American Fisheries Society Symposium 62:xxxx, 2008

Declines of American Eel in North America: Complexities Associated with Bi-national Management

ROB MACGREGOR[†]
Ontario Ministry of Natural Resources
P.O. Box 7000, 300 Water Street—5 North, Peterborough, Ontario K9J 8M5 Canada

ALASTAIR MATHERS[‡]
Ontario Ministry of Natural Resources
RR 4, Picton, Ontario K0K 2T0 Canada

PETER THOMPSON
Fisheries and Oceans Canada
520 Exmouth Street, Sarnia, Ontario N7T 8B1 Canada

JOHN M. CASSELMAN
Queen's University, Department of Biology, Bioscience Complex
116 Barrie Street, Kingston, Ontario K7L 3N6 Canada

JOHN M. DETTMERS
Great Lakes Fisheries Comission
2100 Commonwealth Boulevard, Suite 100, Ann Arbor, Michigan 48105 USA

STEVEN LAPAN
New York State Department of Environmental Conservation
Cape Vincent Fisheries Station
P.O. Box 292, Cape Vincent, New York 13618 USA

THOMAS C. PRATT
Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
1 Canal Drive, Sault Ste Marie, Ontario P6A 6W4 Canada

BILL ALLEN
Heritage One
9 First Avenue, Box 85, Burke's Falls, Ontario P0A 1C0 Canada

[†]Corresponding author: rob.macgregor@ontario.ca
[‡]Corresponding author: alastair.mathers@ontario.ca

Status of American Eel Fishery

Background and Life History

The decline of American eel *Anguilla rostrata* in many parts of its North American range is well documented, especially in the Great Lakes basin (Haro et al. 2000; Casselman 2003). We have chosen to end this section with a short summary of the declines and associated causal factors, as some of the complexities associated with the decline are relevant to a discussion of American eel governance. In addition, we have included brief summaries of the geographic distribution of the eel fisheries in North America, harvest dynamics, impacts of globalization and the evolution of governance structures as necessary precursors to making recommendations on future governance for American eel.

While discussions periodically arise regarding whether American eel are truly panmictic (i.e., a single, nonstructured breeding population), the current science suggests that they are, and several of our arguments are based on this premise. It is difficult to see how this species could not be panmictic given our current biological understanding of American eel (e.g., all eels in the St. Lawrence River–Lake Ontario system are female), and the appropriate precautionary approach is to manage eels as if they are panmictic until contrary evidence is presented. However, we recognize that the genetic investigations performed to date on American eels are spatially-limited, and if future research results in panmixia being challenged our proposed governance structures and management strategies will need to be re-visited.

All American eel are part of a panmictic population that spawns in only one place in the world—the Sargasso Sea in the Atlantic Ocean (Avise et al. 1986; Wirth and Bernatchez 2003). Eel larvae (leptocephali life stage) drift with ocean current, a journey that may take years to complete with some eels traveling as far as 6,000 km from their source. Unpigmented, postlarval American eel (glass life stage) initiate migration into estuaries and quickly become pigmented (elver life stage), and then many migrate inland into streams, rivers and lakes. American eel then feed and grow (yellow life stage) for up to 25 years before mature (silver life stage) eel migrate back to the Sargasso Sea to spawn. American eel are not the obligate catadromes once believed, as recent evidence indicates that some individuals spend their entire life cycle in the marine environment (Lamson et al. 2006). Additional information on the complicated life cycle of the American eel is available in Tesch (1977) and COSEWIC (2006). The migratory nature of their life cycle puts American eel in close association with humans, and during their migration American eel must run a gauntlet of anthropogenic effects (e.g., barriers, significant turbine mortality at hydro-electric facilities, and fishing at all life stages). The cumulative effect on eel is likely severe.

Importance of American eel to Aboriginal People

"During the months of September and October, they [the Montagnais] live for the most part on fresh eels" and their stocks of smoked eels lasted them until … January"
The Jesuit Relations (in Junker-Anderson 1988)

"The most considerable Fishery of [the natives] *is that of Eels*"
Hennepin, 1699 (in Junker-Anderson 1988)

That American eel played a central role in the 1999 Supreme Court of Canada (SCC) decision of R v. Marshall (SCC 1999) is a relatively recent example of the strong connections between many aboriginal people and eel. This relationship has been important

for centuries and remains so today (Prosper 2001). American eel has been highly significant in the traditional lifeways of Aboriginal people in eastern North America, not just for food and trade but for ceremony, medicine and a wide range of functional uses (Prosper 2001; Prosper and Paulette 2003; Allen 2007). For instance, there are rich cultural and lifeways connections between Mi'Kmaq and American eel (*Kat*). Eel was a traditional and important food source for many of the Mi'Kmaq people throughout the year, the subject of legend, used medicinally and considered to have many spiritual qualities. For instance, *Kat* was involved as an important spiritual and ceremonial offering to the grandfathers (called feeding of Grandfather—*Apuknajit*) to give thanks for allowing the people to survive the most difficult time of year (Prosper 2001).

In reference to historical fishing practices by Aboriginal people in the St. Lawrence River–Lake Ontario area, contemporary observers agree the eel was the single most important of the fish species pursued by all of the Iroquoian peoples, with the possible exception of the Mohawks (Junker-Anderson 1988). Eels were a very important source of food in villages, and it is apparent that smoked eels were commonly used as traveling food, being lightweight and highly nutritious. In Ontario, at least six registered archaeological sites document eel remains of pre contact age, approximately 500–1,000 years old. Two additional sites over 4,000 years old on the Québec side of the Ottawa River yielded substantial eel remains, the most prevalent faunal remains present (Allen 2007). At least three of the New York State Six Nations had, at one time or another, an Eel Clan—the Cayuga, Onondaga and Tuscarora. Few animals are singled out for clan names; clans named after fish are rare, so the eel clan designations are a further indicator of the significance of the species to Indigenous people.

As further archaeological information and traditional knowledge from Aboriginal people are collated and summarized, much can be learned about the former distribution and abundance of American eel in other waters, We have noted elsewhere (e.g., see Section entitled *Understanding the Complexity of American Eel Management*) that American eel appear to have been virtually lost from many important waters prior to the collection of formal records. However, as eels have been integral to the lifeways of many Canadian First Nations and U.S. Tribes, a wealth of information regarding historical eel distribution, use and abundance appears to be available within the traditional knowledge of Aboriginal people. For instance, the mere understanding that Aboriginal languages have words meaning eel (e.g., *Kat* (Mi'Kmaq), *Pimizi (Algonquin* Anishnaabemowin*),* and *Kinebikoinkosew* (Cree)) and the fact that such words appear on surviving maps (Macdonald 1985) can provide valuable clues for eel researchers to follow-up and piece together former eel range and use. In short, no discussion of American eel management should minimize or ignore the valuable input and knowledge of Aboriginal people. It will be important to take advantage of this knowledge before it is lost; it is becoming apparent that only a few Aboriginal people in some areas can recall memories involving the eel, perhaps as a result of declining eel abundance in their nearby waters (Prosper 2001).

Geographic distribution of the fishery

American eels are commercially harvested at virtually all life stages, and in most habitats including freshwater lakes and rivers, estuaries, the Atlantic Ocean, the Gulf of Mexico and the Caribbean Sea. They are harvested as glass eels and elvers primarily for aquaculture in Asia and to some extent Europe, as yellow eels for bait and food, and as silver eels for food (ASFMC 2000).

Commercial American eel fisheries extend from Maine to the Gulf of Mexico in the USA, with only the states of Alabama and Mississippi excluded. Canadian commercial fisheries now occur in the four Atlantic Provinces (Newfoundland, New Brunswick, Prince Edward Island, and Nova Scotia), and Québec. The Province of Ontario closed their commercial fishery in 2004. In addition, FAO commercial catch records indicate that glass eels or elvers are harvested in Mexico, Cuba, and the Dominican Republic (EIFAC/ICES 2001).

Harvest dynamics and value of fishery in each area

It is difficult to characterize trends in the commercial fishery by geographic area or life stage because either harvest or effort data are nonexistent and highly unreliable, and size and age data are largely undocumented (EPRI 1999). The paucity of effort data also complicates comparison of commercial landings and population trends. Glass eel and elver fisheries developed in Maine, Massachusetts, Virginia, North Carolina, and South Carolina during the 1970s. Since then, fisheries also developed or were re-established in Connecticut, Rhode Island, New York, New Jersey, Delaware, South Carolina, and Florida (ASMFC 2000). A glass eel and elver fishery was established in Canada in the Nova Scotia-Bay of Fundy region around 1990. Glass eel and elver harvest data are available from Maine only for 1977, 1988, and 1994–present.

Casselman (2003) described trends in U.S. and Canada commercial catch data, which are similar over the period 1950–2000 (Figure 1). Catches declined dramatically in the 1990s following record-high combined United States and Canadian catches averaging 2,000 metric tons annually. Declines in U.S. catches preceded those in Canada by a decade, primarily due to predominantly smaller and younger eels in the U.S. fishery. Central coastal states dominate U.S. harvest (80%), followed by northern (19%) and southern (1%) states. Significant declines in commercial catch occurred in northern and southern states during the 1980s and 1990s in the USA (Figure 2). Catches in the central states remained fairly stable through the late 1990s before falling below the long-term mean.

The majority of the commercial catch in Canada from 1950 to 2000 (57%) came from the St. Lawrence River and Lake Ontario (Ontario and Québec), though the catches predominantly occurred in Québec waters of the lower St. Lawrence River (Casselman 2003). More than 100 years of commercial catch data for American eels at an extremity of the species range in the upper St. Lawrence River–Lake Ontario system (Figure 3) indicated that, despite relatively sustained effort and an approximate five-fold increase in value, catches declined sharply throughout the 1990s. Commercial harvest in Québec, which is primarily related to the silver eel fishery in the St. Lawrence River estuary also declined dramatically in the 1990s (Figure 3). Catches from the lower St. Lawrence region experienced a synchronous exponential decrease, with a combined catch in the late 1990s 59% less than the long-term mean (Chaput et al. 1997; Casselman 2003). Catches in the Nova Scotia-Bay of Fundy region increased from the late 1980s to the early 1990s (Figure 4), but decreased to slightly above the long-term mean in the late 1990s. This region accounts for approximately 14% of the Canadian catch, and is closer to the source of eel recruitment. Reported commercial landings were nearly equal in the USA (48%) and Canada (52%; Casselman 2003).

Impacts of globalization on the fishery

Global demand for eels has had a strong influence on the development of fisheries for the glass, elver, yellow and silver life stages

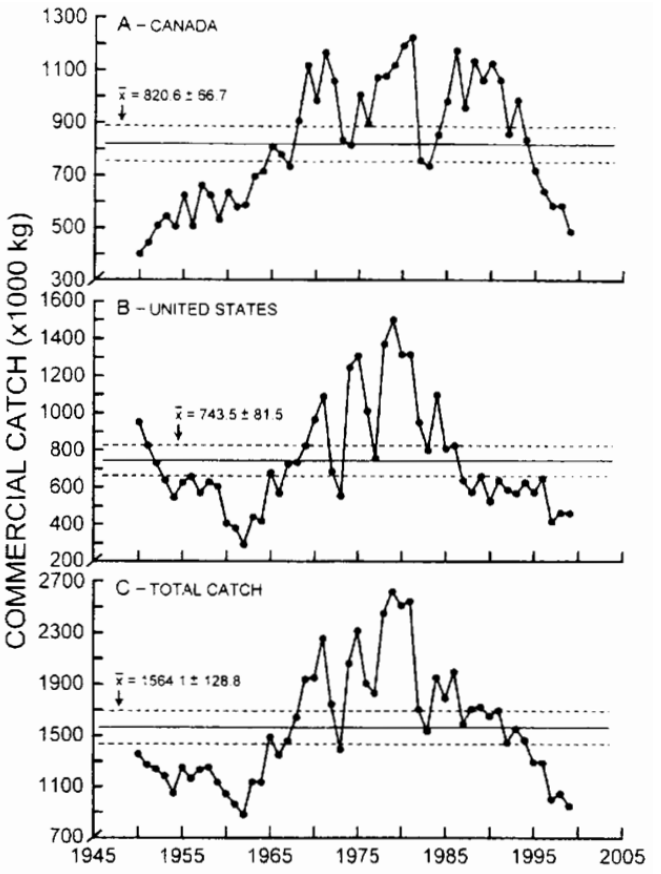

Figure 1. Commercial catch of eels reported for 50 years (1950–1999), combined for Canada (A), United States (B), and total catch (C). Means (*solid lines*) and 95% confidence intervals (CI; *dashed lines*) are delineated. From Casselman 2003.

of the American eel. Declining abundance of wild stocks of the three most commercially important anguillid species has increased the demand for American eels (Dekker et al. 2003). Historically, domestic markets for American eels in the USA and Canada have been small relative to European and Asian markets. Before 1978, landed price was strongly related to American eel harvest level in the upper St. Lawrence River and Lake Ontario (Casselman et al. 1997a). However, between 1993 and 2002, harvest in this same area declined by 10 metric tons per year in spite of continued increases in landed value of American eels to nearly U.S.$4/kg (Mathers and Stewart, in press).

Elver fisheries have existed for European eels *A. anguilla* and Japanese eels *A. japonica* for over a century (Tesch 1977; Moriarty 1990; Gousset 1990; Heinsbroek 1991); whereas the establishment of commercial fisheries for American eel elvers are a recent development (Jessop 1997). The high demand and insufficient supply of elvers for culture of eels in Asia and Europe led to development of American eel glass and elver fisheries to supply these markets (Jessop 1997). Elvers were first fished in the USA for export to Asia during the early 1970s (Fahay 1978; Jessop 1997), while the elver fishery in Canada began in 1989 in rivers surrounding the Bay of Fundy and the Atlantic coast of Nova Sco-

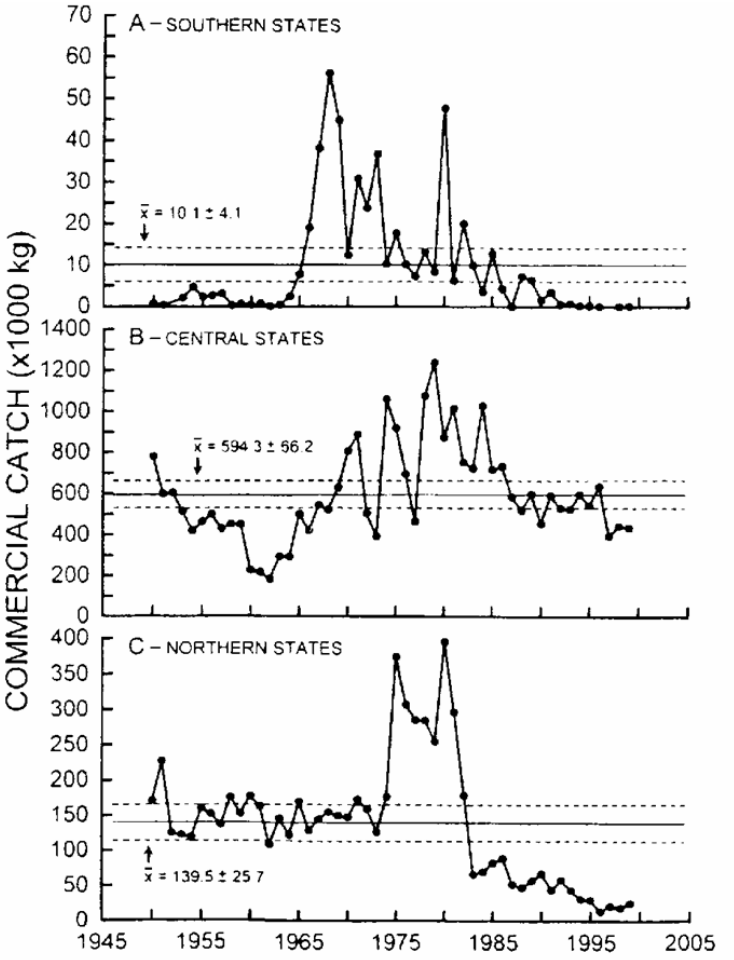

Figure 2. Commercial catch of eels reported for 50 years (1950–1999) for the United States, separated by region: southern (A), central (B), and northern (C) coastal states. Atlantic coastal states are defined in Casselman 2003; means and 95% CI as in Fig. 1. From Casselman 2003.

tia (Jessop 1997). The Canadian commercial elver fisheries have had an annual estimated gross landed value of up to CAN$1,600,000 (Jessop 1997). The continuing high value of elvers (e.g., greater than U.S.$500/kg) may have the potential to encourage the development of illegal fisheries. A U.S. Fish and Wildlife Service, Division of Law Enforcement (USFWS-DLE unpublished, 2005) summary of illegal harvest reported that due to the high "on the street" price for Atlantic seaboard glass eels (U.S.$1,213/kg in the early fishery to U.S.$212/kg later), harvest of American eel is reportedly one of the largest commercial fishing activities on the east coast. The USFWS-DLE first recognized illegal take of glass eel, and possibly other life stages, in the summer of 1997. The underreporting of glass eel and elver catches occurred to an unknown, but possibly substantial, degree before 1998 in the United States (ICES 2000), though this was not believed to have occurred in Canada as the Canadian glass eel and elver quotas have never been fully utilized.

Changing global markets for American eel led to changes in the gear used in some

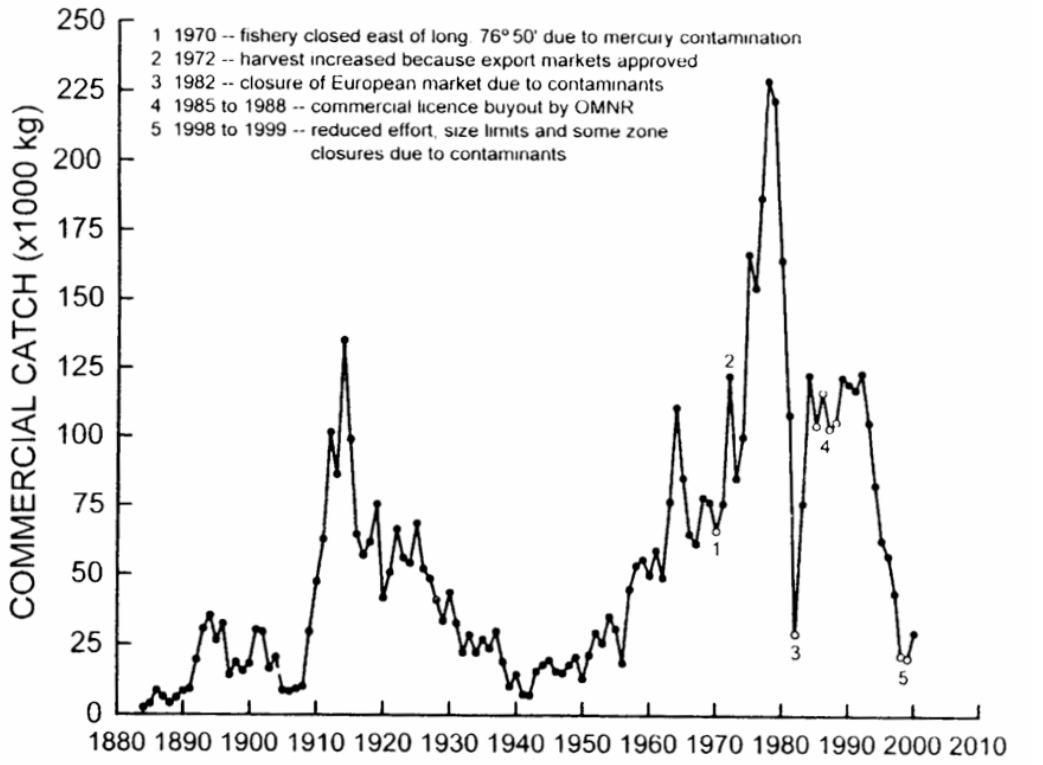

Figure 3. Commercial catch of eels for 117 years (1884–2000) for upper St. Lawrence River-Lake Ontario. Major events that could have affected the commercial eel fishery and catch are indicated at the top of the figure. OMNR—Ontario Ministry of Natural Resources. From Casselman 2003.

yellow eel fisheries and the type of product sold. For example, eel lines accounted for 65% of harvest from 1959 to 1979 in Ontario, with hoopnets and trapnets making up the bulk of the remaining harvest (Kolenosky and Hendry 1982). The majority of these fish were sold frozen to European markets. The fishery has shifted in recent years, however, with 98% of the harvest taken in hoopnets and trapnets in 2002 because 1) the markets for live eels (primarily in Asia) have become more lucrative, making American eels caught in entrapment gear more desirable than those caught with hooklines which have a relatively low rate of survival, and 2) the entrapment gear catches a variety of commercial species making it more economical to fish given the reality of lower eel abundance. In 2002, 93% of eels were sold live for an average price of U.S.$4.01/kg, while 7% were frozen and sold for an average price of U.S.$2.51/kg (Mathers and Stewart, in press).

Other globalization patterns, such as international trade and shipping, have had major negative effects on American eel throughout their range. For instance, the spread of invasive species and parasites has been facilitated via the long-range transportation of goods with a changing global economy. One of the far-reaching impacts of zebra and quagga mussel (*Dreissena* spp.) colonization on aquatic ecosystems throughout the Great Lakes basin is their influence on the distribution of American eel in Lake Ontario and the St. Lawrence River. Declines in nearshore catches of American eel with electrofishing

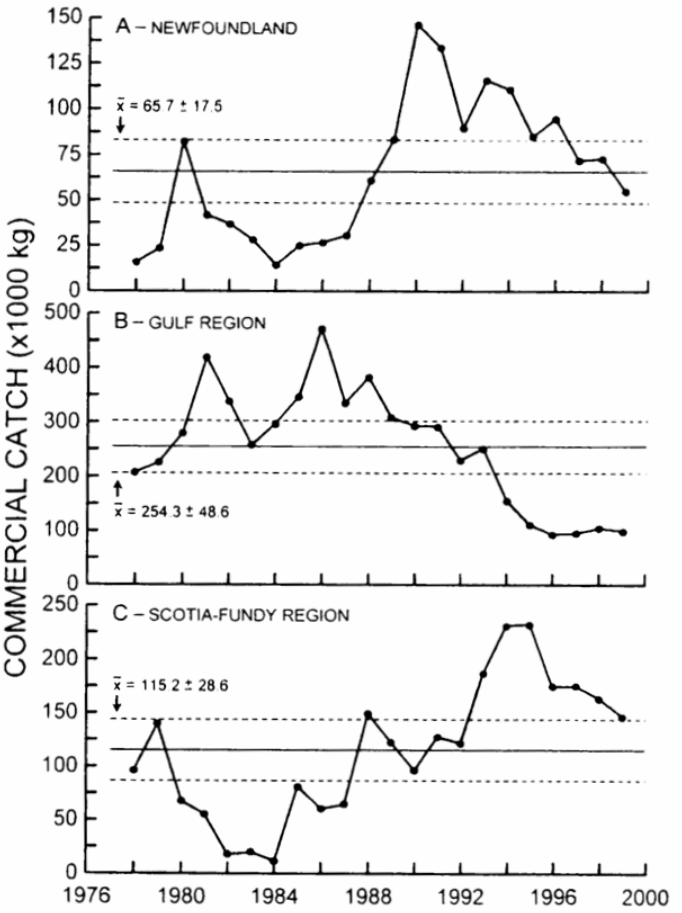

Figure 4. Commercial catch of eels for 22 years (1978–1999) for Newfoundland (1A), Gulf region (B), and Scotia-Fundy (C), Nova Scotia and New Brunswick combined. Means and 95% CI as in Fig. 1. From Casselman 2003.

in Lake Ontario during the day are positively correlated with increased water transparency caused *by Dreissena* colonization in the early 1990s (Casselman 2003). Parasites and disease organisms are also spread by increased transportation of live fish outside their natural ranges, as illustrated by the introduced nematode *Anguillicola crassus*, an American eel swim bladder parasite. The nematode spread into Europe from shipments of Japanese eels 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 American eel captured in Winyah Bay, South Carolina, in 1995 (Fries et al. 1996). Since then, the parasite has been detected in American eels in the Hudson River and Chesapeake Bay (Barse and Secor 1999; Morrison and Secor 2003). During recent surveys, all eels that were examined from rivers in Rhode Island and Massachusetts had the parasite; some parasites were also documented in Maine waters (K. Oliveira, University of Massachusetts, personal communication). The parasite has not been found in Canadian waters to date. The potential spread of this parasite beyond its current range is a significant concern during transportation and stocking of American eels.

Status and importance of American eels, with special reference to the St. Lawrence River and Lake Ontario

> *"It is wonderful how many of these fish* [eels] *are found in this great river* [St. Lawrence]. *It is thought that this great abundance is supplied by some lakes in the country far north, which…make us a present of this manna that nourishes us…."*
>
> Jesuit Relations (*in* Junker-Anderson 1988)

American eel were once much more abundant and widely dispersed throughout their range (Casselman 2003; in press). For example, American eel were once found throughout the Mississippi drainage in substantial numbers and provided important fisheries for Native Americans; now they are rarely seen in that system (Casselman 2003). Declines over the past three decades occurred over the majority of the range but are particularly dramatic and obvious in the past decade. A recent peer review of the American eel stock assessment by the Atlantic States Marine Fisheries Commission (ASMFC) reports that the abundance of yellow eel has declined in the last two decades and that they are at or near documented low levels. Moreover, the report suggests that if the indices represent a range-wide phenomenon, there is a real risk that spawning stock biomass has declined. If the declines result from unsustainable rates of total mortality, recruitment failure is a possible consequence (ASMFC 2006a).

Casselman (2003) performed Mann-Kendall trend analyses on 17 scientific indices describing American eel abundance at various life stages across the species' range, eight of which exhibited significant negative trends. The strongest patterns of decline occurred in data series that were "more northern, longer, and included larger individuals". The remaining indices included six showing no significant trends and three showing positive trends. Neutral or positive indices were generally associated with the central part of the range, closer to the source of recruitment.

Declines in one important segment of the population at the extremity of the range, associated with the Great Lakes basin in the upper St. Lawrence River and Lake Ontario, are well documented with fisheries-independent data (Casselman 2003). American eel were historically very abundant in the St. Lawrence River, Lake Ontario and the adjoining Ottawa River watershed. They provided important commercial fisheries since European contact and, as noted earlier, were very important to Aboriginal people (Junker-Anderson 1988). Declines of American eel in other parts of its range are a matter of concern for Aboriginal people (Prosper 2001).

Declines in American eel abundance in the upper St. Lawrence River and Lake Ontario are best documented by the nearly complete loss of recruitment to this segment of the population (Casselman et al. 1997b; Casselman 2003). Precipitous declines in recruitment reached three orders of magnitude over the past three decades. Moreover, declines in all other abundance indices have matched these declines in recruitment when appropriate age lags are considered (Casselman 2003; in press). The major decline of American eel in the aforementioned region is of particular concern because eels in this region are all large, highly fecund females. Given their high fecundity and former high abundance, American eel in the upper St. Lawrence River and Lake Ontario would have likely comprised a substantial proportion of the overall fecundity for the entire species (COSEWIC 2006).

The loss of perhaps the most fecund segment of the species is particularly disconcerting. Although the species still persists in Lake Ontario and the upper St. Lawrence River, it was lost as a fishery resource in Ontario when the province closed its commercial and sport fisheries in 2004. American eels also were an

important ecological component of the fish community in these waters. Through catadromy, they provided an integrating link between the ocean and the Great Lakes basin. As a top predator, they would have helped structure and stabilize the nearshore fish community. The loss of this abundant nearshore predator could potentially have destabilized the fish community allowing easy expansion of inshore invaders such as round gobies *Neogobius melanostomus*, which are now established in the Lake Ontario-St. Lawrence River system (J. M. Casselman, Queens University, unpublished data).

In recent years, this decline has generated particular concern, e.g., GLFC Position Statement (GLFC 2002); Quebec Declaration (Dekker et al. 2003), because of the historical importance of American eel in the fish community of the Lake Ontario and St. Lawrence River. Overall declines, particularly associated with the upper St. Lawrence River and Lake Ontario, resulted in thorough status reviews of American eel for consideration under the *Endangered Species Act* (Ontario; OMNR 2006), the *Species at Risk Act* (Canada; COSEWIC 2006), and the *Endangered Species Act* (United States; Federal Register 2007). The significant decline of the Great Lakes segment of the American eel population, and the concern over its sustainability and indeed its continued existence in the Great Lakes, emphasize the need for a strong and sustained approach to address the issue and suggest that this segment of the population may merit special protection.

Evolution of Governance Structures

Background

The International Council for the Exploration of the Seas (ICES) recently recommended taking a precautionary approach that includes relevant biological reference points for fishery management implementation (ICES 2000). The overall goal of a precautionary approach to management is to ensure against future harm to populations, especially in the absence of suitable data for development of stock–recruitment relationships. Such a strategy might include ensuring that fishing mortality remains below natural mortality, adjusting fishing effort to account for substantial uncertainty around the lack of long-term fisheries independent data series and estimated population size for American eels. There will also be a need to ensure that compliance with all regulations is monitored and enforced. Given the uncertainties and in many instances paucity of long-term data series relating to American eel status in many jurisdictions, application of the precautionary approach would seem to be the most appropriate management strategy.

At present, North American eel management and regulatory systems, with few exceptions, are rudimentary, largely focusing on effort controls or size limits to manage harvests. This situation is a legacy of the 25 or so independent jurisdictions not fully appreciating the complex panmictic and migratory nature of the American eel, the general availability of only very basic biological information, a lack of information regarding critical habitat, the complexities in dealing with other sources of mortality (e.g., turbine mortalities associated with hydro-electric facilities) and barriers to migration. In comparison with other fisheries, the eel fishery, while culturally and regionally important, is relatively insignificant on a jurisdictional, national or continental scale. All these factors explain the low priority that many jurisdictions have assigned to their eel management regimes or to the importance of coordinated management. Most North American jurisdictions recognize the need for harvest regulation at a continental level, but until recently little effort has been made to achieve coordinated management of American eel.

Currently, most North American regulations governing fish harvests are promulgated by states, some provinces, or the Canadian federal government (Fisheries and Oceans Canada: DFO). In Canada, fisheries management occurs under a system of federal-provincial cooperation; the provinces exercise fishery proprietary rights (licensing and allocation) in inland fresh waters and the federal government has responsibilities for management and control. In the inland fresh waters of Ontario and Québec provincial natural resource agencies have been delegated responsibility for the administration of federal legislation (Fisheries Act, Canada). In the four Atlantic provinces, DFO administers the legislation in both inland and coastal waters (out to the 322 km limit of the Exclusive Economic Zone (EEZ; Thompson 1974). The management of fisheries and impacts on fish may also be influenced by endangered species legislation. Federally, Canada has the Species at Risk Act that governs endangered aquatic species, while provinces like Ontario (Endangered Species Act) also have legislation that may affect the management of aquatic species.

In Ontario, commercial harvests of American eel fisheries had been managed since 1984 under a system of Individual Transferable Quotas (ITQs). In response to significant declines in abundance indicators, eel quotas were reduced by 50% in 2001 and again in 2002. However, the eel decline was so rapid that most commercial harvesters fell far short of harvesting their full quotas. In 2004, Ontario set commercial eel quotas to zero for the foreseeable future in an effort to protect those American eel remaining in the system.

The commercial fishery for glass eels or elvers in the Nova Scotia-Bay of Fundy region is limited; a total of 9 licenses had until recently a fixed quota of 1,000 kg per license (Stevens 1997). The quota has been reduced by 10% since 2005, though the total harvested by a license holder could be increased by 10% provided the incremental catch would be destined for domestic conservation stocking.

Much of the foregoing has addressed fisheries based American eel harvests. In addition, the Fisheries Act (Canada) addresses regulatory controls concerning fish habitat, deleterious substances, fish passage and killing fish by means other than fishing. DFO, the federal agency, has the lead in upholding the regulations outlined in the *Act*. Numerous sections of this *Act* are directly relevant to the impact of dams, turbines and loss of fish habitat for American eels in Canada. To date few of these areas of the *Act* have been directly applied, although actions are currently under consideration.

While no formal multi-agency organization similar to the ASMFC exists in Canada that spans the national range of American eel, several high level government organizations (e.g., the Canadian and Atlantic Councils for Fisheries and Aquaculture Ministers) and bilateral federal-provincial fora do play a role in American eel management. Under the auspices of these groups, a number of coordinated multi-jurisdictional efforts addressing American eel have been initiated.

In 1997, DFO and the Québec and Ontario Ministries developed a very general management plan for American eel in response to provincial concerns over declining abundance. Unfortunately, little progress was made (P. C. Thompson, Fisheries and Oceans Canada, and R. B. MacGregor, Ontario Ministry of Natural Resources, personal communication), and in response to further concerns expressed by Ontario and Québec over the continued significant declines of American eel, DFO and the two provincial Ministries began to again consider how to coordinate national management of American eel in 2002. In response, the Canadian Eel Working Group (CEWG) and the Canadian Eel Science Working Group (CESWoG) were established and met for the first time in 2003. They established several sub-commit-

tees to examine habitat, downstream passage around barriers, research and assessment and inter-jurisdictional matters. In 2004, the Minister of DFO announced that the federal and Ontario and Québec provincial agencies had agreed to begin working towards a 50% reduction in anthropogenic mortality of American eels (DFO 2004).

American eel are under consideration for listing as a species at risk under federal and provincial legislation in Canada. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) issued an assessment and status report recommending that eel be listed with a status of special concern nationally (COSEWIC 2006). DFO, in collaboration with the Ontario and Québec Ministries of Natural Resources, prepared a draft American eel management plan for Canada to address fishing and turbine mortalities and habitat issues in late 2006. The agencies began public consultations on the potential federal listing and on the national management plan early in 2007 (DFO 2007). The listing and implementation of the management plan are unlikely to occur before 2008. American eel are also proposed for listing as endangered in Ontario, but listing awaits the passage of Ontario's Bill 184, a new Endangered Species Act for Ontario, which is currently before the legislature.

Harvest regulations for all life stages are promulgated by the individual states in the USA, as inland and coastal (up to 4.8 km offshore) fisheries management is more clearly a state responsibility than in Canada. The National Marine Fisheries Service assumes fisheries management responsibility from 4.8 to 322 km offshore (EEZ). As noted, the ASMFC is an inter-jurisdictional body that brings the states together on common fisheries management needs. In 2000, it developed an integrated Fishery Management Plan (FMP) for American eels (ASMFC 2000) which sought to promote a holistic management approach for the species along United States coastal waters from Maine to Florida, while recognizing the rights of individual states to manage their own waters. The FMP sets out an approach based on life stages of American eel and its goals are to:

- Protect and enhance the abundance of American eel in inland and territorial waters of the Atlantic states and jurisdictions, and contribute to the viability of the American eel spawning populations; and
- Provide for sustainable commercial, subsistence and recreational fisheries by preventing over-harvest of any eel life stage.

Much of the plan's effort focuses on sharing information that can be used to enhance management activities. For instance, the FMP directs the states to report estimates of commercial harvest by month and region as defined by each state. The FMP also directs states to estimate recreational harvest by season, and with the exception of Maine, South Carolina, and Florida, all Atlantic coast states have implemented a 6-in minimum size limit (ASMFC 2006b), and most states have implemented a possession limit of 50. In addition, most states have adopted varying combinations of commercial fishery controls, including season closures and gear restrictions. The ASMFC adopted an addendum to the FMP in February 2006 to improve the reporting of catch and effort data for the commercial fishery by recommending that the states institute trip-level reporting of landing and effort data, using standardized units of measure (ASMFC 2006b).

Federally, the Endangered Species Act, administered by the U.S. Fish and Wildlife Service (USFWS), also recently assessed the status of American eel in U.S. waters. In response to a petition launched in 2005, listing under the legislation was considered in 2006, but in their 12-month finding the USFWS determined that listing was not required (Federal Register 2007; see section entitled *Species at*

Risk Status). In addition, the Federal Energy Regulatory Commission has a lead role in licensing hydroelectric facilities, and provides for consideration for amelioration of environmental and fishery impacts. Currently there is no such formal process in Canada, though provisions of the Fisheries Act (Canada) can provide similar regulatory controls.

Recent management initiatives

Most of the science available (e.g., Cairns and Casselman 2004) suggests that there is a clear need for an immediate and significant reduction in anthropogenic mortality to prevent further declines and set the scene for recovery of American eel. Given aforementioned uncertainties and complexities associated with American eel management, appropriate implementation of the precautionary approach seems warranted.

Much work on improving and instituting more comprehensive American eel management approaches is now underway in Canada and the USA. In addition, both countries are working to address and correct potential "at-risk" status. Root causes of American eel decline need to be identified and strategies developed to facilitate the recovery of American eel in a more comprehensive and sustainable fashion. The work needs to ensure sustained and coordinated stock assessment and associated research, harvest monitoring and compliance, and state of resource reporting. It also needs to address research requirements to develop mitigation strategies for other significant sources of mortality that have been identified for American eel.

In Canada, the aforementioned recommendation of a 50% reduction in known anthropogenic sources of mortality by the CEWG resulted in the development of an initial plan and the implementation of a series of management actions to achieve this objective (Cairns and Casselman 2004). Ontario closed all fisheries for American eel throughout the province in 2004 in an attempt to protect the remaining eels within that jurisdiction (Mathers and Stewart, in press). Québec bought out (retired) a number of commercial fishing licenses in Lac St. Pierre and other parts of the St. Lawrence River between 2004 and 2006; the reduction in licenses is expected to reduce eel harvests in these waters. In 2005 and 2006, DFO introduced some effort control measures (size restrictions, shorter seasons) in the Atlantic Provinces to reduce fishing mortality in those waters. In all cases, agencies have encountered resistance for these and any future reductions given the lack of progress in mitigating the known turbine mortalities at the major hydro-electric facilities on the St. Lawrence River and elsewhere.

The Canadian Eel Steering Committee Relating to Passage and Associated Habitat Issues on the St. Lawrence River recently completed a decision analysis process aimed at identifying the best approach for facilitating downstream passage at the St. Lawrence River hydroelectric facilities (Greig et al. 2006). Approximately 40% of the highly fecund silver American eel are cumulatively killed in the turbines at these two facilities as they travel downstream during their spawning migration. The development of an action plan based on the results of the decision analysis is underway.

As a first step, Ontario Power Generation, in cooperation with the Ontario Ministry of Natural Resources and the Ontario Commercial Fish Association, funded the stocking of approximately 144,000 cultured advanced elvers (76 mm TL) in the upper St. Lawrence River in the fall of 2006. This experimental stocking is viewed as an initial means to increase abundance while methods are being developed to reduce anthropogenic mortality and improve survival during downstream passage at the Moses-Saunders and Beauharnois Generating Stations. Stocking American eel in the St. Lawrence–Lake Ontario system

is a first for these waters and, while it is anticipated that additional stocking efforts will take place in succeeding years, there is considerable uncertainty regarding the ultimate effectiveness of this project. A sound and sustained effectiveness monitoring program will be required to evaluate success and adapt the program as information comes forward. It will be at least a decade before adequate evaluation of the response can be completed, particularly in silver American eel abundance, and it will be extremely risky to focus only on stocking as "the" means to improving the status of American eel in these waters. Moreover, there is considerable uncertainty regarding the probability that these stocked eel will mature, survive the gauntlet of turbine and fisheries mortalities and find their way to the Sargasso Sea in sufficient numbers to spawn and have a positive impact on the reproductive output of the species. Other actions identified in the decision analysis have not yet been undertaken as negotiations to develop a final action plan continue.

There have been four recent developments on the inter-jurisdictional front. Firstly, the Atlantic Council of Fisheries and Aquaculture Ministers (ACFAM: comprised of Ministers from the Atlantic provinces, Québec, Nunavut Territory and the Government of Canada) agreed to have their agencies participate in and provide advice on the development of an integrated conservation plan for American eel with the Province of Ontario in March 2006 (P. C. Thompson, Fisheries and Oceans Canada, and R. B. MacGregor, Ontario Ministry of Natural Resources, personal communication). Secondly, the Great Lakes Fishery Commission (GLFC) formed a bi-national American eel Task Group in mid-2006 aimed at setting science priorities, coordinating funding strategies, and developing a recovery strategy for eels in the St. Lawrence River and Lake Ontario. The Task Group involves representatives of the USFWS, DFO, the provinces of Ontario and Québec, and New York State. This is a major step towards developing a bi-national approach to managing the American eel. In these two cases, the organizations moved to begin collaboration with a jurisdiction not formally part of their charters: Québec in the case of GLFC, and Ontario in the case of ACFAM. This shows that there are avenues to address, at least in the interim, the unique governance challenges posed by a species that straddles so many jurisdictions. Thirdly, the ASMFC reviewed its fishery management plan for American eel during 2006, finding that the current stock status remained poorly understood and that member states needed to develop data so as to report landings by life stage (ASMFC 2006a). The review also identified numerous research priorities, including increasing upstream and downstream passage of American eel, coast-wide sampling for yellow and silver eels, annual estimates of young-of-year abundance, and development of stock assessments that can lead to sustainable reference points that will inform what sustainable harvest levels of American eel will be (ASMFC 2006a). Finally, Canadian agencies under the leadership of the CEWG and CESWoG developed a draft management plan in November 2006 compliant with the Species at Risk Act in response to the 2004 inter-governmental decision (DFO 2004) to develop a management strategy (DFO 2007) and COSEWIC's 2006 recommendation to list American eel as a species of "special concern". The draft plan is undergoing stakeholder consultation in early 2007 for later revision and finalization; it will contribute to the Government of Canada's listing decision-making process with respect to the Species at Risk Act.

In the USA, the ASMFC continues attempts to assess and report on the state of American eel along the Atlantic Seaboard and has adopted and recently updated a coordinated eel management plan for the numerous jurisdictions within its mandate. However, the ASMFC's authority is limited to control-

ling commercial and recreational fishing activity; it has no direct authority over issues such as habitat loss and barriers to migration, mortalities due to turbines and other broader ecosystem issues.

The recent Federal Energy Regulatory Commission's re-licensing of the New York State portion of the international Moses-Saunders Generating Station on the St. Lawrence River led to the establishment of the Fish Enhancement, Mitigation and Research Fund by the New York Power Authority and overseen by the USFWS; a significant component of the fund's objectives is aimed at funding research projects addressing enhanced American eel escapement from Lake Ontario and the St. Lawrence River.

Species at Risk Status

As noted earlier, American eel have been recommended for national listing in Canada (special concern) and for provincial listing in Ontario (endangered); however, final decisions on official listing under the respective legislation are not expected until at least 2008.

In the meantime, the USFWS has determined that listing American eel as threatened or endangered is not warranted (Federal Register 2007). The finding was constrained by the need to demonstrate that American eel is in danger of extirpation within a significant component of its range, or likely to become an endangered species within the foreseeable future. Because of a lack of scientific information relating to population-level status of American eel and the best genetic information that the species is panmictic, the USFWS concluded that range-wide persistence of American eel was not in doubt. The finding appeared to rely heavily on information suggesting that some American eel complete their life cycle in marine environments and on two short-term data series relating to glass eel abundance. The finding placed less emphasis on longer-term data series that illustrated declining trends in abundance of yellow and silver American eel. Unlike the Species at Risk Act in Canada, the Endangered Species Act does not provide for designation and protection measure for species of special concern.

It is not within the scope of this paper to comment substantially on the official designation of American eel under species at risk legislation; however, we are compelled to comment that (1) numerous data series suggest American eel is in decline in significant components of its range, (2) substantial habitat has been lost, (3) numerous and significant sources of anthropogenic mortalities exist for American eel, and (4) American eel is semelparous with late onset of maturity, particularly for the northern, more fecund segment of the population. Numerous threats have been identified, and their cumulative effects were not addressed in detail within the 12-month finding, but they apparently have been substantial. The precipitous (99%) loss of recruitment to Lake Ontario and the Susquehana River, the major declines in silver American eel landings in Québec fisheries, the fact that yellow American eel are at or near historic lows within the ASMFC jurisdictions, and the 50% decline in the Chesapeake Bay VIMS index all point to significant cause for concern, regardless of designation as a species at risk. The lack of designation under the Endangered Species Act should not be perceived as a reason for inaction. Waiting to take appropriate action until a species is threatened with extinction is not in the best interests of agencies, ecosystems, or stakeholders. Strong, coordinated management actions are required to reverse the decline in American eel, actions that include habitat as well as fisheries management. Managers must also be mindful of the parallels between the experiences managing European eel and those of American eel. We certainly do not wish to be faced with the even more dire circumstances of European eel (ICES 2006; Dekker 2008, this volume).

Understanding the complexity of American eel management

Declines and governance problems associated with American eel are similar to those experienced with other anguillid eels (e.g., European eel, Dekker 2008, this volume), and there appear to be many parallels between the situation of European and American eels. Fisheries exist throughout the range and, most significantly, exploit virtually all life stages. Man-made barriers continue to inflict mortalities, restrict distribution, decrease abundance, and reduce productivity of American eel throughout Canada and the United States. It is clear that the existing governance approaches to manage American eel and prevent declines have not been sufficient and a more comprehensive approach is required.

Excluding the Gulf of Mexico states and those states in the Mississippi River drainage, 19 states, 6 provinces and two federal governments have some jurisdiction to manage the species. This is further complicated by the fact that issues relating to habitat, barriers and water quality that affect eels are often managed by environmental agencies not also responsible for fisheries management. In other parts of the eels' range, including the coastal areas of the Caribbean as well as the Mississippi River drainage and Gulf States, fisheries management activity is not actively directed towards American eel. The unique and complex migratory life cycle of the American eel makes research, stock assessment, management and conservation particularly difficult. The panmictic nature of the American eel and the numerous sources of mortality underscore the need for highly coordinated management and protective measures across many jurisdictions. To date this has not occurred, but efforts are now underway to move in this direction.

The large range of this species makes estimation of the population size extremely challenging using classical fisheries techniques. Calculation of the relative contribution to the spawning stock by various geographic areas would help to prioritize management activities. This has been attempted by Castonguay et al. (1994) and by COSEWIC (2006); however, the techniques available for this calculation are less than ideal and subject to debate. Ultimately, the political will to implement management actions is often lost without irrefutable information to prioritize management actions; this is contrary to the precautionary approach but is a reality in some jurisdictions.

Casselman (2003) has described the long history of use of American eel in North America, and many of these fisheries are deeply entrenched in the culture and socio-economic fabrics of many local communities. Moreover, it is important to remember the significant nutritional, material and spiritual importance of American eel to some First Nations communities. We have discussed the current governance institutions and some of the factors leading to the low priority that some management agencies have attached to eel management. These aspects have resulted in low government investment in, and lack of long-term commitments to, rigorous stock assessment, harvest monitoring, conservation and compliance, and state-of-resource reporting. This is particularly disconcerting as the species appears to be approaching collapse in significant portions of its range.

Not only do past and current eel management practices appear to diminish both the significant ecological services and contribution to biodiversity provided by this unique catadromous species, the legacy of management leaves governments and society with the high costs of trying to rebuild a depleted population. We have also noted that, like few other species, American eel, because of their panmictic and highly migratory nature, need coordinated assessment and reporting across their entire range. The circumstances of the American eel today in significant components

of its range exemplifies why fishery managers must re-evaluate the way priorities are set for future fisheries and habitat management. The intent here is not to lecture, as we fully understand the pressures, commitments and trade-offs that fisheries management agencies face; rather, we feel it is important to learn from the lesson of American eel management that there is the essential need to set fisheries management priorities in a more holistic, comprehensive manner, having regard for the broad ecological importance of species and intrinsic (nonmarket) socio-economic values attached to all species by society. It is an argument supporting a broader ecosystem approach to fisheries management.

The circumstance of American eel may be a classic example of two phenomena documented in fisheries literature: the "tragedy of the commons" (Hardin 1968) and the "invisible collapse" (Post et al. 2002). For the former, it is not only a race to fish among American eel harvesters. There is heightened tension among stakeholders (e.g., harvesters and hydroelectric utilities; McCleave 2001) when faced with having to "share the pain" for accepting financial losses that may be associated with efforts to reduce mortality. For example, discussions between hydroelectric and fishing stakeholders can focus on who's really most at fault, or who should make the first move to reduce mortality. Commercial harvesters are reluctant to reduce their harvests when hydroelectric facilities are known to kill substantial quantities of eels on the same system (McCleave 2001). Hydroelectric utilities can be reluctant to invest in mitigation strategies to improve American eel passage when they know that substantial commercial harvests occur on the same system. Discussions can become politicized in value debates between notions of clean, cheap energy sources versus the unquantified or perceived low value of commercial eel harvests. There can also be value-laden trade-off discussions among stakeholders and agencies debating the financial significance of potentially losing a species and the costs of replacing their ecological services, loss to biodiversity and nonmarket economic benefits they provide to society versus the mitigation costs, lost market opportunities, not to mention the costs of restoring a species to treat risk population levels.

The tragedy is also the inability of the numerous management agencies in the 25 jurisdictions to holistically manage the species. Agencies rarely can act independently without putting their stakeholders at financial risk or causing unwanted political fallout because the playing field will not be level. Conservation actions undertaken in any single jurisdiction can be compromised by the lack of similar measures elsewhere. For American eel, the situation is further complicated by the fact that jurisdictions occur in two countries with different legal, social, economic and cultural circumstances and traditions. In short, no one agency or jurisdiction can effectively manage American eel on its own.

With respect to the invisible collapse, American eel can be viewed as an excellent nonrecreational fisheries example of this phenomenon where Post et al. (2002) have shown that numerous sport fisheries have collapsed but remained largely invisible in scientific literature, public perception and management action. They propose four reasons for their invisibility, three of which apply to American eel and their status: 1) numerous small, diffuse fisheries across a wide geographic range, 2) difficult for management agencies or fishers to develop an accurate picture at scales longer and larger than their own experiences. For long-lived species, poor intergenerational memory leads to declining expectations and a shifting baseline, and 3) inadequate assessment necessary to characterize status of stocks and fisheries.

Until recently, American eel have not been assessed in detail over much of its range, particularly by fishery-independent means.

Efforts to summarize commercial harvests across the range have only recently been attempted, and these efforts have been plagued by inconsistent and varying levels of reporting, and largely lack effort data. In addition, eel fisheries tend to be numerous, but small and diffuse across a very broad geographic range; declines in any one discrete area would tend to impact a relatively small number of fishers and local economies and hence not receive much regional or national exposure. American eel is a long-lived species, and in the face of relatively short-term independent data series and poor intergenerational memory among eel fishers and biologists, declining expectations and a shifting baseline over time would not be surprising.

For example, few today would realize that eels in the St. Lawrence River and Lake Ontario were once so abundant in these waters that Jesuit missionaries reported as many as a thousand eels could be speared in one night by the Onondaga of the St. Lawrence Iroquois (Casselman 2003; Junker-Andersen 1988); this is an area where commercial fisheries are now closed and eels rarely seen. The Ottawa River (Ontario and Québec), a major tributary of the St. Lawrence River stretches a distance of 1,271 km from source to mouth and drains some 146,300 km^2. It is one of the largest single watersheds within the North American range of eels and once supported important commercial eel fisheries (Dymond 1939); based on archaeological evidence (Allen 2007) eels in this watershed were very important to Aboriginal people for centuries. Only through recent acquisition of some Traditional Ecological Knowledge and anecdotal information from some retired Conservation Officers has it been re-discovered that eels penetrated deep inland to numerous important lacustrine habitats within the upper reaches of the Ottawa River watershed, including Lake Temiskaming. However, in the face of major dam construction at the turn of the 20th century (Haxton and Chubbuck 2002) eels apparently had largely disappeared from much of the upper watershed and associated lakes by the 1930s, before adequate records were kept, and have declined to remnants of their former abundance in the lower reaches of the watershed. As few readily accessible records are available, new biologists are often surprised to learn that American eel even existed in the upper reaches and inland lakes associated with the upper Ottawa River watershed.

Given the diffuse nature of eel fisheries and large number of sources of anthropogenic mortality impacting American eel across its range, combined with the panmictic nature of eels, their broad geographic range and varying fecundity patterns, there should be little surprise that few would see or accept that population level declines were occurring before declines reached or approached at-risk status. This could largely be a function of the panmictic nature of eels. American eel recruitment to especially distant parts of its range appears to be in some manner related to overall density of elvers; it is believed that very large pulses of recruitment are required to drive recruits to the extremity of their range (Casselman 2003). While declines would be most precipitous first at the extremities of its range (e.g., Lake Ontario), declines in recruitment and abundance in areas nearer to the source of recruitment (e.g., Sargasso Sea) may appear to be less significant, or not appear at all for some time.

We have noted the number and magnitude of the various sources of anthropogenic mortality experienced by American eel (many of which remain relatively unchecked), and it is not unexpected to see the declines that are occurring. That it took so long for the declines to become apparent can be attributed to the lack of strong stock assessment data and low priority traditionally given to this species by fisheries management agencies. In addition, it may be a testament to the resilience of this species and cause for optimism that timely, coordinated, and intense efforts to rehabilitate it will be

successful. Indeed, as noted earlier, declines in some parts of the range are extreme and could affect overall fecundity and status for the entire species (Casselman 2003). Hence, future management of American eel needs to give due regard to the species in important productive segments of its range and, as American eel are panmictic, this may require conservation in other components of its range where declines may not be so precipitous.

One note for optimism is that there is an example of successful eel conservation from New Zealand (e.g., Boubee et al. 2000). Programs developed by the federally funded Foundation for Research Science and Technology were implemented to conserve yet utilize anguillid resources. The major New Zealand eel fisheries are under a quota management system, with individual transferable quotas set as a proportion of the annual total allowable commercial catch. The quota systems were implemented on South Island in October 2000 and North Island in 2004. The Maori are provided a customary take and granted commercial access rights as part of the quota management system. Annual stock assessment provides an update on stock status. The challenge appears to be trying to integrate other agencies and water resource users that affect eel stocks through habitat loss, drainage alterations, and hydroelectric impacts on eel passage. The program appears to be successful to date, as longer-lived longfin eels *Anguilla dieffenbachii* are in gradual decline but are not considered to be threatened with extinction and the shorter-lived shortfin eels *A. australis* have shown fluctuating but relatively stable harvest.

Recommendations for the Future

"Kat can be used to tell us about the health of both the oceanic and inland water systems. We should listen more to the animals…."
Prosper and Paulette, 2003

Recommendations

As American eel travel thousands of kilometers through freshwater, marine and brackish environments, face a gauntlet of anthropogenic threats and cross numerous jurisdictions, the species may well be viewed as the ultimate integrator, bringing together numerous jurisdictions, scientists, Aboriginal people and a diversity of interests across a wide geographic range. Some, including Aboriginal people, view American eel not only as an important commodity, but as a bellwether species sending an integrated message about the state of the environment (Hoag 2007; Prosper and Paulette 2003). Future development of management and governance structures for American eel will need to be mindful of this and develop a more holistic approach to eel management that includes not only traditional fisheries management, but also incorporates marine and freshwater habitat, Traditional Ecological Knowledge and participation from Indigenous people, and stakeholder participation.

Management actions aimed at protecting American eel and European eel have largely been unsuccessful in halting declines and rebuilding stocks as, until recently, actions have not been well coordinated at the appropriate scale in recognition of the unique life cycle of these species. In addition, it is important that strict compliance be achieved for those actions that have been implemented. While recent progress is being made in developing more comprehensive approaches to the sustainable management of American eel, this discussion highlights the need for a more highly coordinated inter-jurisdictional and bi-national approach to American eel management, assessment, research and conservation efforts, and one that incorporates participation and knowledge of Indigenous people.

We advocate the establishment of a bi-national American eel governance structure that would undertake to halt further declines,

bring together and coordinate existing jurisdictional and national efforts, and set forth a comprehensive recovery plan. Internationally, fisheries bodies have been developed to assist management of similar straddling stock issues for other species (e.g., North Atlantic Salmon Conservation Organization). Clearly, such a coordinating structure for American eel would need to be "bare bones" given the financial challenges facing our fisheries management agencies, the potential short time frame available given the continuing decline of American eel and the typical timeframe international negotiations can take. The ultimate goal of this body would be to set common principles and management objectives, and coordinate fisheries, habitat and mitigation research across the species' range in North America, aimed at reducing mortality, increasing silver eel escapement, and ultimately developing a bi-national American eel management and recovery plan for the species. The plan would need to be comprehensive, set strategic priorities, and include fisheries, habitat and other broader ecosystem approaches. Finally, the plan would need to establish recovery targets and include a significant effort to establish long-term commitments to assessment and state-of-resource reporting across jurisdictions to track success and provide for adaptive management.

Specific consideration of the important role of stakeholders, First Nations and Tribes during the development and implementation of management plans will be needed to ensure transparency and the ultimate success of any management plan that is developed. This will be crucial for individual agencies and jurisdictions. Agencies will retain local or regional regulatory jurisdiction, and will need the support provided by inclusive and transparent processes to deal with local and regional issues (e.g., concerns relating to economic impacts on harvesters or utilities).

While there are clearly numerous institutional constraints to effective fisheries management (Thompson 1974), and there may be some unique issues relating to American eel biology and inter-jurisdictional management, several authors have recently provided sufficient guidance to assist in the development of a North American governance structure; guidance that encourages effective planning and precautionary approaches while advancing a more holistic ecosystem approach to American eel management on an international and inter-jurisdictional scale (e.g., Witherell et al. 2000; Sissenwine and Mace 2003; FAO 2003; European Commission 2004; ICES 2004).

In addition, serious consideration should also be given to seeking the approval of the two federal governments to petition to list the American eel under Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Such a listing could improve the domestic reporting of American eel harvests through the tracking and control of American eel exports, especially of glass eels and elvers, in what is believed to be a largely undocumented international trade for these life stages. Listing would trigger monitoring and inspection at ports of departure and entry using a permit system and greater compliance and monitoring effort would be required. A valid Appendix III permit indicates that harvest occurred legally in accordance with the permit issuing authority.

In the near term, as these longer term processes evolve, we recommend that a precautionary approach to American eel management be adopted one that recognizes the panmictic nature of American eel and encourages all groups to think globally while acting locally to protect this resource. In addition, any new approaches to American eel management will need to adopt a broader ecosystem approach that considers threats at all life stages of American eel and include marine, estuarine and freshwater habitat protection/enhancement. We recommend that the following actions be taken at various life

stages and at every opportunity while new more holistic governance structures evolve; the intent is to take actions that will contribute to positive population-level response in American eel:

Policy

• Use the precautionary approach and rationalize glass eel and elver harvests to ensure adequate recruitment and ensure that surplus is available for conservation stocking.

• Immediately develop and implement appropriate regulations and policies enabling reductions in turbine mortalities of silver eel and improvements in eel passage at major barriers. These will be required both for new and existing facilities and will benefit many fish species.

• Develop eel harvest policies in both freshwater and estuarine waters that will contribute to improved escapement, particularly for silver eel

• Ensure accurate reporting of commercial eel harvest and effort at all harvested life stages.

• Deploy resources to ensure strict compliance to regulations and policies and minimize poaching.

• Develop an approach to incorporate indigenous traditional knowledge and participation in the development of eel management plans.

Regional Scale

• Identify key watersheds in each region where significant improvements in eel production and escapement would be achieved (for example identify watersheds where access by elvers and yellow eels to productive lacustrine habitats would be enhanced; identify important sources of mortality that will need to be addressed).

Watershed Scale

For key watersheds and habitats, develop management plans for American eel that will ensure:

• Significant improvements in silver eel escapement.

• Significant reductions in fishing and turbine mortality, particularly for silver eels.

• Significant improvements in access for elver and yellow eel to important eel habitat.

Science

• Immediately establish a bi-national science working group to coordinate data management and analyses aimed at developing population level annual status reports for American eel. This group would identify data gaps; develop a sound long-term bi-national assessment program enabling regular sound recruitment and stock status analyses at the population level.

• Incorporate Traditional Ecological Knowledge to reconstruct former eel abundance and distribution.

Summary and conclusions

In conclusion, key messages advanced in this paper include the following:

1. American eel were once incredibly abundant throughout their range, including the Great Lakes and upper St. Lawrence River.

2. The panmictic nature of the species and its complex, catadromous life cycle makes it unique in its needs for survival throughout its various life stages and the geographic habitats which it requires.

3. Serious negative impacts on American eel abundance include human-induced mortality from such factors as turbine mortality, exclusion from critical habitats by obstruc-

tions such as dams, and harvest at virtually every stage of its life cycle.

4. The relatively low priority accorded American eel by fisheries management agencies historically has resulted in much less information being available about this species than for the many other fish species managed for the public benefit.

5. Management actions largely have been unsuccessful as they have been implemented on regional scales without recognition of the implications of the panmictic nature of this species. To date agencies have not effectively addressed the broad scale of action required to manage American eel on a sustainable basis.

6. Despite this, American eel has supported viable commercial fisheries for many years and related socio-economic benefits have largely been lost in some formerly important areas and have been significantly reduced in others.

7. Catastrophic declines in American eel abundance in formerly important portions of their range have resulted in corresponding declines in the ecological role traditionally played by this top predator in contributing to aquatic ecosystem stability.

8. An effective bi-national management plan is required in order to stabilize declines in American eel abundance and to rebuild it to levels that can sustain former levels of ecological and socio-economic benefits.

9. Effective management of this species and the benefits it can produce also requires establishment of an effective and efficient international, inter-jurisdictional organization created and supported by all jurisdictions with responsibilities for management of American eel.

10. An effective bi-national management plan and the corresponding inter-jurisdictional organization to coordinate management of this species needs to be adopted and implemented at the very earliest opportunity as time continues to work against the sustainability of American eel as a species, in the absence of such tools.

11. Considerable Aboriginal interest and traditional knowledge exists regarding American eel; it will be essential to work closely with Aboriginal people and incorporate their participation and knowledge into future management plans for American eel

Acknowledgments

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