreased appetite, and reduced swimming performance (Barse and Secor 1999). Van Ginneken *et al.* (2005) found that swim bladder parasites cause bladder shrinkage, leading to higher cost of swimming and reduced migration capacity.

Over the past five years, almost 1,200 eels have been examined in the upper St. Lawrence – Lake Ontario system and no swim bladder parasite was found (J.M. Casselman, OMNR, pers. obs.). Since 2002, many hundreds of silver eels in downstream migration in the lower St. Lawrence River have been sampled annually for swim bladder examination but no parasites have been detected (G. Verreault, MNRF, Secteur Faune Québec, pers. comm.). During the first attempt of elver stocking in the upper St. Lawrence River, from Bay of Fundy to the upper Richelieu River and Lake Champlain, none of the 128 elvers examined carried this parasite (Dumont *et al.* 2005). The subsample examined in the 2005 program was also free of *A. crassus* (P. Dumont, MNRF, Secteur Faune Québec, pers. comm.). Moreover, a Nova Scotian study found an absence of *A. crassus* in eels (Barker 1997). Although *A. crassus* has not been detected in Canada, its advancement northward on the US coastline, and its current presence in Maine close to the Canadian border, suggests that the arrival of this parasite in Canada may be imminent.

Stocking

Stocking may represent a way to reduce the sharp decline and recruitment failure of the American eel in the upper St. Lawrence River. As a trial of this concept, 40,000 elvers (mean length 60.3 ± 3.0 mm) were captured in the Bay of Fundy (New Brunswick), marked with tetracycline, and released in Lake Morin (4 km^2) on the south shore of the St. Lawrence estuary (Verreault *et al.*, submitted). Elver stocking in Lake Champlain was proposed in 2003 by the Association des pêcheurs d'anguilles et de poissons d'eau douce du Québec (Quebec St. Lawrence Estuary commercial fishermen) in collaboration with MNRF, Secteur Faune Québec (Dumont *et al.* 2005). In May 2005, 600,000 elvers were translocated from Bay of Fundy to the upper Richelieu River (P. Dumont, MNRF, Secteur Faune Québec, pers. comm.). Deserted habitats not impeded with hydro-dams in the St. Lawrence watershed could be utilized as growth habitats for eels to increase the overall eel abundance (Verreault *et al.*, submitted) in Canadian waters.

However, there is much uncertainty regarding the benefits of stocking to American eel conservation. The density of stocked eel is a consideration in stocking programs since high densities can lead to male-dominated sex ratios (Krueger and Oliveira 1999). A stocking density of 100 elvers per ha in Lake Morin (FEA2) resulted in 27.2% males after four years of growth (Verreault *et al.*, submitted). Therefore, to maintain a high proportion of females within the St. Lawrence watershed stocking needs to be achieved on a low density basis. Another point of concern is whether silver eels originating from distant sources will find appropriate migration pathways to reach the Sargasso Sea and spawn successfully. European studies on this matter give conflicting results (Westin 1990; Moriarty and Dekker 1997; Dekker 2004). Limburg *et al.* (2003) reported that stocked eels in the Baltic sea showed evidence of maturity at the silver stage and migrated back to the Sargasso Sea. Nevertheless, homing to the spawning grounds may be based on the memory of migration during the early life stages, with magnetic cells in the jaws as a navigation tool (Feunteun 2002). Finally, it is not known if the survival and subsequent escapement of translocated elvers is greater than or less than their survival and subsequent escapement if the elvers had been left to grow in their natural habitat. The question is further complicated by the possibility that translocation might alter sex ratio and size at maturity, which will affect potential egg deposition per exiting silver eel.

SPECIAL SIGNIFICANCE OF THE SPECIES

Historically, the American eel possessed the largest range of any fish species in the western Hemisphere, and had a dominant position by numbers and biomass in many habitats it occupied. The American eel was one of the most important freshwater fish species in commercial, recreational and Aboriginal catches in the St. Lawrence River watershed. An obvious trend of decline has been pointed out from the recruitment index in Cornwall for FEA1 (Great Lakes– Western St. Lawrence), and from upstream migration data on the Sud-Ouest River for FEA2 (Eastern St. Lawrence), components composed of large fecund females that correspond to an important part of the reproductive potential of the species.

Aboriginal people have historically fished eels throughout the Canadian range of the American eel for subsistence food purposes. Aboriginal lands located within the species' range include the following specific claims and Indian reserves: 1) FEA1: Bay of Quinte, Akwesasne, Kanesatake, Kahnawake, Odanak, Wolinak, Lorette, Nation Huronne Wendake; 2) FEA2: Premiere Nation Malecite de Viger, Cacouna, Innue Essipit, Betsiamites, Listugui Mi'gmaq Government, Restigouche, Maria, Micmacs of Gesgapegiag, Seven Islands, Innu Takuaikan Uashat Mak Mini-Utenam, Mingan, Natashquan; 3) FEA3: Eel River Bar First Nation, Pabineau, Eel Ground, Buctouche, Fort Folly, Acadia, Bear River, Mill Brook, Paq'tnkek First Nation, Waycobah First Nation, Wagmatcook, Chapel Island First Nation, Membertou, Lennox Island, Abegweit.

The first Europeans to allude to the importance of native American eel fisheries, specifically those associated with the St. Lawrence River system, were Jacques Cartier in 1535 and Samuel de Champlain (reviewed by Casselman 2003). Indeed, eel fishing was already a valuable and traditional activity for Aboriginal people at the time of European exploration of the St. Lawrence River watershed (Bourget 1984, cited in Robitaille *et al.* 2003). There is evidence of eel fisheries as early as 3,000 years ago. Native fishers fished with stone weirs on rivers, eelpots made of ash splints, and winter and summer spears (Gordon 1993, cited in Prosper 2001). Native people, including the Montagnais, fished eels during the fall season near Quebec City and along the lower St. Lawrence estuary with spears or weirs set up on the tidal flats (LeJeune 1634, cited in Robitaille *et al.* 2003; Casselman 2003). The Jesuits also reported that the Onondaga of the St. Lawrence Iroquois fished eels in the Finger Lakes region, south of Lake Ontario, and in tributaries of Lake Ontario, particularly in Oneida Lake on the Oswego River, in the Ottawa River (Morrison and Allumettes islands) and at Pointe-du-Buisson in the early 1900s, with two-way weirs and sluices and speared at night from canoes (Junker-Anderson 1988, cited in Casselman 2003; Pilon 1999, cited in Verreault *et al.* 2004; M. Courtemanche, Université de Montréal, pers. comm.). A summer spear fishery occurred in the Thousand Islands section of the upper St. Lawrence River as well (Stevens 1958, cited in Casselman 2003). Given the importance of eels for the Onondaga, an Eel Clan was formed (Tooker 1978, cited in Casselman 2003). The decline in abundance in the St. Lawrence watershed threatens the longstanding association of the St. Lawrence Iroquois with an important species and historic food resource (Casselman 2003).

In the Maritimes, the Mi'kmaq people have traditionally had a deep cultural and economic relationship with eels (Anonymous 2002). They are primarily fished for food and skin, but used for a variety of purposes as well (Anonymous 2002). Archaeological evidence indicates six fishing methods used by the Mi'kmaq: baited traps, unbaited traps, spears, hooks, nets, and weirs (Prosper 2001). However, the spear remains the fishing gear of choice reflecting a Mi'kmaq cultural practice (Anonymous 2002). American eels were a traditional and important food source for many of the Mi'kmaq people year round. The best locations to fish eels in St. George's Bay (Nova Scotia) were at Lakevale, Harver Boucher, Pomquet and Antigonish Harbour (Eales 1966, cited in Anonymous 2002). Eel fishing experiences in Pomquet Harbour have been described as extremely successful but, since the early 1990s, the American eel has become generally much less plentiful throughout the Maritime region (Anonymous 2002). The decline of the American eel threatens the longstanding Mi’kmaq relationship with the eel.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Commercial fisheries for American eels are regulated by fishing season, number of licences, gear type, setting, minimum size limit, or quotas. Commercial fisheries are not permitted in substantial parts of the eel's Canadian range. The fishery was closed in Ontario in 2004. No commercial fishery targets eels reared in FEA2. Eel fishing is not premitted in the great majority of freshwater habitat in the southern Gulf of St. Lawrence area (FEA3). The majority of freshwater and coastal eel habitat in the Scotia-Fundy area and in Newfoundland is unfished (Cairns *et al*. unpubl. ms.). Regulations and licensing policies have changed through time. Fisheries and Oceans Canada, along with the Quebec Ministry of Natural Resources, Wildlife and Parks and the Ontario Ministry of Natural Resources have agreed to develop an integrated conservation-management plan to arrest significant population decline of the American eel. A worldwide decline of eel resources, including the American eel, has been declared at the International Eel Symposium in 2003 (American Fisheries Society Annual Meeting; Dekker *et al.* 2003).

The American eel and its habitat are protected by the Canadian *Fisheries Act.* Prior to 2006 the American eel was not assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), nor was it listed by the Canadian *Species at Risk Act*, or by The World Conservation Union (IUCN) and is being reviewed in this status report for the first time. NatureServe (2005), a network providing scientific information to help guide effective conservation action and natural resource management, listed the American eel as *Secure* (S5) for Canada and the United States, as a species as a whole. However, NatureServe Canada (2005) designated eels *Apparently secure* (S4) in Labrador and Prince Edward Island and *Vulnerable* (S3) in Quebec. Present statuses for the Canadian provinces and the states of the United States were last reviewed in September 1996 (Table 7). A revision of the NatureServe statuses has been recently requested by the USFWS (H. Bell, USFWS, pers. comm.). NatureServe Canada includes independent conservation data centres such as the Atlantic Canada Conservation Data Centre, the Ontario Natural Heritage Information Centre and the Centre de données sur le patrimoine naturel du Québec.

Table 7. Present statuses for the American eel in Canada and of ranked and applicable states in the United States (last review in September 1996; NatureServe 2005). Bold indicates Canadian provinces and regions.

Province or State	Status
Wisconsin	S1: Critically imperilled
Illinois, Kansas, West Virginia, Wisconsin	S2: Imperilled
Quebec, Iowa, Georgia, Oklahoma, South Dakota, Tennessee, Vermont	S3: Vulnerable
Labrador, Prince Edward Island, Arkansas, District of Columbia, Indiana, Kentucky, Maryland	S4: Apparently secure
Ontario, New Brunswick, Nova Scotia, Newfoundland, Alabama, Connecticut, Delaware, Kentucky, Louisiana, Maine, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Texas, Virginia	S5: Secure
New Mexico	SX: Presumed extirpated

American eel components in the United States are currently being examined on several fronts. The United States Fish and Wildlife Service (USFWS), in coordination with the National Marine Fisheries Service, is undertaking a status review of the species to determine whether listing is warranted under the Endangered Species Act (USFWS 2005). Additionally, the USFWS Division of Scientific Authority is considering a proposal to list the species in Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). They are currently completing the information collection stage. The Atlantic States Marine Fisheries Commission (ASMFC) is also completing a stock assessment of the American Atlantic (L. Munger, ASMFC, pers. comm.). ASMFC developed the Interstate Fishery Management Plan for the American eel in order to protect and enhance the abundance of the species in both inland and territorial waters to provide sustainable subsistence, recreational and commercial fisheries by preventing overharvest of any eel life stage (USFWS 2005).

TECHNICAL SUMMARY

Anguilla rostrata
american eel — anguille d'Amérique

Range of Occurrence in Canada: Accessible freshwater, estuaries, and sheltered salt water of Newfoundland, Nova Scotia, Prince Edward Island, New Brunswick, Quebec and Ontario to Lake Ontario and lower Niagara River. Continental shelves are also used by migrating juvenile and silver eels. The northern limit in Canadian waters is the Hamilton Inlet-Lake Melville estuary of Labrador.

Freshwater Ecological Areas (following the COSEWIC national system):
FEA1: Great Lakes-Western St. Lawrence (Ontario and western and central Quebec)
FEA2: Eastern St. Lawrence (eastern Quebec)
FEA3: Maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and the central and southern parts of Quebec's Gaspé Peninsula)
FEA4: Atlantic Islands (Newfoundland)
FEA5: Eastern Arctic (Labrador)

Extent and Area Information	**FEA1**	**FEA2**	**FEA3**	**FEA4**	**FEA5**	**SPECIES**
Extent of occurrence (EO)(km²) -based on polygons see text - Canadian Range	391,515	546,122	292,923	177,586	75,472	2,065,932
• *Specify trend in EO*	Decline	Decline?	Increase?	Stable ?	Stable ?	Decline
• *Are there extreme fluctuations in EO?*	No	No	No	No	No	No
Area of occupancy (AO) (km²)-based on Lake Ontario 0-10m area, Verreault et al. 2004 for Quebec, Museum records for Ontario, and Canadian waters outer limit (buffer of 370 km)	97 400	161 400	635 200	627 500	130 700	1 653 200
• *Specify trend in AO*	Decline	Decline?	Stable ?	Stable ?	Stable ?	Decline
• *Are there extreme fluctuations in AO?*	No	No	No	No	No	No
• *Number of known or inferred current locations*	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
• *Specify trend in #*	Decline	Decline?	Stable ?	Stable ?	Stable ?	Decline
• *Are there extreme fluctuations in number of locations?*	No	No	No	No	No	No
• *Specify trend in area, extent or quality of habitat*	Decline	Decline?	Stable?	Stable?	Stable?	Decline
Information for eel components	**FEA1**	**FEA2**	**FEA3**	**FEA4**	**FEA5**	**SPECIES**
Generation time (average age of parents in the component). Ranges refer to parental ages of eels reared in salt and fresh water, respectively	22	9-22	9-22	9-22	9-22	9-23
• *Number of mature individuals*	424,000 in 1997	Unknown	Unknown	Unknown	Unknown	Unknown
• *Trends in components:*	Decline	Decline?	Increase?	Unknown	Unknown	Decline

• *% decline over the last 10 years or 3 generations* Note: No data are available for changes over 3 generations of female fresh-reared eel, which is approximately 66 years. Data in this row are from Table 5. Reported landings in FEA3-5 declined by 26.2% over ~1 freshwater gen. and ~3 saltwater gen. Data from Ontario reflect the upper St. Lawrence/Lake Ontario part of FEA1. Data series from Quebec reflect the whole FEA1 population. FEA 1 may supply ~27-67% of global spawn output (see text Contribution of the St. Lawrence eel population) - a > 90% decline in this area may indicate a loss of 25-60% of the global spawn. The calculations are based on unproven methodologies and may be an overestimate; for that reason a range of values is given. See Table 5 [1]Landings [2]ladder index *Elecrofishing densities over 1-2 generations, [3]Electrofishing counts over 1 generation. Also landings in FEA 3-5 declined ~26%	Ontario ~ 98.8% (Quinte trawl index) 99.5% (Moses-Saunders ladder index) Quebec ~15.1% (St. Nicholas index) ~63.9% (Quebec silver eel landings, ~1 generation	Unknown	Rest. +74.8%* Miramichi ~43%* Margaree ~87.9%* Stewiake ~81.6%[3] Elsewhere Unknown	Unknown	Unknown	Unknown
• *Are there extreme fluctuations in number of mature individuals*	No	Unknown	No	Unknown	Unknown	Unknown
• *Is the total component severely fragmented?*	No	No	Partly	Unknown	Unknown	No
• *Specify trend in number of components / subcomponents*	Decline	Stable	Stable	Stable	Stable	Decline (FEA1)
• *Are there extreme fluctuations in number of components / subcomponents?*	No	No	No	No	No	No
Threats	**FEA1**	**FEA2**	**FEA3**	**FEA4**	**FEA5**	**SPECIES**
• *Actual*						
• *Loss of habitat (dams)*	X	X	X	X		X
• *Turbine mortality*	X	X		X		X
• *Fisheries*	X		X	X		X
• *Contamination*	X	X				
• *Change in oceanic currents*	X	X	X	X	X	X
• *Parasites - Anguillicola crassus*	X	X	X	X	X	X
• *Low pH*			X			

Rescue Effect (immigration from outside source) Not Applicable	**FEA1**	**FEA2**	**FEA3**	**FEA4**	**FEA5**	**SPECIES**
Status of outside component(s)? USA: Rescue effect is not applicable since this is a catadromous, panmictic species, all components breed in one area (*see* text – Rescue Effect)	N/A	N/A	N/A	N/A	N/A	67.5% decline in reported US landings since 1970s
• *Is immigration known or possible?*	Yes	Yes	Yes	Yes	Yes	Yes
• *Would immigrants be adapted to survive in Canada?*	Yes	Yes	Yes	Yes	Yes	Yes
• *Is there sufficient habitat for immigrants in Canada?*	Yes	Yes	Yes	Yes	Yes	Yes
• ***Is rescue from outside components likely?*** – yes, but not really applicable – see note above	Yes	Yes	Yes	Yes	Yes	Yes
Quantitative Analysis	**No Data**	**No Data**	**No Data**	**No Data**	**No Data**	**No Data**

EXISTING STATUS

NatureServe Status [NatureServe (2005) last revised in 1996; *see also* Table 7]
Global G5
National **US** - N5
Canada - N5
Regional: US - AL- S5, AZ - SNA, AR - S4, CT - S5, DE - S5, DC - S4, FL - SNR, GA -S3S4, IL - S2, IN - S4, IA - S3?, KS - S2, KY - S4S5, LA - S5, ME - S5, MD - S4, MA -S5, MI - SNA, MS - S5, MO - SNR, NE - SNR, NY - SNA, NH - S5, NJ - S5, NM - SX, NY - S5, NC - S5, OH - SNR, OK - S3, PA - S5, RI - S5, SC - SNR, SD - 3?, TN - S3, TX - S5, VT - S3, VA - S5, WV - S2, WI - S1S2 . **N.B.** the US is currently reviewing the status of this species for possible listing under the Endangered Species Act.

Canada: LB - S4, NB - S5, NF - S5, NS - S5, ON - S5, PE - S4S5, QC - S3

Wild Species 2000 (Canadian Endangered Species Council 2001)

National - N6
Provincial - N – 4*, QC -3, NB - 4, NS -4, PE - 4, LB - 4, NF - 4

*Dextrase indicated that this should be 2 (A. Dextrase, Ontario Ministry of Natural Resources, Peterborough, Ontario; annotated rank comments in relation to the data output for the Wild Species web site resulting from the November 2001 query for freshwater fish species).

COSEWIC

First assessed in 2006 as Special Concern.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** not applicable
Reasons 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 (no long-term indices are available for Scotia/Fundy, Newfoundland, and Labrador) 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, but time series of elver abundance, although relatively short, do not show evidence of an ongoing decline. 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, including habitat alteration, dams, fishery harvest, oscillations in ocean conditions, acid rain, and contaminants, may continue to impede recovery.	
Applicability of Criteria **Criterion A**: (Declining Total Population): Not Applicable. The Canadian segment of the population in the Great Lakes/Upper St. Lawrence Basin has declined by approximately 99% since the 1970s (based on landings, ladder indices, and test fishing indices), and is continuing to decline for reasons that are not well understood and may not be reversible. Decline has also been documented at four of five sites in the lower St. Lawrence and Gulf of St. Lawrence; however, the overall decline in Canadian waters is unknown **Criterion B**: (Small Distribution, and Decline or Fluctuation): Not applicable – EO and AO exceed threshold values**.** **Criterion C**: (Small Total Population Size and Decline): Not applicable - Total population size although unknown is undoubtedly well above the threshold value. **Criterion D**: (Very Small Population or Restricted Distribution): Not applicable – the species is widespread and numerous, threshold values are exceeded. **Criterion E**: (Quantitative Analysis): Not applicable – no data.	

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BIOGRAPHICAL SUMMARIES OF THE REPORT WRITERS

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The report was prepared under the aegis of the Canadian Eel Science Working Group (CESWoG), which consists of biologists from the Ontario Ministry of Natural Resources (OMNR), the Québec Ministère des Ressources naturelles et de la Faune (MRNF, Secteur Faune Québec) and the Department of Fisheries and Oceans. Its mandate is to coordinate eel research and assessment in Canada. CESWoG's contributions to this report were coordinated by four members. J.M. Casselman of OMNR, conducts research on fresh water and fisheries ecology in eastern Ontario. Dr. Casselman has retired from OMNR since completion of the first draft of this report, but continues his research as a senior scientist emeritus and adjunct professor, Department of Biology, Queen’s University in Kingston, Ontario. N.E. Mandrak of Fisheries and Oceans, works on endangered aquatic species in central Canada. F. Caron of MRNF, Secteur Faune Québec, conducts research on salmon, eels, and other diadromous species in Quebec. D.K. Cairns of Fisheries and Oceans, does eel research in the southern Gulf of St. Lawrence.

COLLECTIONS EXAMINED

Not applicable.