

Fishery Management Report No. 36
of the
Atlantic States Marine Fisheries Commission



Interstate Fishery Management Plan for American Eel

April 2000

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Prepared by the
American Eel Plan Development Team

And

Approved by the
Atlantic States Marine Fisheries Commission
November 1999

This document was prepared in cooperation with the Atlantic States Marine Fisheries Commission's American Eel Management Board, American Eel Technical Committee, American Eel Plan Development Team, and the American Eel Advisory Panel.

A report of the Atlantic States Marine Fisheries Commission pursuant to U.S. Department of Commerce, National Oceanic and Atmospheric Administration Award Nos. NA97 FGO 0034 and NA07 FGO 024 .



ACKNOWLEDGMENTS

The Atlantic States Marine Fisheries Commission developed this Interstate Fishery Management Plan for American Eel. The Plan Development Team (Team), chaired by Heather M. Stirratt, Fishery Management Plan Coordinator, ASMFC, and previously John Field, consisted of (in alphabetical order): Mr. W.-Dieter N. Busch, U.S. Fish and Wildlife Service; Mr. Lewis Flagg, Maine Department of Marine Resources; Mr. Daniel M. Kuzmeskus, U.S. Fish and Wildlife Service; Mr. John McClain, New Jersey Division of Fish, Game & Wildlife; Mr. Stewart Michels, Delaware Division of Fish and Wildlife; Mr. Charles Moore, South Carolina Department of Natural Resources; Ms. Julie Weeder, Maryland Department of Natural Resources; and Mr. John Whitehead, East Carolina University. The Team worked under the guidance of the American Eel Management Board Chaired by Dr. Lance Stewart, Governors Appointee, Connecticut, the Advisory Panel, and the Technical Committee and thanks these groups for the valuable guidance that they provided.

The Team also acknowledges the efforts of the many people who worked to create this Fishery Management Plan (FMP). The team acknowledges access to and extensive use of specific reports of value in preparing this FMP and thanks their authors. These reports included: *Maine's American Eel Species Management Plan* prepared by The Joint Committee on American Eel Management for Maine (1996); *American Eel (Anguilla rostrata) Scoping Study Report* by W.A. Richkus and K.G. Whalen, Versar, Inc. (Final Report, March 1999); *An overview of European and American eel stocks, fisheries and management issues*, by Brian M. Jessop (1997); *Distribution and Availability of Atlantic Coast Freshwater Habitats for American Eel (Anguilla rostrata)* by Busch et al. (1998); *American Eel (Anguilla rostrata) In Lake Ontario and its Tributaries: Distribution, Abundance, Essential Habitat and Restoration Requirements* by S.J. Lary and W.-D.N. Busch (1997); and *Management of the European Eel* edited by C. Moriarty and W. Dekker (1997).

The efforts of all who reviewed and edited plan drafts are appreciated. Some of those providing specific information or extensive editorial support included (in alphabetical order): Tim Brush, NHP Rep.; Alex Haro, USGS-MA; Tim Hobbs, ASMFC-intern; Brian Jessop, DFO-Canada; Capt. Lawrence Kelly, NY; Fred Kircheis, ME; Drew Kolek, MA; Sandra Lary, ME; Richard Snyder, PA; Julie Weeder, MD; John Whitehead, ECU-NC; Gail Wippelhauser, ME.

INTERSTATE FISHERY MANAGEMENT PLAN FOR AMERICAN EEL

EXECUTIVE SUMMARY

American eel (*Anguilla rostrata*) occupy a significant and unique niche in the Atlantic coastal reaches and its tributaries. Historically, American eel were very abundant in the East Coast streams, comprising more than 25 percent of the total fish biomass (Smith and Saunders 1955; Ogden 1970). The abundance of this species declined from the historic levels but remained relatively stable until the 1970s. More recently, fishermen, resource managers, and scientists postulated a further decline in abundance from harvest and limited assessment data. This resulted in the establishment of working groups by the Atlantic States Marine Fisheries Commission (ASMFC) to develop a Fishery Management Plan (FMP) for the American eel in order to protect and restore the species. This FMP is a working document that describes the goals and objectives for the species, its current status, ecological challenges affecting the species, and management options and actions needed to reach and maintain the goals. The Plan also identifies issues that need additional research support. A summary of life history, recent abundance indices, and habitat issues is included in the FMP.

GOAL

The goal of this FMP is to conserve and protect the American eel resource to ensure its continued role in the ecosystems while providing the opportunity for its commercial, recreational, scientific, and educational use. Specifically, the goal aims to:

1. 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 population; and
2. Provide for sustainable commercial, subsistence, and recreational fisheries by preventing overharvest of any eel life stage.

Primary Objectives

- Improve knowledge of eel utilization at all life stages through mandatory reporting of harvest and effort by commercial fishers and dealers, and enhanced recreational fisheries monitoring.
- Increase understanding of factors affecting eel population dynamics and life history through increased research and monitoring.
- Protect and enhance American eel abundance in all watersheds where eel now occur.
- Where practical, restore American eel to those waters where they had historical abundance but may now be absent by providing access to inland waters for glass eel, elvers, and yellow eel and adequate escapement to the ocean for pre-spawning adult eel.
- Investigate the abundance level of eel at the various life stages, necessary to provide adequate forage for natural predators and support ecosystem health and food chain structure.

The American eel occupies and is exploited in fresh, brackish and coastal waters along the Atlantic from the southern tip of Greenland to northeastern South America. The species has a catadromous life cycle, reproducing only in the Sargasso Sea and spending the majority of its life in freshwater. After hatching and ocean drift, initially in the pre-larval stage and then in the leptocephalus phase, metamorphosis occurs. In most areas, glass eel enter the nearshore area, although there have been reports of leptocephalus found in freshwater in Florida (J. Crumpton, Florida Game and Freshwater Fish Commission, Eustis, pers. com.). Glass eel, elvers, yellow and silver eel are found in the marine environment during part of their life cycle. Elvers, yellow and silver eel also make extensive use of freshwater systems. Therefore, a comprehensive eel management plan and comprehensive set of regulations must consider the various unique life stages and the diverse habitats used, in addition to society's interest and use of this resource.

Harvest pressure and habitat losses are listed as the primary causes of any possible historic and recent decline in abundance (Castonguay et al. 1994a and 1994b). Several factors contribute to the risk that heavy harvest may adversely affect American eel populations: (1) American eel mature slowly, requiring 7 to 30+ years to attain sexual maturity; (2) glass eel aggregate seasonally to migrate; (3) yellow eel harvest is a cumulative stress, over multiple years, on the same year class; and (4) all eel mortality is pre-spawning mortality. Habitat losses have been a chronic problem since the arrival of Europeans. Blockage of stream access, pollution, and nearshore habitat destruction limit habitat availability for eel. Castonguay et al. (1994b) indicated that oceanic changes may now also contribute to decline in eel abundance. Busch et al. (1998) estimated that diadromous fish, dependent on access to Atlantic coastal watersheds, may be hindered from reaching up to 84% of upstream habitats.

Planning and regulatory activities require information, specifically, the abundance and status of the species and its habitat. Management is made difficult by the paucity of long-term data sets describing eel abundance at any life stage. Although eel have been continuously harvested, consistent data on harvest are often not available and when available, are not good indicators of abundance because harvest is dependent on demand for eel. Where available, most of the data are of short duration and data collections were not standardized between management agencies. Few other long-term data sets are available from fish ladders, impingement sampling, research collections, and monitoring programs. In addition, changes in year-class strength are not readily recognizable because most samples of fish include fish of similar sizes but from an unknown number of year classes.

A compilation of all available information on eel fisheries and biology suggests that the data are fragmented and/or incomplete. Therefore, the FMP identifies standardized commercial and recreational regulation and surveys and monitoring programs by each state. If harvest rates are determined to have a substantial, negative impact on the American eel population, harvest restrictions will be recommended.

Each state is responsible for implementing management measures and the identification and protection of habitat within its jurisdiction to ensure the sustainability of the American eel population that resides within state boundaries. Since the American eel is one panmictic population, significant management action will have range-wide implications. The FMP suggests new funding and improved coordination, in order to effectively standardize regulations, collection of abundance data at various life stages, and evaluation of habitat and restoration.

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DEFINITIONS

LIST OF ACRONYMS AND ABBREVIATIONS

ASMFC.....	Atlantic States Marine Fisheries Commission
Board	American Eel Management Board
GLFC.....	Great Lakes Fishery Commission
FDA.....	U.S. Food and Drug Administration
NMFS.....	National Marine Fisheries Service
OMNR.....	Ontario Ministry of Natural Resources
Plan.....	American Eel Fishery Management Plan
SAC.....	American Eel Stock Assessment Committee
Technical Committee	American Eel Technical Committee
USFWS	U.S. Fish and Wildlife Service
MRFSS.....	Marine Recreational Fishery Statistics Survey

AMERICAN EEL LIFE STAGES

Pre-leptocephalus	Short-lived larval stage from hatching to the free-swimming leptocephalus stage.
Leptocephalus	A long-lived larval stage which is flattened from side to side and shaped somewhat like a willow leaf. This stage drifts and swims in the upper 300 m (1,000 ft.) of the ocean for several months, growing slowly to a length of 5-6.4 cm (2-2.5 in.).
YOY or Young of Year	Young-of-the-year fish less than or equal to 8.5 cm in length, representing a single year class
Glass eel	For the purposes of this Fishery Management Plan, glass eel are metamorphosed leptocephali that are miniature, transparent eel that range in size from 5-10 cm (2-4 in.). Metamorphosis occurs at sea, perhaps near the edge of the continental shelf. Glass eel enter estuaries and ascend rivers during winter and spring, earlier in the southern portion of the range, later in the northern portion. Glass eel ascend estuaries by drifting on flooding tides and holding position near bottom on ebb tides and also by active swimming along shore in the estuaries and above tidal influence.
Elvers	For the purposes of the Fishery Management Plan, “elver” refers to the stage after glass eel. Elvers are pigmented juvenile eel, typically less than 10 cm (4 in.) in length. This life stage may encompass several age classes.

Yellow eel Immature eel that are dark on the back and often yellowish on the ventral surface and are of variable size that varies by latitude and/or salinity, and also by sex when that is established. They have typically spent more than one year in a stream or estuary and are greater in length than 10 cm (4 in.).

Silver or migratory eel Following a variable period of growth as a yellow eel, which may increase with latitude, another metamorphosis occurs to form the silver eel or migratory stage. Metamorphosis may include ventral color change to silver, increase in eye diameter, non-feeding behavior and usually a thickening of skin, although this stage can be highly variable. These mature eel move downstream and seaward to spawn in the Sargasso Sea that next winter or early spring (assumed but not documented).

OTHER DEFINITIONS

Catadromous Spawning and larval development and migration occurring in the open ocean, feeding and growth occurring in estuaries and fresh waters, and adults returning to the ocean.

Dip net An active capture gear consisting of a rigid frame filled with netting, firmly attached to a rigid handle and manually operated by a single person.

EEZ Exclusive Economic Zone for the U.S. coastal ocean, extending from 3 to 200 nautical miles offshore

Escape panel or Excluder Area of mesh in capture gear that allows pre-determined smaller sizes to escape or that prevents larger sizes from entering.

Fyke Net (elver or glass) A funnel-shaped net designed to intercept moving marine organisms and retain them in a confined space. The net is of various length from cod end to wing tips and is fitted with various size netting. For glass eel the net measures 0.3 cm (1/8 in.) mesh square measure or less.

Hoop Net A stationary cylindrical net fitted with mesh that is placed at the bottom of a body of water. The gear includes wings or leads attached to the mouth of the net.

Panmictic Single breeding population exhibiting random mating. Offspring from any parents capable of inhabiting any suitable habitat in any portion of the range.

Pot A cylindrical or rectangular trap with funnels that is baited. The gear is typically made of mesh.

Sheldon Eel Trap A box trap with netted wings used to intercept and capture glass eel or elvers.

Spear	The historically most widely known and used method for capturing eel during the early eel fisheries, often consisting of a spatula-shaped center piece with three teeth on each side, each tooth having a single barb. A 3-9 m (10-30 ft.) long wooden pole is attached to this instrument for probing the soft muddy bottom through a hole in the ice or from a boat.
Trap	Passive gear similar to but smaller than weirs. May have one or two wings facing upstream to take descending silver eel. Wings, if present, do not block entire stream and unit is considered portable.
Weir	A trapping device consisting of two wings extending from opposite shores of the stream running obliquely downstream and converging to form a funnel, to which is attached a box trap. As silver eel descend streams, the wings guide them into the box trap. This passive capture gear is semi-permanent, constructed of wood or other solid material, and usually blocks most or the entire channel.

FOREWORD

Charge to Develop a Fishery Management Plan

The Atlantic States Marine Fisheries Commission (ASMFC), at its October 1995 Annual Meeting, voted to initiate the development and implementation of a Interstate Fishery Management Plan (FMP) for American Eel. Due to commercial harvest association with horseshoe crabs, the initial charge was for a joint plan. However, this charge was modified more recently based on biological and ecological differences between the species so that the management of these two species will be addressed in separate plans. The Atlantic coastal states concluded that a coordinated, interstate plan would best address conservation and fishery issues for the American eel. ASMFC is a compact of the fifteen Atlantic Coast states, created to promote the better utilization of the fisheries (marine, shell and anadromous) along the Atlantic seaboard by the development of a joint program for the promotion and protection of such fisheries.

Development of a Public Information Document

A Public Information Document (PID) was prepared to obtain input from the public and interested commercial and recreational users on alternatives and recommendations for state management programs in the development of the American Eel Fishery Management Plan (FMP). The PID briefly discussed the American eel life history and the problems associated with the species' management, status of stocks, current ocean and riverine fisheries, and monitoring and information needs. Public hearings on the PID were held during the spring of 1997.

Purpose of this Fishery Management Plan

The American Eel Fishery Management Plan is a working document that describes the goals and objectives for the species, its current status, recent and historical trends, the ecological challenges affecting the species, management options and actions needed to reach and maintain the goals, and issues that need additional research support. A summary of life history information, recent abundance indices, and habitat issues is included. Species management plans need to be dynamic and are designed to be updated as new data are obtained. This Fishery Management Plan will undergo periodic review to ensure that it reflects any changes in species status, the latest in research and resulting changes in Goals, Objectives and Strategies based on these findings, and changes in human attitudes and needs.

Upon completion and approval of the FMP, ASMFC states are obliged to implement its requirements. In the event that a state does not completely implement an ASMFC fishery management plan, the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) provides that the U.S. Secretary of Commerce may impose a moratorium in that state's particular fishery. All ASMFC fishery management plans must include specific measurable standards to improve the status of the stocks and determine compliance with the standards.

A species plan aids in directing management and research efforts. It focuses attention on areas of management strength as well as those that need more development. It provides information to the public on the current knowledge concerning the species, including descriptions of ecological stresses that may limit the abundance and distribution of the species. Overall, a species

management plan provides for the regulation of human activities that impact a species so that the population remains sustainable and viable. At the same time, it should allow for recreational and commercial harvest while also supporting the natural diversity of the ecological system(s) it inhabits.

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

1.1.1 Statement of the Problem

American eel has a catadromous life cycle, reproducing in the ocean and spending the majority of its life in brackish or freshwater. Any management program must, therefore, involve both marine and inland stakeholders in the management process. Spawning occurs in the Sargasso Sea, producing the larval stage (pre-leptocephalus and leptocephalus) which drifts and swims towards the continental shelf and subsequently metamorphoses into glass eel. Glass eel, elvers, yellow eel, and silver eel are found in the marine environment during part of their life cycle. Elvers, yellow eel, silver eel, and possibly glass eel also make extensive use of freshwater systems. Therefore, a comprehensive eel management plan and comprehensive set of regulations must consider the various unique life stages and the diverse habitats used, in addition to society's interest in and use of this resource.

There is both substantive data and anecdotal information that suggest segments of the American eel population have declined in recent years. The cumulative effects of multiple life stage harvest impact the American eel population. Several factors contribute to the risk that heavy harvest may adversely affect American eel populations: (1) American eel mature slowly, requiring 7 to 30+ years to attain sexual maturity (K. Oliveira, Univ. of Maine pers. comm); (2) glass eel aggregate seasonally to migrate (Haro and Krueger 1988); (3) yellow eel harvest is a cumulative stress, over multiple years, on the same year class (Richkus and Whalen 1999); (4) all eel mortality is pre-spawning mortality (McCleave 1996); (5) changes in year-class abundance are not readily recognizable because harvest abundance data include fish of similar sizes but from a number of year classes (Ritter et. al. 1997). Other factors that may contribute to a possible population decline are structures impeding upstream and downstream passage, increased predation, habitat degradation, poor water quality, and variable oceanic conditions.

American eel have been and continue to be an important resource for biodiversity and human use. The eel and elver fishery in the United States has had a long history (Crawford 1996). The eel has a wide distribution and commercial value throughout its range. The American eel is also a species whose total range includes most of the east coasts of North America, Central America, and northern South America. Significant management action, therefore, has range-wide implications. In addition, the American eel is very important to many Native American tribes, not only as a subsistence food resource, but also for its cultural and spiritual values. The Atlantic States Marine Fisheries Commission's (ASMFC) American Eel Fishery Management Plan for the Atlantic Coast of the US is intended to aid in restoring a healthy and viable American eel population while providing surplus resources for a sustainable eel fishing industry.

1.1.2 Benefits of Implementation

Members of the public have expressed concern over the proper management of American eel to ensure ecological stability. An unregulated American eel fishery and loss of habitats may result in a population collapse with resulting losses to society and to other fish and wildlife resources. Progressive coast-wide management of the American eel population would ensure the long-term viability of the population for continued harvest and would provide necessary quantities of juveniles and adults for use by other fish and wildlife resources. Conservation of the species will provide for biodiversity in natural and existing community food webs (predator-prey interactions).

1.1.2.1 Biological and Environmental

A certain amount of American eel juvenile and adult biomass must be maintained to meet the needs of those species for which eel is an important food source. Despite the range of habitats occupied by the American eel, the importance of eel as prey for other fishes, aquatic mammals, and fish-eating birds has not been well documented. However, American eel juveniles and adults are a seasonal food item of various finfish and data are available that eel are preyed on by fish-eating birds and mammals such as mink (Sinha and Jones 1967; Seymour 1974). The degree of dependence upon the various life stages of American eel by these species is unknown.

1.1.2.2 Socioeconomic

The American eel population has long been important to recreational and commercial fisheries. The fisheries are seasonal, but economically important, providing direct and indirect employment such as gear manufacturing, food processing, and shipping. Landings for American eel fluctuate widely. Much of the commercial fishery is undocumented, but may be of significant economic value (Figure 1). Although relatively few people are engaged full-time in eel fishing, part-time and casual fishermen gain an essential supplementary income. In addition, many coastal multi-species fisheries could not be sustained in the absence of eel (F. Perry 1993/pers. comm.; ASMFC Pub. Hear. Dover, DE 1997).

The significance of American eel to Native American tribes' subsistence and culture is also well established. Tribal communities have documented use of American eel in addition to other fish and game for subsistence. In some cases, seasonal tribal eel harvests have historically provided food fish for up to a year (Speck 1940). In addition, the American eel represents cultural and spiritual values to many Native American tribes by contributing to their sustenance, a focal point of Native American philosophy and lifestyle that goes well beyond the mere value of a resource as food. For example, the passing down from generation to generation of skilled knowledge on basket trap and weir designs and use is a cultural value related to the American eel resource, thus contributing to Native American sustenance (Speck 1940).

Price Per Pound for American Eel (in 1998 dollars) vs. Eel Landings Data

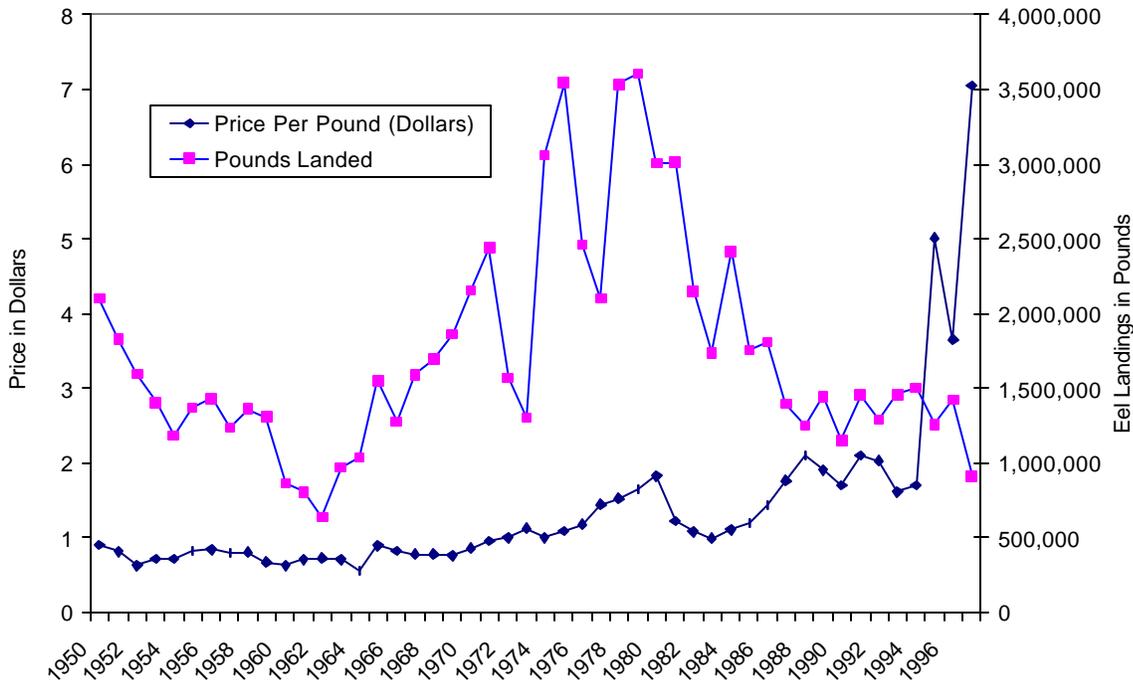


Figure 1. Price per pound for American Eel and the number of American eel pounds landed from 1950 to 1998 (NMFS, Fishery Statistics and Economics Division, 11-15-99, pers. comm.). Note that the last three years reflect the inclusion of reported glass eel landings and associated dollar values.

1.2 Description of the Resource

1.2.1 Species Life History

American eel are a unique and versatile fish species, which are highly migratory with multiple habitat requirements and feeding habits. Eel utilize a large geographic range from the entire east coast of the North and South American continents, into inland areas of the Mississippi and the Great Lakes drainages, and north into Canadian province tributaries. The species is supported throughout its range by a single source, as one spawning population in the Sargasso Sea provides all juvenile eel to be dispersed throughout its entire range each year (Figure 2). Eel have multiple habitat requirements, utilizing open oceans, large coastal tributaries, small freshwater streams, lakes and ponds. They are opportunistic feeders, requiring and utilizing multiple levels of the food chain including phytoplankton, insects, crustaceans, a multitude of fish species, and even larger prey. Individuals live for many years in freshwater and estuarine environments, before returning to the ocean as adults to reproduce once and die.

Despite the fact that in many respects American eel are an adaptable species, a multitude of known pressures on all life stages have a cumulative deleterious effect on the species as a whole. Specifically, the glass, elver, yellow and silver eel life stages are harvested commercially, which reduces their abundance at multiple life stages. This includes the adult reproductive stage since all eel mortality is pre-spawning mortality. The geographic range and habitat availability of American eel has been reduced by obstructions in migratory routes. Freshwater habitat degradation and consequential reduced food productivity levels negatively impact the freshwater life stages. It is possible that contaminants are having a negative impact on the reproductive success of American eel that grew to adulthood in contaminated habitat areas, since eel are known to have a high contaminant bioaccumulation rate (Richkus and Whalen 1999). Oceanographic changes influencing larval drift and migration could impact the overall year-class success (McCleve 1998; Castonguay 1994b), and the fact that the species consists of a single spawning population could make it particularly vulnerable to drastic oceanic variations.

It is, therefore, critical to understand the intricacies of the distinctly different life stages of the American eel. Despite this need, there is little information on any given life stage since there are few species to which the American eel life cycle could be compared, and all of the life stages are distinctly different from each other, with their own difficulties in researching. Specifically, little is known of what occurs in the last phase of the silver eel (mature) life stage; from the time the adult emigrates from freshwater, spawns and dies. The location of the spawning grounds in the Sargasso Sea has been generally identified by the appearance of larvae (leptocephali) in the plankton, but the exact location is unknown. There is also little information on the oceanic egg, leptocephali, and glass eel life stages prior to their arrival in coastal areas.

1.2.2 The Life Cycle

American eel are a catadromous fish species, spending most of their life in freshwater or estuarine environments and migrating back to the ocean to reproduce. The life cycle begins when the eggs hatch and leptocephali are carried by the Gulf Stream from the spawning grounds in the Sargasso Sea, a large portion of the western Atlantic Ocean east of the Bahamas and south of Bermuda. They are consequently dispersed by the prevailing currents along coastal areas, and the glass eel and elvers enter freshwater tributaries. Some elvers travel upstream to spend the majority of their life growing as yellow eel in rivers, streams, ponds and lakes. Mature adults migrate back downstream to return to the Sargasso Sea, where they reproduce in winter and early spring, and then die (Eales 1968; Jessop 1984).

Genetic evidence shows this species to be a panmictic population (Williams 1984) and recruitment levels throughout its range relate to the total number of eel combined from the entire range that survive to successfully reproduce. Potential changes in oceanographic conditions may have an impact on juvenile recruitment to coastal tributaries (Castonguay 1994a&b). American eel in the northern portion of their range mature at greater ages and sizes than in the southern portion, resulting in northern females being the most fecund and having a relatively long life span (Helfman 1987). More recent studies have indicated that the determination of sex may be density dependent (K. Oliviera, U. of Maine pers. comm.).

A potential threat to the overall health of the population is the non-indigenous eel swimbladder nematode (*Anguillicola crassus*). It is a parasite native to marine and freshwater areas of eastern Asia, from Japan and China to Vietnam. Its native host is the Japanese eel (*Anguilla japonica*).

The nematode has been documented to have significant negative impacts on the European eel (*Anguilla anguilla*), and on American eel in Texas and South Carolina.

1.2.3 The Life Stages

1.2.3.1 Egg

American eel spawn in the winter and early spring in the Sargasso Sea, a large portion of the western Atlantic Ocean east of the Bahamas and south of Bermuda and the eggs likely hatch in the same vicinity. Egg diameter is about 1.1 mm, however there is no information on the required environmental conditions or incubation period for the eggs. Artificially spawned Japanese eel (*Anguilla japonica*) eggs were hatched in 38-45 hours at 23 °C (Facey and Van Den Avyle 1987). American eel fecundity has been reported as a length - weight relationship that can range between 0.5 and 4.0 million eggs per female; large females (1000 mm in length), potentially produce as many as 8.5 million eggs (Facey and Van Den Avyle 1987). The relationship between eel size and fecundity can also be expressed as: $\log F = -4.29514 + 3.74418 \log TL$, $\log F = 3.2290 + 1.1157 \log W$, where F = number of eggs per female, TL = total length (mm), and W = total weight (g) (Wenner and Musick 1974). A fecundity of 0.4-2.6 million eggs was reported in females from Chesapeake Bay ranging from 50-72 cm in length (Wenner and Musick 1974). In the only other study of American Eel fecundity, 63 female eels in Maine were reported to have a fecundity of 1.4 – 21.9 million eggs for eels ranging from 45-113 cm in length (McCleve and Oliveira 1998). It is assumed that the spawning and nursery habitat that is found in the Sargasso Sea is an essential component in the hatching success.

American eel are benthic, long-lived and lipid rich. Therefore, American eel can accumulate high concentrations of contaminants, potentially causing an increased incidence of disease and reproductive impairment as is found in other fish species (Couillard et. al. 1997). An analysis of the contaminants in migrating silver eel in the St. Lawrence River showed that the highest concentrations of chemicals were found in the gonads. Concentrations of PCB and DDT were found to be 17% and 28% higher in the gonads than in the carcasses. The chemical levels in the eggs could exceed the thresholds of toxicity for larvae. Also, since the migrating females are not feeding, the chemical levels in the eggs could be even higher at hatching, increasing the likelihood of toxicity to the larvae (Hodson et.al. 1994).

Pressures/Impacts

- Contaminants may be having a negative impact on the reproductive success of American eel that grew to adulthood in contaminated habitat areas.
- Spawning habitat degradation caused by the harvest of seaweed/algae (*Sargassum sp.*) in the Sargasso Sea, the only known spawning grounds of American eel.

1.2.3.2 Leptocephalus

After hatching and a brief pre-larval stage, the American eel enter a larval leptocephalus stage. The larvae are shaped like a willow leaf, flattened from side to side. Leptocephali drift and swim in the upper 300 m of the water column for several months, growing slowly to a length of 5-6 cm (Kleckner and McCleave 1985). The spatial and temporal distribution of larvae is a result of oceanic circulation patterns and the swimming behavior of the larvae (Figure 2). At sea, perhaps

at the edge of the continental shelf, the shape of the larvae dramatically metamorphoses into miniature transparent eel, termed glass eel.

Potential changes in oceanographic conditions may have an impact on juvenile recruitment to coastal tributaries. Castonguay (1994a) suggests two hypotheses for investigation: 1) a weak, slow Gulf Stream would cause larvae to miss the optimum period for metamorphosis and to be lost to the population when they reach the position of the stream where lateral transport would have ordinarily placed them and, 2) recent cooling events and oceanographic changes in the northwest Atlantic may have perturbed the physical processes that carry glass eel to the continent. Castonguay (1994b) also explores the indirect evidence of a weakening Gulf Stream and ways in which it may interfere with larval transport of American eel, as well as changes in the strength or location of thermal oceanfronts.

Pressures/Impacts

- Potential / exploratory harvest of leptocephali.
- Changes in oceanographic conditions, a weakening Gulf Stream and recent cooling events in the northwest Atlantic may potentially have an impact on juvenile recruitment to coastal tributaries.

Figure 2. American eel leptocephali spatial and temporal distribution by size. Source: Uwe Kils, Rutgers U.



1.2.3.3 Glass eel

The glass eel life stage occurs when the leptocephali metamorphose at sea to resemble miniature, transparent eel. They are transparent with elongated, rounded bodies and range in length from 4.8 to 6.5 cm (Hardy 1978). They actively migrate toward land and freshwater and ascend rivers during the winter and spring. It has been demonstrated, in European glass eel, that this change in behavior was caused by the detection of the odor of freshwater, as well as temperature gradients (Facey and Van Den Avyle 1987). This migration occurs earlier in the

southern portion of the range and later in the northern portion (Helfman et al. 1984; McCleave and Kleckner 1982). Glass eel ascend estuaries by drifting on flooding tides and holding position near bottom on ebb tides and also by actively swimming along shore in the estuaries and

above tidal influence (Barbin et al 1994). Glass eel in estuaries and those ascending into freshwater eventually become pigmented elvers.

Pressures/Impacts

- Since artificial reproduction is not yet feasible, the intensive aquaculture industry in eastern Asia (150,000 t production) is dependent upon and supported by wild-caught glass eel and elvers (Moriarty and Dekker 1997).
- Glass eel commercial fisheries are scattered throughout the American eel's range. A limited import trade in glass eel from Europe to the United States exists for the food industry. Glass eel harvest in recent years has given rise to serious concern as to the future viability of the eel industry.
- Lack of up and downstream passage for migrating glass eel.

1.2.3.4 Elver

The elver life stage occurs when the glass eel ascend into brackish or fresh water and become pigmented, generally at 10.0 cm or less in length. At this early stage, they are active at night and burrow during the day. They move into the water column on flood tides and return to the bottom during ebb tides (McCleave and Kleckner 1982). Elvers have been shown to be attracted to the odor of brook water and decaying leaf detritus and microorganisms (Facey and Van Den Avyle 1987). Upstream migration of elvers can occur over a broad period of time from May (during peak migration) through October (Richkus and Whalen 1999). The migration occurs earlier in the southern portion of its range and later in the northern portion (Helfman et al. 1984; McCleave and Kleckner 1982).

Elvers are brown in color and are usually fully pigmented at 6.5 mm to 9.0 cm in length (Hardy 1978), although pigmented American eel have been observed less than 6.5cm in Florida (J. Crumpton, Florida Game and Fresh Water Fish Commission, Eustis pers. comm.). They eventually begin swimming upstream possibly due to changes in water chemistry and river current velocities (Facey and Van Den Avyle 1987). They grow slowly, reaching about 12.7 cm after the first year in freshwater (Bigelow and Schroeder 1953). Growth rates are highly variable, leading to considerable variation in length within age groups and poor predictability of size at age (Facey and Van Den Avyle 1987).

Pressures/Impacts

- Since artificial reproduction using mature eel is not yet feasible, the intensive aquaculture industry in eastern Asia (150,000 t production) is dependent upon and supported by wild-caught glass eel and elvers (Moriarty and Dekker 1997).
- Elver commercial fisheries are scattered throughout the eel's range in both the marine and freshwater habitat areas. Elver harvest in recent years has given rise to serious concern as to the future viability of the eel industry. The elver fishery in the United States has had a long history with wide distribution and commercial value throughout its range.
- Lack of adequate up and downstream passage for migrating elvers.

1.2.3.5 Yellow Eel

The yellow eel resembles the adult form and occurs after the elver stage. Yellow eel are usually yellow or green in color and range in size up to about 28.0 cm for males and 46.0 cm for females (Hardy 1978). They inhabit bays, estuaries, rivers, streams, lakes, and ponds where they feed primarily on invertebrates and smaller fishes (Ogden 1970). Usually by Age II, the eel have entered into the yellow phase. Depending on where they cease their upstream migration, some yellow eel reach the extreme upper portions of the rivers while others stay behind in the brackish areas (Hardy 1978, Fahay 1978). The timing and duration of yellow eel upstream migration is watershed specific and can occur over a broad period of time from March through October, peaking in May through July. Yellow eel can continue migrating until they reach sexual maturity (Richkus and Whalen 1999). In the upper St. Lawrence River, yellow eel migration is monitored between June and October, and 72.2% of the upstream migration occurs between July 18 and August 17 (Casselman et al. 1997). The growth rates of yellow eel are variable, depending on latitudinal trends (slower growth occurs in the north than in the south) and habitat productivity (slower growth occurs in freshwater than in estuaries) (Richkus and Whalen 1999).

Timing of sexual maturity in the yellow eel has been correlated with specific size ranges. Most sexually mature males are over 28.0 cm and, in the northern populations, they are older than Age 3 (Hardy 1978, Fahay 1978). Most sexually mature females are over 46.0 cm and they are older than Age 4 in the northern populations (Hardy 1978, Fahay 1978). Length-age relationships vary considerably within the northern portion of their range. The following year-class size information has been reported for Rhode Island: Age 4 total length (TL) 27-46 cm; Age 5 - TL 28-51 cm; Age 6 - TL 28-51 cm; Age 7 - TL 29-58 cm; Age 8 - TL 33-64 cm; Age 9 - TL 38-62 cm; Age 10 - 37-65 cm; Age 11 - TL 46-65 cm (Bieder 1971).

There are several environmental variables that can influence sexual determination in American eel, the resulting ratios of females and males, and age at sexual maturity. In the northern portion of their range eel mature at greater ages and sizes than in the southern portion, resulting in northern females being the most fecund and having a relatively long life span (Helfman 1987). For example, numerous studies have found the St. Lawrence River-Lake Ontario eel to be exclusively female (Dutil 1987; Vladykov 1966). J. Casselman (OMNR pers. com.) also found them to be relatively older and larger. McCleave (1996) found that females are more abundant in the northern part of their range, males are more abundant in the southern part of their range, and that females grow larger and mature later than males. However, Foster and Brady (1982) found only females in Maryland where sex could be determined (N=1,000); Helfman et al. (1984) found in a Georgia river that 64% of estuarine eel were female and 94% of freshwater eel were female; Hansen and Eversole (1984) noted that females outnumbered males 23 to 1 in South Carolina. Some data suggest that there is a further isolation of the sexes by salinity. Females were found to be more prevalent in freshwater systems while males more frequently inhabit estuaries (Facey and LaBar 1981). Recent work indicates that sex determination might be influenced by density (K. Olivera, U. of Maine pers. com.). If this is the case, sex ratios may be changing towards more females throughout their range due to lower numbers of eel.

Maturation occurs in 8 to 24 years in the Chesapeake Bay Region, but may occur earlier in southern regions and later in northern regions. In the southern regions, females older than eight years old or longer than about 70 cm were rare and males older than five years old or longer than 40 cm were also rare. In contrast, maturing females in the Newfoundland study averaged 13

years of age and more than 70 cm long (Bouillon and Haedrich 1985). Female eel from Lake Champlain averaged 16 years old and nearly 70 cm long (Facey and LaBar 1981). Eel greater than age 20 were found in Lake Champlain. Males were not present, or were not captured, in the two northern studies. There is evidence that males are rarer at higher latitudes and in inland waters (Helfman et al. 1987). The size and distributional differences between the sexes led Helfman et al. (1987) to hypothesize that male and female American eel experience different natural selection pressures which result in different life history traits. They suggested that males tend to be found in the more productive habitats, closer to the spawning area, favoring rapid growth and maturity at a small size. This is a time-constrained life history strategy. Females are distributed over all suitable habitats dispersed widely through the geographic range, and slower growth to greater size and age is favored. Increased size results in increased fecundity. This is an energy-constrained life history. The evolutionary scenario hypothesized by Helfman et al. (1987) requires further research, but may be a critical concept in managing the species in different parts of the geographic range and in different habitats.

Pressures/ Impacts

- Yellow eel spend a lengthy period of time before reaching sexual maturity, are harvested throughout that period, and are susceptible to overharvest.
- Lack of adequate up and downstream passage for migrating juveniles.

1.2.3.6 Silver Eel

The silver eel life stage, which is the migrating and sexually mature eel, begins after a lengthy period as a yellow eel. Between the time of beginning the downstream migration and leaving the estuary for the open ocean, the yellow eel metamorphose into the adult silver eel phase, which is better suited for ocean migration (Wenner 1973, Facey and Van Den Avyle 1987). Silver eel may begin their seaward spawning migration in late summer through fall from New England tributaries (Facey and Van Den Avyle 1987). The yellow eel undergoes several physiological changes in becoming a silver eel, including: (1) a color change from yellow/green to metallic, bronze-black sheen; (2) body fattening; (3) skin thickening; (4) enlargement of the eye and change in visual pigment; (5) increased length of capillaries in the rete of the swim bladder; and (6) digestive tract degeneration (Facey and Van Den Avyle 1987). These changes have not been observed often or at all in specific state waters and are capable of varying with latitude and temperature (J. Crumpton, Florida Game and Fresh Water Fish Commission, Eustis pers. comm.). Migrating silver eel have been observed to cover 38 km in 40 hours, showing considerable vertical movements in the water column with no behavioral changes associated with diel or tidal cycles (Stasko and Rommel 1977). Little is known about the oceanic spawning migration and the means by which the spawning grounds are located are poorly understood (Miles 1968). It has been suggested that American eel use the geoelectrical fields generated by ocean currents for orientation (Rommel and Stasko 1973). The depth at which American eel migrate in the ocean has been hypothesized to vary with light intensity and turbidity (Edel 1976). Migration has been suggested to occur within the upper few hundred meters of the water column (Kleckner et al. 1983; McCleave and Kleckner 1985). However, Robins et al. (1979) photographed two *Anguilla* eel, believed to be pre-spawn American eel, at depths of about 2,000 m (on the floor of the Atlantic Ocean) in the Bahamas.

No information exists on the spawning requirements, behavior, or the exact location of spawning within the Sargasso Sea. Adult eel are believed to spawn in the winter and early spring in the

Sargasso Sea, which is a large portion of the western Atlantic Ocean east of the Bahamas and south of Bermuda. Genetic studies indicate that American eel are a single panmictic breeding population (Williams and Koehn 1984). At this time only a few published studies of fecundity of the American eel exists where the relationship between eel size and fecundity was expressed as: $\log F = -4.29514 + 3.74418 \log TL$, $\log F = 3.2290 + 1.1157 \log W$, where F = number of eggs per female, TL = total length (mm), and W = total weight (g). A fecundity of 0.4-2.6 million eggs was reported in females from Chesapeake Bay ranging from 50-72 cm in length (Wenner and Musick 1974) while Barbin and McCleave (1997) reported a range of 1.8 to 19.9 million eggs.

Pressures/Impacts

- Commercial fisheries throughout the silver eel range in freshwater and estuarine habitat areas.
- Mortality caused by hydropower turbines during the downstream migration of adults.
- Harvest of the seaweed/algae (*Sargassum sp.*) in the Sargasso Sea and potential capture of silver eel prior to reproduction.

1.2.4 Food Habits

American eel depend on a wide range of food at different life stages and in different habitats. At various times and locations they feed on every level of the food chain.

Eel are carnivores and consume a variety of foods including demersal fishes and benthic invertebrates such as insects, crayfish, snails, and worms (Ogden 1970; Scott and Crossman 1973; Facey and LaBar 1981). Benthic organisms such as crayfish, various gastropods, and demersal fish are significantly more common in shallow littoral and stream habitats than in deep, cold water habitats. Godfrey (1957) concluded that about 10% of the eel examined had consumed whole fish, while 90% contained mostly insects. Facey and LaBar (1981) suggest that eel rely heavily on benthic organisms as evidenced by 43% of eel stomachs containing insects. Fish were found in 26% of the stomachs. Overall, smaller eel (43-57 cm) rely more on insects than larger eel (57 cm). In eight New Jersey streams, food size was also found to increase with eel size. Smaller eel fed on mayflies, megalopterans, and caddisflies (Smith 1985). Fish comprised at least 25% of the diet for approximately 20% of eel in New Jersey streams; bottom dwelling and sluggish species were most prevalent (Ogden 1970). Facey and LaBar (1981) indicated that the higher percent of fish in the diet of eel in Lake Champlain might have been due to the larger size of the eel in their samples (approximately 61-cm).

American eel leptocephali feeding habits have not been reported. However, the dentition and gape of the mouth suggest that they are capable of feeding on individual zooplankton and phytoplankton. Elvers collected from Cooper River, South Carolina, ate mostly larval and adult chironomids, cladocerans, amphipods, and fish parts (McCord 1977). More types of food were eaten by intermediate-sized yellow eel than by elvers or maturing yellow eel (Wenner and Musick 1975). Fish occur in the diet of intermediate-sized yellow eel during the winter and spring, while insects and mollusks were eaten from spring through fall (Wenner and Musick 1975). Yellow eel shorter than 40 cm in New Jersey streams mainly ate aquatic insects, whereas larger eel fed mostly on fish and crustaceans (Ogden 1970). Yellow eel in the lower Chesapeake Bay fed on crustaceans including blue crab (*Callinectes sapidus*), bivalves such as soft-shelled clams (*Mya arenaria*) and polychaetes (Wenner and Musick 1975). Eel have been considered to

be significant predators on young salmonids, but this is not well supported in the literature (Facey and Van Den Avyle 1987; Godfrey 1957). Bigelow and Schroeder (1953) describe the American eel as feeding on whatever prey/food items happen to be found in its habitat. Given their poor eyesight and nocturnal feeding habits, yellow eel probably rely on their keen sense of smell to locate food (Fahay 1978). A diel foraging study in the Pettaquamscutt River estuary of Rhode Island showed that the foraging activity of estuarine eel was primarily nocturnal in late summer through autumn. The study also identified a peak of activity at nightfall, with most of their captures in traps occurring one hour after sunset (Sorensen et al. 1986). Yellow eel swallow some types of prey whole, but also can tear pieces from large dead fish, crabs and other items (Facey and Van Den Avyle 1987). Eel have been reported to accomplish this tearing off by biting and spinning rapidly (Helfman and Clark 1986).

1.2.5 Stock Assessment Summary

Historical Overview

The American eel has been an important food for native Americans since the pre-colonial era (Crawford 1996). Because eel are also present in European waters, this resource was well known to, and used by, the earliest European settlers to the North American continent. The first systematic records of eel harvests in Maine were collected in 1887 and harvests have been recorded more or less continuously since 1989. Atkins (1887) reported on the early Maine eel fisheries as follows: "Eel are taken with spears, in traps and pots set for the most part in tidal waters, and in weirs built across the streams that they descend in the autumn." Throughout the first half of the 20th century, the eel fishery was small (Crawford 1996).

European eel species and Asian eel species fisheries had declined by the late 1960s and their markets were in need of an external source (Crawford 1996). American eel that were exported from southern New England filled that need. The American commercial fishery has traditionally supplied American eel for the regional and the European food market, domestic trotline bait, and small bait eel for domestic sport fisheries. Glass eel and elvers are cultured to marketable size in Asia. When the Asian domestic stocks are inadequate, a strong market develops for American glass eel and elvers. The Asian market for American glass eel and elvers was strong from 1972-1977, declined dramatically in 1978, and began to strengthen in the 1990's.

Current Status

The current status of the American eel stock is poorly understood. This is due to limited and non-uniform stock assessment efforts and protocols across the range of this species. Reliable indices of abundance of this species are scarce. Limited data from indirect measurements (harvest by various gear types and locations) and localized direct stock assessment information are currently collected.

Although eel have been continuously harvested, consistent data on harvest are often not available. Harvest data is often a poor indicator of abundance, because harvest is dependent on demand and may consist of annually changing mixes of year classes. Most of the data collections were of short duration and were not standardized between management agencies. Harvest data from the Atlantic coastal states (Maine to Florida), indicate that the harvest has declined after a peak in the mid-1970s (Figure 3). Annual eel catch ranged from 885,267 lbs. to

3,608,357 lbs. between 1970 and 1998, but the catches averaged 2,540,599 lbs. between 1970 and 1984, and 1,356,434 lbs. between 1985 and 1998. The lowest harvest (between 1970 and 1998) was 885,267 lbs., which occurred in 1998. Because fishing effort data is unavailable, however, finding a correlation between population numbers and landings data is problematic.

In addition to commercial harvest, there are a few long-term data sets from fish ladders, impingement sampling, research collections, and monitoring programs. In 1974, Ontario Hydro and OMNR constructed the largest eel ladder in the world at the Moses-Saunders Hydroelectric Dam (Eckersley 1981; OMNR 1986). Eel count data from the ladder indicate there has been a significant and dramatic decrease in the number of eel ascending the ladder since the mid-1980's (Figure 4) (Casselmann et al. 1997). However, this decline in eel counts may be an artifact of lock/water flow usage at the Beauharnois Dam which is downstream from the Moses-Saunders facility. Long-term data from the Conowingo Dam fish lift in Maryland, on the Susquehanna River, show a decline in elver counts from 1974 through 1996 (Figure 5).

Richkus and Whalen (1999) performed a trend analysis on eel migration data from 1984 to 1995, including data from the Moses-Saunders eel ladder (Table 1). Their results indicate significant negative trends for yellow and/or silver eel abundance in Ontario, Quebec, New York, and Virginia, although silver eel declines in the St. Lawrence River basin may be due to escapement reductions from upper St. Lawrence dams and water flow control rather than fisheries. The authors found no trends for glass eel or elvers, but those data sets were generally not complete and may not have covered the years where the largest declines were observed in other data sets (Richkus and Whalen 1999).

Richkus and Whalen's (1999) results support observations and concerns made by the state and federal fishery resource agencies, conservation organizations, and fisheries interests that the eel resource has been declining in abundance. As stated in the Goals of this Plan (Section 2.1) the purpose of this management effort is to reverse any local or regional declines in abundance and institute consistent fishery-independent and dependent monitoring programs throughout the management unit.

Recent Changes in Harvest

Domestic and overseas markets utilize American eel from most life stages. Most harvest data show a decreased recruitment and catch of glass, yellow and silver eel. Data on European eel also show a considerable decline in abundance since the late 1970's (Moriarty and Dekker 1997).

American Eel Harvest For The Atlantic States

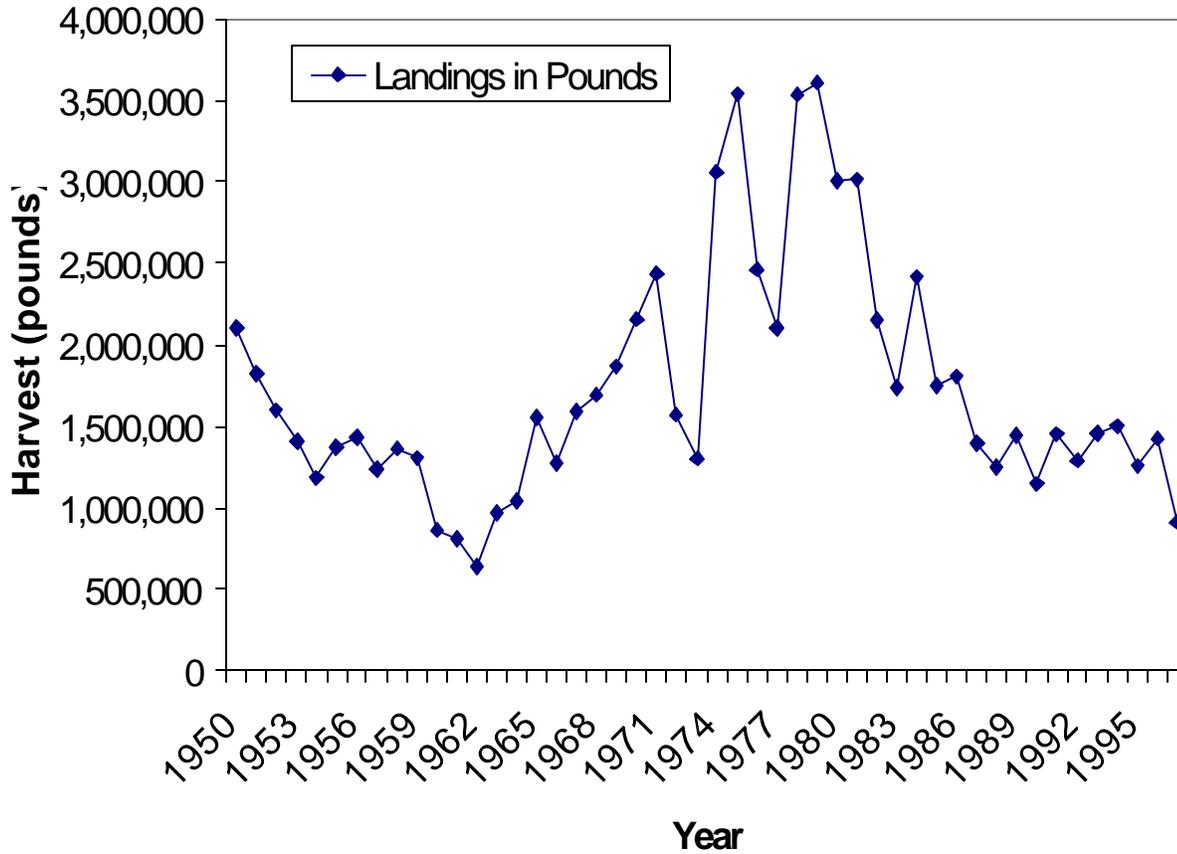


Figure 3. Annual harvest as reported by the Atlantic States from 1950 to 1998 (NMFS, Fishery Statistics and Economics Division, 11-15-99, pers. comm.).

**American Eel Passage During A 31-Day Peak Migration Period
at the R.H. Saunders Eel Ladder in Cornwall, Ontario from 1974
to 1998**

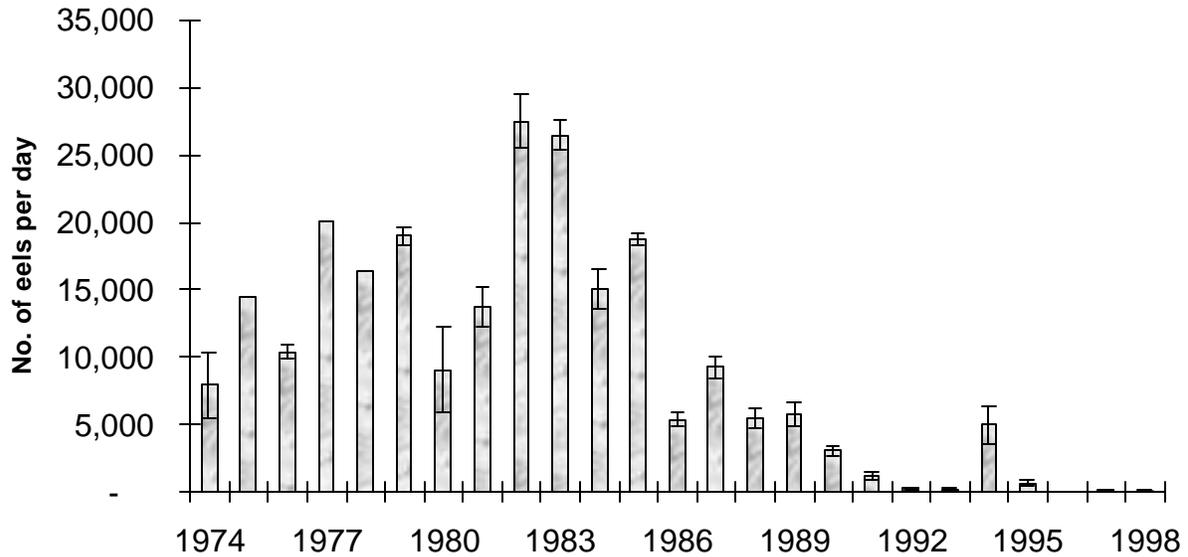


Figure 4. Mean number of eel ascending the eel ladder per day at the Moses-Saunders Hydroelectric Dam at Cornwall, Ontario, during a 31-d peak migration period from 1974-98. Vertical bars indicate the 95% confidence intervals (from Casselman et al. 1997, Mathers et al 1998).

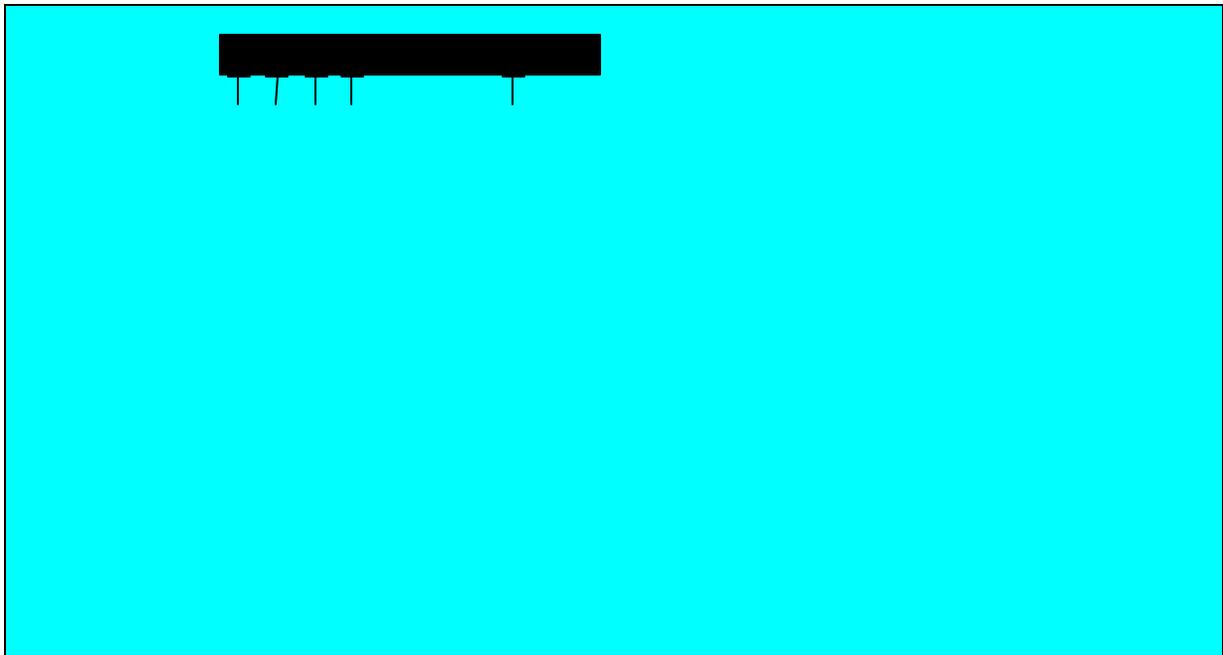
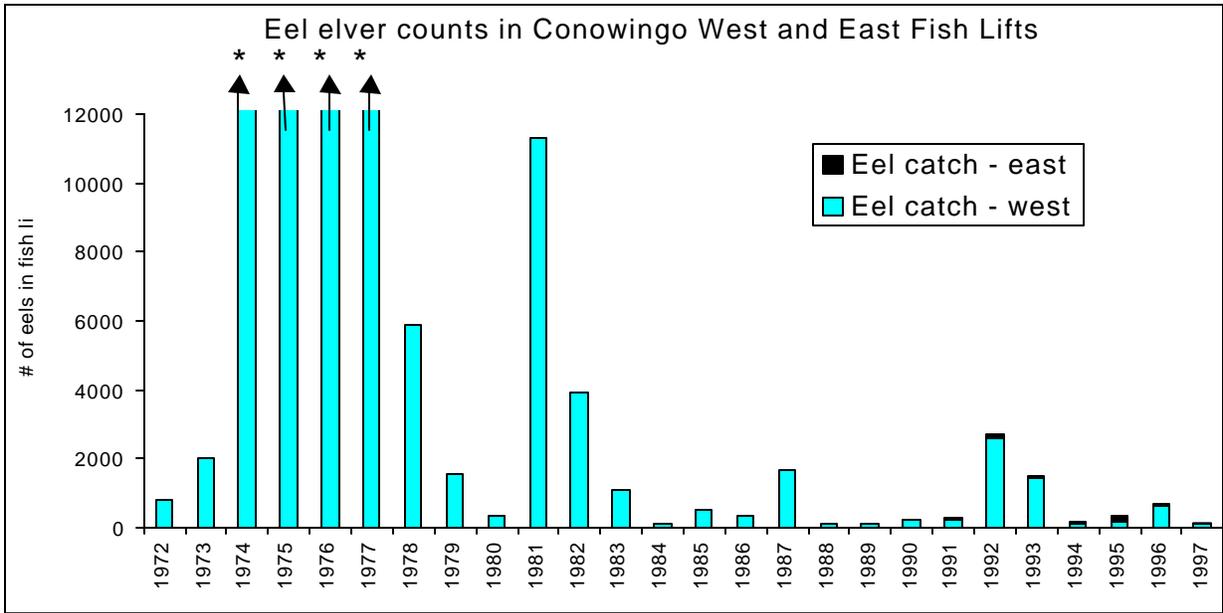


Figure 5. Data from Conowingo Dam fish lift, Susquehanna River, 1972-1997.

***Counts of eel in fish lifts for 1974, 1975 and 1976 were 126,543, 64,375, and 60,409 respectively (J. Weeder, MD DNR person. comm.). * Counts of fish per operating hour for 1974, 1975, 1976, 1977, and 1981 were 183.87, 209.69, 161.09, 35.35, and 41.20 respectively (J. Weeder, MD DNR person. comm.).**

Table 1. Summary of data sources used in Mann-Kendall trend analysis of eel abundance time series. Significance was determined at $\alpha = 0.05$; NS = not significant. Table is arranged approximately north to south. (Richkus and Whalen 1999)

State/ Province	Location	Available Years	Collection Method	Eel Life Stage	Mann-Kendall Trend Analysis (1984-95)
Nova Scotia	East River, Sheet Harbor	1990-97	Irish elver trap	Elver	NS
Ontario	St. Lawrence River	1974-95	Fish Ladder	Yellow eel	Negative P < 0.001
Ontario	Lake Ontario	1984-96	Commercial electrofishing	Yellow eel	Negative P < 0.01
Quebec	St. Lawrence River (lower)	1979-95	Weir trapping	Silver / Yellow eel	Negative P < 0.01
New Hampshire	Statewide	1988, 1990-97	Commercial eel pot	Yellow eel	NS
New York	Hudson River	1985-1995	Beach Seine Survey	Yellow eel	Negative P < 0.1
New York	Hudson River	1985-1995	Fall shoal survey	Yellow eel	NS
New York	Hudson River, Roseton	1973-96	Impingement sampling	Silver / Yellow eel	NS
New York	Hudson River, Danskammer	1974-96	Impingement sampling	Silver / Yellow eel	Negative P < 0.001
New Jersey	Little Sheepshead Creek	1989-94	Bridge netting	Glass eel	NS
PRFC	Potomac River	1988-97	Commercial eel pot	Yellow eel	NS
Virginia	North Anna River	1981-97	Electrofishing/ electroseining	Yellow eel	Negative P < 0.01
Virginia	VIMS trawl survey; rivers and estuaries	1954-96	Trawl sampling	< 180 mm (elvers/glass eels)	NS
Virginia	VIMS trawl survey; rivers and estuaries	1954-96	Trawl sampling	181 – 350 mm	NS
Virginia	VIMS trawl survey; rivers and estuaries	1954-96	Trawl sampling	< 350 mm (silver eel)	Negative P < 0.05
Virginia	VIMS trawl survey; rivers and estuaries	1954-96	Trawl sampling	All ages combined	NS

From the above data, it is apparent that overall eel harvest has declined. In addition, eel abundance in upstream migration has declined in the St. Lawrence (Casselman et al. 1997) and Susquehanna River Systems. Richkus and Whalen (1999) concluded that the trend analysis shows broad-based evidence for a stock-wide abundance decline of American eel from 1984 to 1995.

1.3 DESCRIPTION OF THE FISHERY

1.3.1 Commercial Fishery

Jessop (1997) provides a brief but highly concise summary of the status of the American eel fishery along the Atlantic seaboard of the United States. It is presented below with a few updates concerning Pennsylvania and New Jersey.

Glass eel/Elver Fishery

Interest in fishing for American elvers and glass eels, primarily for export to Asia for aquaculture, developed in **Florida, North and South Carolina, Virginia, Massachusetts and Maine** during the early 1970s (Fahay 1978; Keefe 1982; Mullis 1982). Elver/glass eel fisheries failed to develop in Florida, ceased in 1977 in North Carolina and probably also in South Carolina, and were prohibited in 1977 by a 15 cm minimum size limit in Virginia and a 10 cm minimum size limit in Massachusetts (CBP 1991). The **Potomac River Fisheries Commission** imposed a 6-inch minimum size effective January 1, 1992, applying to both commercial and recreational fisheries, therefore eliminating any glass eel/elver fishery. Reported catches in Maine were 10 t in 1977 and 7.6 t in 1978 (Dow 1982) but catch statistics are unavailable for the other states. The Maine elver/glass eel fishery collapsed after 1978 due to market conditions, but continued at a low level until growing substantially in 1994. Reported catches of 3.3 t occurred in 1994, 7.5 t in 1995, and 4.6 t in 1996 (CAEMM 1996; L. Flagg, Maine Department of Marine Resources, pers.comm.). With the exception of 1977 and 1978, elver/glass eel catches in Maine cannot be separated from yellow/silver eel catches prior to 1994 when specific records of elver/glass eel catches were initiated. During the late 1980s or early 1990s, elver/glass eel fisheries were developed or reestablished in **Connecticut, Rhode Island, New York, New Jersey, Delaware and South Carolina** but no catch data are available. Elver/glass eel fisheries do not occur in any **Gulf of Mexico** states.

The recent surge of interest in fishing for elvers/glass eels and the sometimes-chaotic nature of the fishery has evidently caught state fishery managers unprepared. Few states, which presently permit elver/glass eel fisheries (Maine, Connecticut, South Carolina, and Florida), have comprehensive regulations for those fisheries. Although 11 of 15 Atlantic coastal states presently ban elver/glass eel fisheries, several states prohibited the elver/glass eel fishery only recently in response to a perception of uncontrolled development. Permits to fish elvers/glass eels may specify various conditions, such as quota, area to fish (all are restricted to tidal waters), gear types, season, etc.

Maine leads other elver/glass eel fishery states in modernizing its elver/eel fishery regulations. It has recently proposed and/or implemented regulatory changes to increase elver/large eel license fees to \$200.00 in an effort to dedicate license fee revenues to eel research and provide enforcement for the fishery. Maine has imposed a March 15-June 15 fishing season and two day weekly closed time for elvers/glass eels (defined as eel less than 15 cm long). It will also limit the number, type, and methods of operation of gear units available to each fisher in an attempt to control fishing effort, limit elver/glass eel fishing to the intertidal area and the shoreward one-third of a stream (both shores), and prohibit both elver/glass eel fishing within 46 m of any dam and bycatch of other species (CAEMM 1996).

The **Connecticut** regulations were minimal until 1996, e.g., no small mesh fyke nets, but pots and dipping are permitted; catch reporting requirements permit minimal interpretation of catches. In 1996, Connecticut defined the glass eel as less than 10 cm in length, instituted a March 1-May 31 glass eel fishing season with a weekly closed period from 6:00 pm Saturday to 6:00 am Sunday, prohibited obstruction of more than 50% of the stream width and placement of traps within 7.6 m of each other, limited traps to a maximum of 10 within the state and 3 in any stream (dipnets are the preferred fishing gear) and required monthly catch reporting by logbook. The elver/glass eel fishery in **New Jersey** was unregulated prior to 1997 when it was restricted to dipnets only and a fishery season was implemented (February 15-April 20) with a Sunday closure. The elver/glass eel fishery has been closed since 1998. (ASMFC 1997; J. F. McClain, New Jersey Division of Fish, Game and Wildlife, pers. comm.).

At various periods between 1957 and 1980, elvers (range 23,000 to 6,000,000 elvers) were annually stocked in the Susquehanna River, **Pennsylvania** upriver of hydroelectric dams, but no commercial eel fishery is permitted, and personal use harvesters are restricted to 50 eel per person per day.

Virginia issued, in 1996, two permits to fish a total of about 800 kg of elvers/glass eels for local aquaculture; no additional permits are planned for several years. When the cultured elvers have been reared to sale size, 10% must be returned to the state for release in the wild. **South Carolina** has an active elver/glass eel fishery. A limited fishery exists for elvers in Florida, and one experimental permit has been issued for harvesting glass eel.

The number of elver/glass eel fishers is generally unregulated in those states where an elver/glass eel fishery occurs (excluding **Virginia** where two permits exist, and **Florida** where the glass eel/elver fishery has been under limited regulation and three special device permits exist). In **Maine**, the number of commercial finfish permits (which may be used to fish eel as well as other species) almost tripled between 1985 and 1995 and more than doubled between 1994 and 1995 to over 3,300 permits, of which over 1,500 are believed to be elver/glass eel fishers (CAEMM 1996). As of the 1999 fishing season, Maine representatives claim that permits have been reduced by two-thirds of the 1994-1995 reports (J. Goldthwait Person. Comm.). **Connecticut** has had a moratorium on new commercial fishing licenses since 1995 but existing licensees can fish elver/glass eel if they choose. In **New Jersey**, over 2,100 licenses were issued for the 1997 elver/glass eel dip-net fishery (J. McClain, New Jersey Division of Fish, Game and Wildlife, pers. comm.). **South Carolina** had no mechanism for determining participation in the elver/glass eel fishery in coastal waters until 1996 when a permit was instituted (B. McCord, South Carolina Department of Natural Resources, pers. comm.). In 1997, about 65 permits for elver/glass eel hoop nets (a type of fyke net) and 11 permits for dip nets were issued. Each permit may authorize one or more units of gear.

Some states (**Connecticut**, **South Carolina**, and **Florida**) have no minimum length limit for eel retention (Table 2). **Maine** has a 6 in minimum size limit except during the elver season, which runs from March 15 through June 15. **New Hampshire** has a 10 cm minimum size limit as does **Massachusetts**, except for aquaculture (Amaral 1982). A 15 cm minimum size limit was imposed in **Virginia** in 1977 (CBP 1991) and has existed in **Georgia** since at least the early 1980s (J. Music, Georgia Department of Natural Resources, pers. comm.). **New York**, **Rhode Island**, **Delaware**, **Maryland**, **PRFC** and **North Carolina** have only recently (1992-1995) imposed a minimum length limit of 15 cm so as to protect elvers/glass eels for local aquaculture

development or, more urgently, to prevent uncontrolled development of an elver/glass eel fishery. These states await the recommendations on elver/glass eel fishery development expected in the ASMFC fishery management plan for eel. In 1994, Maryland permitted a daily harvest per person of up to 25 eel of less than 15 cm for use as bait, primarily by anglers.

Maine has a defined elver/glass eel fishing season (March 15 to June 15). No states with an elver/glass eel fishery, other than Maine, have begun collection of catch statistics although this is expected to change when the ASMFC fishery management plan for eel is implemented. Poaching of elvers/glass eel is believed a serious problem in many states but enforcement of the often minimal regulations is poor due to the nature of the fishery (very mobile, nighttime operation) and low administrative priority.

Table 2. Commercial eel fishing regulations summary ¹.

State/ Province	Minimum Length	Pot Mesh Size ²	Freshwater Fyke	Weirs	License	Comments
Newfoundland	8"		2"/3" Stretch	No	No Data	
Prince Edward Island	18.4"		No	No	No Data	
Nova Scotia	8"		No	No	\$ 10	
New Brunswick	8"		No	No	\$ 10	
Maine	None (3/15-6/15) 6" (6/16- 3/14)	½" x ½"	Yes	Yes	\$ 33 + Gear Fee For Glass Eel For Residents \$ 334 + Gear Fee For Glass Eel For Nonresidents \$ 100 Weir/Pot	\$75 For Dip Net. \$100 Each For First Two Fyke Nets, \$200 Each Next Three, Limit Five, For Glass Eel
New Hampshire	6"	Yes	No	No	\$ 26 Resident \$ 200+ Nonresident	Coastal Netting License Required For Nets & Pots
Massachusetts	4"		No	No	\$ 65 Resident-Saltw. \$130 Nonresident-Saltw.	Freshwater \$25 plus state sports license \$27.50
Vermont						
Rhode Island	6"		No	No	\$ 200	
Connecticut	None	No	No	No	\$ 50 Resident \$ 100 Nonresident	Dip Net Glass Eel. 3/1-5/31 glass eel season with weekly closed periods. License Moratorium.
New York – Marine	6"	1" X ½"			\$ 250 Resident \$ 1250 Nonresident	License Moratorium
New York – Inland	None	No Opening Not > 2" Dia	Yes	Yes	\$ 20 Resident \$ 60 Nonresident	
Pennsylvania	6"					Ban on commercial eel fishing
New Jersey	6"	4/16" Bar	No	No	\$ 10 Bait Net Resident \$ 100 Bait Net Nonresident \$ 100 Min. Fyke/Pot Residents \$ 1000 Min. Fyke/Pot Nres.	Glass eel/elver fishery closed
Delaware	6"	No	No	No	\$ 115 Resident \$ 1150 Nonresident	
Maryland	6"	½" x ½" or escape panel	No	No	\$300 Resident, tidal \$350+ Nonresident, based on home state \$100 unlimited finfish harvester	Limited entry
PRFC	6"	½" x ½"	No	No	\$75 Per Boat	
District of Columbia						No Commercial Fishing
Virginia	6"	½" x ½" with 4" x 4" escape panels	No	No	\$ 150 + Gear Fee	2 Year Wait
West Virginia	None				Resident + Conservation Stamp	Except 5/15-6/30. Gigging, Snagging, Snaring Are Prohibited
North Carolina	6"	1" x ½"	No	No	\$ 10 Resident \$ 50 Non-resident	20 Eel Limit Per Person Per Day
South Carolina	None	½" x ½"	Yes	No	\$ 50 Resident \$ 1000 Nonresident	Dip nets licensed, gear permit also required in addition to licenses
Georgia	6"	1½" x ½"	No	No	\$ 12 Resident \$ 118 Nonresident	
Florida	None	1" x ½"	No	No	\$ 25 Resident \$ 100 Nonresident	

¹ Regs subject to change: contact state for current requirements. ² Escape panels of varying sizes by state required.

Yellow/Silver Eel

The United States fishery for American eel extends from Maine to the Gulf of Mexico. Different geographic regions (north, middle, and south Atlantic, Gulf of Mexico) exhibit differing trends and magnitudes in their eel fisheries, which reflect differences in their fisheries and stock abundances (Fahay 1978). The 1955-1973 fishery was most productive in the middle Atlantic region (New Jersey to Virginia), followed by the north Atlantic region (Maine to New York), south Atlantic region (North Carolina to Florida), and Gulf region where the catch was negligible (Fahay 1978). The regional catch summary statistics reported by Fahay (1978) are slightly lower than statistics recently available from the National Marine Fisheries Service (NMFS 1997), but the regional rankings are unchanged. For the years 1955-1973, regional mean catches were 146 t (range 75-251 t) for the north Atlantic region, 429 t (range 152-930 t) from the middle Atlantic region, and 80 t (range 19-192 t) from the south Atlantic region. For the years 1974-1995, regional mean catches increased to 160 t (range 7-556 t) in the north Atlantic region, to 567 t (range 106-1,349 t) in the middle Atlantic region, and to 236 t (range 6-792 t) in the south Atlantic region. The higher regional mean catch in the 1974-1995 period is accompanied by higher annual variability, reflecting the declining catch in all regions (and most states) from peaks in the mid-1970s and early 1980s to the low values of recent years.

For the Atlantic coast (Maine-Florida), annual eel catch ranged from 384 t to 1,645 t between 1970 and 1995, with values between 1.17 and 5.49 million U.S. dollars (ASMFC 1997). Eel catches averaged 1,179 t between 1970 and 1982 and 635 t between 1983 and 1995, indicating an overall decline in US catch.

Annual trends in reported eel catches by individual states (NMFS Fishery Statistics and Economics Department pers. comm.) comprise three basic groups: declining catch, e.g., Rhode Island, New York; increasing catch, e.g., New Jersey, Delaware, Maryland; and catches that have returned to values typical of those reported prior to the peak catches of the 1970s and early 1980s, e.g., Maine, Massachusetts, Florida (Figure 6). Reported catches in some states declined sharply in 1996 but catch data may be incomplete.

Maine eel catches peaked in the late 1970s at 50-90 t annually and have since fluctuated between 4 t and 30 t, a level only slightly lower than reported between the early 1950s and early 1970s. **In Rhode Island**, eel catches varied moderately from about 9 t to 30 t between 1962 and 1984, then increased to between 19 t and 56 t between 1985 and 1988 before collapsing to about 1 t during 1989 and 1990 (Gray 1991). The catches reported by Gray (1991) during the mid-1980s are not evident in Figure 6 yet both data sets originate from the National Marine Fisheries Service. The variability in Rhode Island eel catch during the 1980s has been attributed to market forces rather than resource status.

Annual reported eel catches in **Connecticut** have usually been less than 10 t since about 1980 but some fishers blame the recent low catches on overharvesting of elvers/glass eels (NMFS 1997; S. Gephard, Connecticut Department of Environmental Protection, pers. comm.). Eel fisheries in inland (primarily Lake Ontario and Hudson River) waters of **New York** state have been closed due to organochloride contamination since 1976, with the exception of a "limited" fishery for export that closed in 1982 (Blake 1982; Lary and Busch 1997). Historically, catches of eel in New York were several times higher in coastal waters (1960-1978 mean catch of 68 t)

than in inland waters (1960-1979 mean catch of 18 t). The export fishery evidently generated high catches in inland (mean 36 t) and coastal waters during the years 1980-1982 (Lary and Busch 1997).

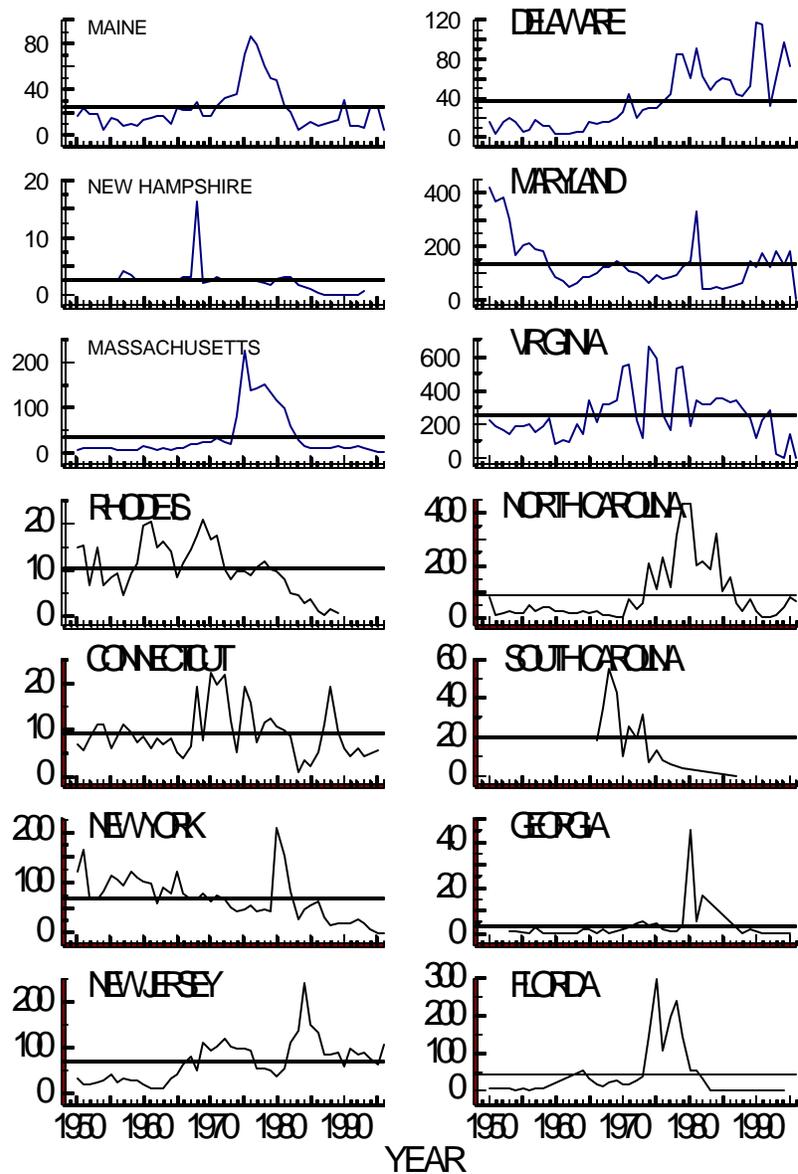


Figure 6. Annual reported (NMFS) catches of American eel, by state, for the Atlantic coast, 1956-96. The vertical line in each graph is the mean catch. Source: Jessop (1997).

In **New Jersey**, eel catches in the primarily coastal pot fishery ranged from 61-98 t between 1989 and 1993, down from the mid-1980s peak of 134 t but near the long-term mean. **Pennsylvania** issued 1 or 2 weir/chute licenses for use on the Delaware River. In 1997, the sole operator reported a harvest of less than one ton. No operations were conducted in 1998. The new

regulations (no commercial sale, 50 fish daily limit, etc.) are expected to result in little, if any, interest in eel weir/chute operations.

In Chesapeake Bay (Maryland and Virginia) recent catches are near the long term (1945-1994) mean of about 450 t (CBP 1995). In **Maryland**, reported eel catches steadily declined from the peak of about 590 t in 1946 to about 45 t in 1963 and have since fluctuated between 45 t and 100 t (CBP 1995). The declining catch since the late 1980s evident in Figure 3 differs from the relatively stable catch reported elsewhere (CBP 1995). Reported catches in **Virginia** fluctuated between about 80 t and 190 t between 1946 and 1966, then increased irregularly to a peak of 659 t in 1974, before declining to 149 t in 1993 and rising to 360 t in 1994 (CBP 1995). Between 1984 and 1994, reported catches averaged 91 t (range 11-134 t) in Maryland (annual catch per fisherman increased from 0.9 to 2.0 t; CBP 1995) and 376 t (range 270-510 t) in Virginia (CBP 1995; Speir 1996). Reported catches in Maryland have thus shown no particular trend since about 1960 while Virginia catches remain near the long-term mean despite the decline from the 1974 peak.

Catches in **North Carolina** and **Georgia** have declined from the peaks in the early 1980s to levels not seen since the 1960s and early 1970s. Before 1970, annual eel catches in North Carolina were usually less than 45 t, then peaked at 436 t in 1980 (Keefe 1982) before declining to 6-26 t in the 1990s. The mean annual catch of the minor fishery in Georgia declined from 8.5 t between 1972 and 1982 to 1.6 t between 1983 and 1995 (J. Califf, Georgia Department of Natural Resources, Brunswick, pers. comm.). Although catches of over 100 t were reported from **Florida** during the mid and late 1970s, the only significant eel fishery in Florida today is the pot fishery of the Saint Johns River. Recently, catches in this fishery have declined, due in part to reduced fishing effort (NMFS 1997; J. Crumpton, Florida Game and Freshwater Fishery Commission, Eustis pers.comm.). Reports indicate that the maximum number of fishers involved in the Florida eel fishery has never exceeded 50 participants (J. Crumpton, Florida Game and Freshwater Fishery Commission, Eustis pers.comm.). Currently, there are 25 – 30 fishers involved in the fishery and participation has been stable since the mid 1980s.

Drawing conclusions from these trends is difficult because the available catch statistics are generally regarded as underestimates, perhaps varying in completeness over time, and fishing effort data are either unavailable or of questionable utility (Foster 1981; CBP 1991; Crawford 1996; NMFS 1997). The current status of the eel stock in most, if not all, states is unknown due to the absence of catch and/or effort statistics and an absence or scarcity of biological study of any kind. A widespread concern about the status of local eel stocks, except perhaps in Pennsylvania, Georgia, Florida, and the Gulf of Mexico where stocks and fisheries are not usually as large as in other areas, reflects more the absence of knowledge about the stocks rather than a well-founded knowledge of decline.

The economically important yellow/silver eel fishery in **Maine** occurs in both inland and tidal waters. The fishery is comparatively well documented and has recently received a comprehensive review and modernization of regulations (CAEMM 1996). Most large eel fisheries south of Maine seem to be primarily coastal pot fisheries with little management and few regulations, other than a license requirement and perhaps minimum size limit or gear and mesh size restrictions (Table 2). Eel fisheries are conducted during the period of natural availability, and few, if any, states have defined fishing seasons. **New Hampshire** has little coastline and no available data on eel fishing. Coastal town authorities (little if any eel fishing

occurs inland) manage the coastal eel fisheries of Massachusetts; state regulations control permitted gear types (Amaral 1982). The tidal water, mainly pot fishery conducted between May and November in **Rhode Island** requires a commercial multispecies marine fishing license but no catch statistics are collected by state agencies for the eel fishery (Gray 1991). **Connecticut** has a relatively small, basically unmanaged, pot fishery for yellow eel in the tidal portions of, primarily, the Connecticut and Housatonic rivers (S. Gephard, Connecticut Dept. of Environmental Conservation, pers.comm.).

Table 3. Commercial landings and value of American eel in the State of Maine.

Year	Landings, pounds	Value	Average Price per Pound
1994	64,135	\$85,473	\$1.52
1993	14,521	28,022	1.93
1992	30,672	55,823	1.82
1991	18,217	27,331	1.50
1990	66,164	86,320	1.30
1989	27,900	29,247	1.05
1988	---- ¹		
1987	13,288	13,700	1.03
1986	16,703	13,219	0.79
1985	24,100	18,288	0.76
1984	8,764	6,610	0.75
1983	11,900	8,925	0.75
1982	45,051	36,637	0.81
1981	55,125	45,308	0.82
1980	105,463	111,061	1.05
1979	111,206	89,214	0.80
1978	133,388	161,892	1.21
1977	175,711	262,596	1.49
1976	191,025	93,665	0.49
1975	154,836	82,380	0.53
1974	79,524	32,318	0.41
1973	79,890	29,555	0.39
1972	70,210	24,578	0.35
1971	54,300	15,204	0.28

¹ No data on landings collected in 1988

Licensed eel fishing in **New York** occurred, primarily in Lake Ontario, the Hudson River (prior to the 1976 closure), and the upper Delaware River (Blake 1982). Only eel less than 36 cm may be fished in the Hudson River proper and other inland waters and must be used for bait because of organochloride contamination. Coastal fisheries are unlicensed and fishing effort is not monitored in either inland or coastal waters. New York enacted, in 1995, a 15-cm minimum size limit and 1.25 x 2.5-cm minimum mesh size for trap nets in marine waters. **New Jersey** fishery regulations require a fishing license for fyke nets and pots, a minimum 4.8-mm bar mesh in pots and a 15-cm minimum size limit. Eel fisheries in **Delaware** were recently licensed and had a 15

cm minimum length limit set in 1995 but are otherwise unregulated and thus have no available catch data.

Maryland and **Virginia** primarily operate pot fisheries for eel in Chesapeake Bay, for which a management plan was developed in 1991 (CBP 1991, 1995; Speir 1996). Prior to the 1991 management plan, **Pennsylvania**, **Maryland**, and **Virginia** had no harvest quotas (**Pennsylvania** has a 50 eel per person per day creel limit), bycatch restrictions or closed season nor do they exist under the management plan. Prior to the 1991 management plan, Virginia had a 1.25 x 1.25-cm minimum mesh size and requirement for two 1.25 x 2.5-cm escape panels for eel pots. Maryland has implemented a similar minimum mesh size under the management plan. Large eel are exported whereas small eel are used for bait in the crab trotline fishery. Such use is of declining importance. Catch reports were not required in Virginia prior to 1973 and the Maryland eel fishery was unlicensed prior to 1981. Furthermore, Maryland did not require reporting of eel catches until 1990 (Foster 1981; CBP 1995; Speir 1996). The National Marine Fisheries Service made estimates of commercial eel landings based on interviews with fishhouse managers for both states from 1929 onward (CBP 1995).

North Carolina has a small, primarily coastal pot fishery, with no catch records maintained for inland waters, although they may be included in the total catch. **South Carolina** recently instituted a permitting system to document total eel gear and commercial harvest (B. McCord, South Carolina Department of Natural Resources, pers.comm.). Traps, pots, fyke nets, and dip nets are permitted in coastal waters. Fishing for eel in coastal waters is often conducted under the guise of fishing for crabs.

Eel fishing in **Georgia** was restricted to coastal waters prior to 1980 when inland fishing was permitted (Helfman 1982). Catch, but not effort, data is available because no specific license is required to fish eel. The **Florida** pot fishery has a 1.25 x 2.5-cm minimum mesh size and no minimum catch size limit, although frequency data indicates that the minimum size harvested by Florida pots is approximately 12 inches (J. Crumpton, Florida Game and Freshwater Fish Commission, Eustis pers. comm.).

1.3.2. Glass Eel Fishery

Maine landings of glass eel have been recorded separately from landings of adult eel since 1994. The elver/glass eel landings and value for 1994 and 1995 (DMR and DIFW 1996) were:

Year	Pounds landed	Value (\$)	Average Price (\$) per Pound
1994	7,347	367,350	50
1995	16,599	3,821,842	230

1.3.3 Bait Fishery

The information available from NMFS concerning eel harvested for bait indicate a decrease in pounds harvested. However, during this period average eel weight ranged from 0.25 to more than 1 pound. While the data needs to also be adjusted for numbers, it is arguable that this trend would remain apparent in light of such adjustments. In addition, recreational bait harvest is not recorded.

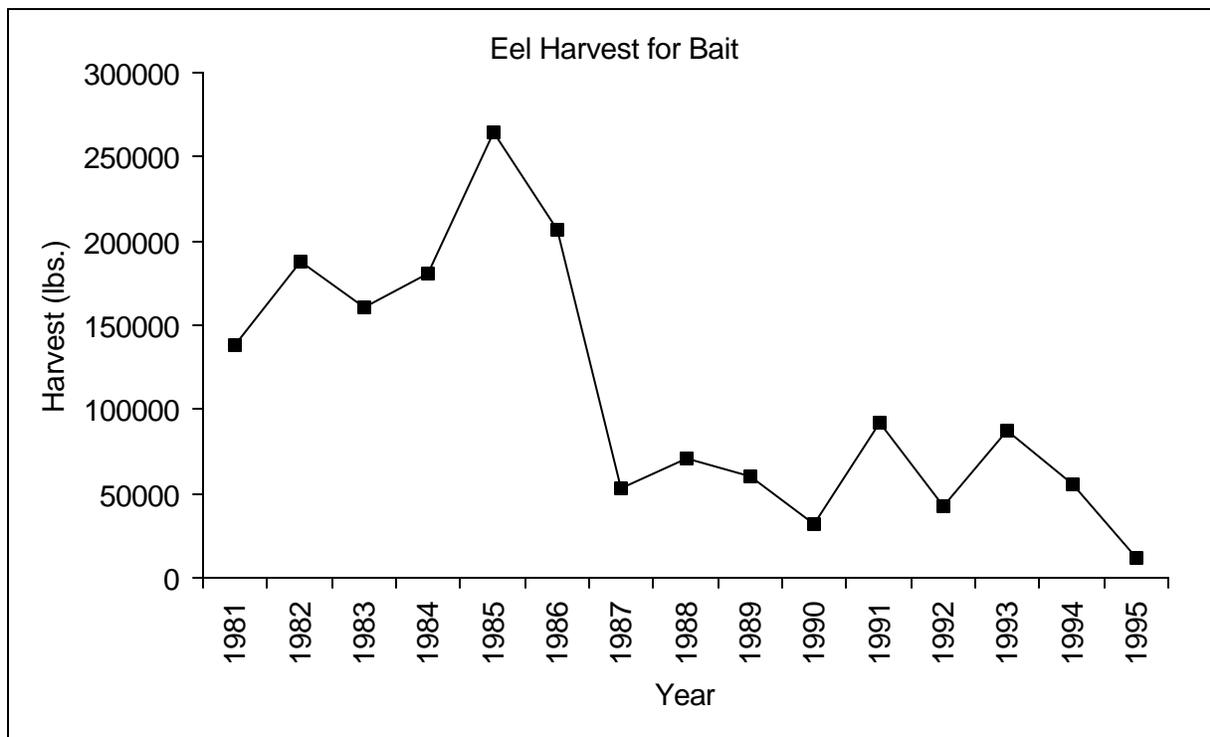


Figure 7. Harvest of American eel for bait (1981-1995) (NMFS)

1.3.4 Overall Commercial Fishery

1.3.4.1 Landings vs. Live Exports

Landings of American eel reported to the National Marine Fisheries Service (NMFS) were variable from 1970 to 1979 with lows in 1973 and 1977 of 592,091 kgs and 955,182 kgs and highs in 1975 and 1979 of 1,610,409 kgs and 1,648,607 kgs respectively. The trend shifted predominantly downward from 1979 to 1995 with a 76.7% decrease in kgs landed from 1979's high to a record low of 384,830 kgs in 1994.

Landings of American eel reported to NMFS were often far below the weight of eel exports reported by the U.S. Census Bureau. In 1993, a harvest of 400 tons of eel was reported to the NMFS but data from the Census Bureau indicate that 1,043 tons of live eel were exported, or 261% more than the reported harvest. Reported harvest decreased 45% during the three-year period from 1993 through 1995. By 1995, the difference in harvest reported to the NMFS or to the Census bureau had dropped to 3.6%.

1.3.4.2 Number and Value of Exports

The number of reported shipments of live American eel from 1992 to 1995 rose 153%, from a low of 240 to a high of 367. The number of reported shipments dropped again in 1996 to 308. The total value of American eel shipments rose dramatically during the time period. Values held relatively steady in 1992 and 1993 at around \$4,600,000, but began to rise in 1994 to \$6,967,019 and then increased in 1995 to \$10,688,579. This represented a 230% increase from the 1992 low. The values dropped again in 1996 to \$8,748,560, but remained 188% above 1992.

The mean value per shipment of American eel increased from 1993 to 1996, but showed a differential rate of increase dependent upon whether the shipment was destined for a European or Asian port. The mean value of a European bound shipment in 1993 was \$14,184. The mean value for a similar shipment increased 65.0% in 1996 to a four year high of \$23,438. The mean value of an Asian bound shipment in 1993 was \$24,297. The mean value rose 59.9% in 1994 to \$38,862 and continued to increase to a four year high of \$42,707 in 1996, for a total 75.8% increase over the 1993 value. The difference in mean shipment value between shipments bound for European and Asian destinations increased from 1992 to 1996 with Asian shipments valued 72.3% more than European shipments in 1992 to an 82.2% higher value for Asian destinations in 1996.

During 1996 the number of live American eel export shipments showed a bimodal distribution with peaks in April and October of 63 and 34 shipments respectively. This contrasted with three shipments of 3 in January, 11 in August, and 8 in December. The total weight of those shipments showed a similar pattern ranging from 2,059 kgs in January to 122,321 kgs in April, dropping to 11,658 kgs in August, rising again to 78,102 kgs in October, and finally ending the year with 12,959 kgs in December. The value of live American eel shipments in 1996 likewise followed a bimodal pattern with peaks of \$2,438,580 in April and \$659,343 in October. The distribution of shipping patterns changed in both port of exportation and port of destination from 1993 to 1996. In both years New York handled the largest number of shipments with 135 in 1993 and 165 in 1996. Boston with 92 shipments and Washington, DC with 51 were second and third largest in 1993. However, by 1996 Maine border ports with shipments trucked to Canada tied for second largest number with Washington, DC at 46. Traffic at Boston dropped to only 13 shipments for 1996. In 1993, 280 shipments or 90.9% of total exportations of live American eel were destined for European ports while 28 or 9.1% were destined for Asian ports. Although the same number of shipments were exported in 1996 as in 1993 (308),

the pattern of destination ports shifted so that 36.6% of shipments went to Asian ports, 47.4% to European ports, and 16.2% went to North American destinations.

Data for weight (kg) of American eel landed in the US for 1970 to 1995 were obtained from National Marine Fisheries Service (NMFS) (personal communication from the NMFS, Fisheries Statistics and Economics Division). Yearly export figures for live American eel shipments for 1993 through 1995 were obtained from U.S. Exports of Merchandise issued by the US Census Bureau (USCB). Monthly figures for live American eel exports for 1996 were obtained from individual monthly CD-ROMS for the U.S. Exports of Merchandise.

Information on American eel landings is collected by NMFS from the states of Connecticut, Delaware, Massachusetts, Maryland, Maine, North Carolina, New Jersey, New York, and Virginia. These data document landings from the majority of states with commercial American eel fisheries, but must be considered only a partial summary, as several other range states are not included.

Information in U.S. Exports of Merchandise is provided by shippers at the time of exportation via submission of a Shipper's Export Declaration (SED) to U.S. Customs Service (USCS). USCS forwards that information to the US Census Bureau for compilation and dissemination to the public. Shippers are required to furnish SED's for all export shipments valued in excess of \$2,500, but this valuation level may mean that some small American eel shipments are not reported at the time of exportation.

There is a further caveat in the use of these data sets as neither differentiates among American eel life stages. In all likelihood, NMFS data consist almost exclusively of adult American eel as it is based on reported landings. USCB data is probably based on adult American eel shipments, but may include some portion of immature American eel, primarily the glass eel or elver stages.

1.3.5 Recreational fisheries

Few recreational anglers directly target eel. Eel, for the most part, are caught incidentally by hook and line fishermen when fishing for other species. The NMFS Marine Recreational Fisheries Statistics Survey (MRFSS), which has surveyed recreational catch in ocean and coastal county waters since 1981, shows a declining trend in the catch of eel during the latter part of the 1990's. From the Atlantic coast area surveyed, the estimated total annual catch of eel ranged from 212,690 eel per year in 1982 to 36,741 eel per year in 1997. About one half of the eel caught were released alive by the anglers. Eel are often purchased by recreational fishermen for use as bait for larger gamefish such as striped bass, and some recreational fishermen may catch eels and then utilize them as bait

1.3.6 Subsistence fisheries

Little is known as to the current extent (i.e., quantity) of subsistence fisheries for American eel. American eel are a valuable subsistence food source for some European and Asian ethnic groups, and, as noted earlier, represent an important food, cultural, and spiritual resource to many Native American tribes.

1.4 Habitat Considerations

1.4.1 Habitat Important to the Stocks

1.4.1.1 Description of Habitat

A habitat area of particular concern is defined, as those waters, substrate, and conditions required for population survival. Such habitat may be limiting for spawning, breeding, feeding, or growth to maturity.

Information inferred from commercial harvest records and various stock assessment efforts indicate that American eel are found in most types of habitats including the offshore, mid-water and bottom areas of lakes, estuaries and large streams. American eel are found to be most prevalent in the nearshore, shallow embayments and tributaries (Adams and Hankinson 1928, Facey and LaBar 1981, GLFC 1996, Helfman et al. 1983, NYSDEC 1997a & b).

American eel are classified as a warmwater species (Adams and Hankinson 1928) that are most abundant in relatively warm streams and shallow lakes or embayments (Ogden 1970), while relatively scarce in deep, steep gradient cold-water lakes (Smith and Saunders 1955). Based on distribution and diet preferences, American eel appear to be very adaptable creatures with the ability to exploit many habitat and food types. Some juvenile American eel, for example, seek out riverine habitat until reaching maturity at which time they return to the ocean. These habitats provide the conditions needed by the organisms (insects, crustaceans, fishes) that eel forage upon.

American eel are bottom dwellers while in estuaries, rivers, and lakes. The presence of soft, undisturbed bottom sediments may be important to migrating elvers for shelter (Facey and Van Den Avyle 1987). American eel have been reported in mud burrows with their heads protruding (Fahay 1978). Few other freshwater fishes display similar habitat use, and as a result, interspecific competition for living space may be limited (Facey and Van Den Avyle 1987). Estimates of the home range of eel extend to 3.4 ha in small streams, tidal rivers, and tidal creeks (Gunning and Shoop 1962, Bianchini et al. 1982, Bozeman et al. 1985) and 2.4 to 65.4 ha in a large lake (LaBar and Facey 1983).

Current research shows extensive use and home-range development of shallow lakes (< 17meters) by American Eel (Daniels 1999). Many riverine systems utilized by American eel in North America contain lakes and large bodies of water, but only the St. Lawrence

basin includes the large inland Lake Ontario. This system is, therefore, the exception and raises doubt that the lake proper is the desired “end point” for the freshwater, inland migration of eel. While Lake Ontario may support a percentage of the stock at any one time, it is likely that the eel inherently continue to seek out riverine habitat in Lake Ontario tributaries, as they do in other East Coast streams. Lake Ontario is very limited in shallow habitats (due to its depth and narrow littoral area) and American eel must seek out their preferred forage in the habitat where it is abundant, such as in embayments and rivers where benthic invertebrate densities are found to be highest (Lary and Busch 1997).

Spawning Habitat

American eel are highly migratory, with spawning and larval development and migration occurring in the open ocean, feeding and growth occurring in estuaries and fresh waters, and migration of adults occurring in the ocean again to complete the life cycle [catadromous life cycle]. American eel spawn in the Sargasso Sea although it has never been directly observed in the field (Facey and Van Den Avyle 1987).

The Sargasso Sea is an oval area in the middle of the Atlantic Ocean, between the West Indies and the Azores, of nearly 5.2 million km² (2 million miles²). Although the boundaries are not easily delineated, the area is identified as the “eye” of a large, slow, clockwise moving gyre of very clear, deep blue colored, warm surface waters, with elevated salinity. The Gulf Stream provides the western boundary, which along with other ocean gyres, such as the North Equatorial Current, encircles the Sargasso. According to Ginsberg (1996), Portuguese sailors named the area for its seaweed since the seaweed’s bulbous floats are similar to grapes (sargaco is the Portuguese word for grape). Sargassum seaweed floats in patches and grows through budding. The warm waters of the Sargasso Sea are low in nutrients, which is attributed to its isolation from the deeper, nutrient rich, cold waters (average depth greater than 3 miles). Plankton production is about one-third the oceanic average, however, tiny crabs, shrimp, octopus and other marine animals are abundant among Sargassum.

Although specific spawning areas used by American eel and their habitat parameters have not been identified, Miller (1995) reported two major distribution patterns for leptocephali. The highest abundance of leptocephali were identified in areas located near fronts in the west of the Subtropical Convergence Zone (STCZ). The smallest leptocephali were reported by Miller (1995) to have been collected near the Bahama Banks in the Florida Current and at stations close to the southerly fronts in the western STCZ. Miller (1995) attributes the concentration of leptocephali to “entrainment by anticyclonic circulation northeast of the northern Bahamas.”

American eel from throughout their range are believed to synchronize their arrival at the spawning grounds. Morphological and physiological evidence suggests that they may spawn in the upper few hundred meters of the water column (Kleckner et al. 1983, McCleave and Kleckner 1985). Spawning has been inferred to take place from February to April within a broad area in the vicinity of the Sargasso Sea between 52° to 72° W longitude and 19° and 29° N latitude (McCleave et al. 1987). Kleckner et al. (1983)

suggested that thermal fronts separating the northern and southern water masses of the Sargasso Sea form the northern limit of American eel spawning and that some feature of the surface water mass in the southern Sargasso Sea serves as a cue for adult American eel to cease migration and begin spawning activity. After spawning, the spent eel are assumed to die (Facey and Van Den Avyle 1987).

American eel are dioecious, oviparous, and rely on external fertilization. Fertilized eggs reached the gastrula stage before dying 15 h later at 20 ° C (Sorensen and Winn 1984). Artificially spawned Japanese eel (*Anguilla japonica*) are known to hatch in 38-45 hours at 23 ° C (Yamamoto and Yamauchi 1974). Spawning occurs in winter and early spring (Wippelhauser et al. 1985, Kleckner and McCleave 1985, McCleave et al. 1987) probably in association with, or delimited by, density fronts meandering east-west in the Sargasso Sea (Kleckner and McCleave 1988). Eggs hatch in about two days in the warm water (Yamamoto and Yamauchi 1974), releasing the leptocephali. Knowledge of the spawning area is based on the distribution of the smallest leptocephali, as adults have never been observed in the Sargasso Sea.

Leptocephali are transported from the spawning grounds to the eastern seaboard of North America by the Antilles Current, the Florida Current, and the Gulf Stream (Facey and Van Den Avyle 1987). The leptocephali drift and swim in the upper 300 m of the ocean for several months, growing slowly to a length of 5-6 cm (Kleckner and McCleave 1985). Most planktonic leptocephali undergo metamorphosis into glass eel at 5.5-6.5 cm in length at 8 to 12 months of age (Facey and Van Den Avyle 1987), that actively migrate from the offshore waters to the coastal embayments and rivers. American eel apparently take advantage of inflowing tides to move into tidal areas (Wippelhauser and McCleave 1987).

Nursery and Juvenile Habitat

Glass eel enter estuaries and ascend the tidal portion of rivers during winter and spring, earlier in the southern portion of the range, later in the northern portion (Helfman et al. 1984a, McCleave and Kleckner 1982) by drifting on flood tides and holding position near bottom on ebb tides, a migratory tactic known as selective tidal stream transport (McCleave and Kleckner 1982, Wippelhauser and McCleave 1987). Glass eel also ascend by active swimming along shore in the estuaries (Sheldon and McCleave 1985), and above tidal influence (Barbin and Krueger 1994).

Upstream migrating glass eel metamorphose into elvers. Glass eel and elvers burrow or rest in deep water during the day (Deelder 1958). Upstream migrations may be triggered by changes in water chemistry caused by the intrusion of estuarine water during high spring tides (Sorensen and Bianchini 1986).

Limited work on preferred freshwater habitats indicates both lentic and lotic habitats are used and growth appears to be more related to density and availability of food than to water body (Oliveira and Krueger 1999). Bigelow and Schroeder (1953) reported that

some elvers are able to surmount obstacles such as falls, dams, and damp rocks during their upstream migrations.

Observation of elver migrations in coastal Rhode Island streams indicates that the main concentration of elvers required about one month to move a distance of 200 m above the tidal zone in a stream with an average gradient of 4 m/km (Haro and Krueger 1991). Elvers orient to river currents for their upstream migration (Tesch 1977) and are strongly attracted to the odor of decaying leaf detritus (Sorensen 1986). Further migration may occur gradually for months or even years (Haro and Krueger 1991).

Elvers exhibit drab pigmentation, dark on the back and often yellowish on the ventral surface, leading to the name yellow eel for this stage. Yellow eel inhabit a variety of habitats and feed opportunistically on various bottom- and near bottom-dwelling animals, mostly invertebrates and slower fishes (Ogden 1970, Wenner and Musick 1975, Facey and LaBar 1981, Lookabaugh and Angermeier 1992, Denoncourt and Stauffer 1993).

Telemetry studies showed that yellow eel in a tidal creek were generally inactive during the day and active at night (Helfman et al. 1983). Growth rates of yellow eel are quite variable, reflecting both latitude (slower growth in the north) and productivity of the habitat, perhaps sex, and probably some difficulty in interpreting putative annual rings in otoliths. Even within a habitat, growth rates of individuals are variable. In Lake Champlain, Vermont, weight of eel was well predicted by length (variation in length accounting for 93% of the variation in weight), but age was poorly predicted by length (accounting for only 27% of the variation in age) (Facey and LaBar 1981). Illustrating the latitudinal trend in length, eel five years of age post-metamorphosis from Georgia averaged about 40 cm long (Helfman et al. 1984b), from South Carolina about 50 cm (Harrell and Loyacano 1980; Hanson and Eversole 1984), while in New Jersey they were about 25 cm (Ogden 1970), and in Newfoundland only about 28 cm (Bouillon and Haedrich 1985). However, the trend is complicated by the habitat variability. In an estuarine habitat in Georgia, five-year-old eel averaged 38 cm, while in two freshwater habitats they averaged 33 cm and 40 cm (Helfman et al. 1984).

Adult Habitat

Yellow eel metamorphose into silver eel and migrate seaward to their spawning grounds. The American eel that are in freshwater drop downstream, traveling mostly at night (Bigelow and Schroeder 1953). During outmigration, adults may inhabit a broad range of depths throughout the water column. Turbine entrainment mitigation efforts at hydroelectric projects may be complicated since bypass systems must be accessed throughout the full depth of the turbine forebay (Richkus and Whalen 1999).

Adult oceanic habitat requirements are not known. However, American eel have been taken at depths greater than 6000 meters.

1.4.1.2 Identification of Habitat and Habitat Areas of Particular Concern

1.4.1.2.1 Ocean

Importance: Spawning - Reproduction for the panmictic population occurs in the Sargasso Sea, therefore, the area used for reproduction might be identified as a habitat area of particular concern. Until recently, no threats to the functional health of this area had been reported.

Concern: Sargassum seaweed is currently harvested in U.S. waters by trawling primarily by one company. The harvesting of sargassum began in 1976, but has only occurred in the Sargasso Sea since 1987. Since 1976, approximately 44,800 dry pounds of sargassum have been harvested, 33,500 pounds of which were from the Sargasso Sea (SAFMC 1998). It is unknown whether this harvest is having direct or indirect influences on American eel mortality. Harvesting sargassum is being eliminated in the south Atlantic EEZ and State waters by January 1, 2001 through a management plan adopted by the South Atlantic Fisheries Management Council (SAFMC 1998). The extent of eel bycatch in these operations is unknown. The drift of leptocephalus larvae from the Sargasso Sea towards the Atlantic coast may be impacted by changes in the ocean currents. Such changes have been predicted to be due to global warming. The potential impact on the drift of larvae is unknown at this time. Currents, primary production, and potential influence of toxins transferred from the adults to the eggs influence the success of hatch, larval migration, feeding and growth.

1.4.1.2.2 Continental shelf

Importance: Larval migration, feeding, growth; juvenile metamorphosis, migration, feeding and growth.

Concern: Glass eel survival (growth, distribution and abundance) is probably impacted by a variety of activities. Channel dredging, shoreline filling, and overboard spoil disposal are common throughout the Atlantic coast, but currently the effects are unknown. Additionally, these activities may damage American eel benthic habitat. However, the significance of this impact also remains unknown. Changes in salinity in embayments, as a result of dredging projects, could alter American eel distribution.

1.4.1.2.3 Estuaries/Rivers

Importance: Juvenile, sub-adult and adult migration corridors and feeding and growth areas for juvenile and sub-adult.

Concern: Elver and yellow eel abundance is probably also impacted by physical changes in the coastal and tributary habitats. Lost wetlands or access to wetlands and lost access to the upper reaches of tributaries have significantly decreased the availability of these important habitats with wetland loss estimated at 54% (Tiner 1984), and Atlantic coastal tributary access loss or restriction estimated at 84% (Busch et. al 1998).

Habitat factors are probably impacting the abundance and survival of yellow and silver eel. The nearshore, embayments, and tributaries provide important feeding and growth habitat. The availability of these habitats influences the density of the fish and may influence the determination of sex. Therefore, since females may be more common in lower density settings (Krueger and Oliveira 1999, Roncrati et al. 1997, Holmgren and Mosegaard 1996, Vladykov 1966, Liew 1982, Columbo and Rossi 1978), it is crucial that the quantity and quality of these habitats be protected and restored (including upstream access). The blockage or restriction to upstream migration caused by dams reduces or restricts the amount of available habitat to support eel distribution and growth. Fish that succeeded to reach upstream areas may also face significant stresses during downstream migration. If eel have to pass through turbines, mortality rates range from 10 to 60 percent (J. McCleave, U. of Maine, Person. Com.) and the amount of injury is not well documented.

An estimate of nearshore habitat area was obtained from NOAA’s Average-Annual, Three-Zone Salinity Metadata and for coastal stream length from Busch et al. (1998) as summarized in Table 4. Although the nearshore zones have been changed due to anthropogenic activities such as dredging, filling, discharges of waste and contaminants and the introduction of exotic species, nearshore habitat trend data are not available for this area. Preliminary data describing trends in lost stream habitat (access length) are presented in Section 1.4.1.2.3.3.

Table 4. Estimated current nearshore habitats (area) and length of access to historic river habitats (potential if currently restricted). Some geographic overlap occurs between the areal (nearshore) and linear (coastal rivers) habitat descriptions (Busch et al 1998).

Habitat		North Atlantic	Mid Atlantic	South Atlantic
Near-shore	Seawater Zone (>25ppt)	5,096 km ²	8,382 km ²	2,713 km ²
	Mixing Zone (0.5 – 25ppt)	229 km ²	10,969 km ²	8,300 km ²
	Tidal Fresh Zone (<0.5ppt)	54 km ²	947 km ²	1,159 km ²
Length of Coastal Rivers	Historic (unrestricted)	111,482 km	199,312 km	246,007 km

The nearshore area totals are the summation of areas designated by NOAA by drawing boundary lines across open water from shorelines. NOAA’s Coastal Assessment Framework (CAF) provided the geographies for the shorelines. Busch et al. (1998) used computer databases and a Geographic Information System to assess the quantity of historic (unrestricted) stream habitat available to American eel.

1.4.1.2.3.1 Access to Tributaries

Large numbers of elvers and yellow American eel migrate inland from coastal waters each year, but obstructions such as dams impede migrants in reaching appropriate upstream habitat. Because of their small size and limited swimming speed, elvers and young eel depend on tides to aid upstream migration. Altering stream flows may limit upstream recruitment. Although elvers will attempt to scale wetted substrates such as dam faces, for many of the migrants dams probably limit migration (Tesch 1977). Cost effective passageways designed specifically for elvers and eel have been developed and tested in Europe, Canada, and New Zealand. Knowledge of where migrants accumulate at a barrier and of migrant size (length) is necessary for construction of passageways.

Downstream passage at hydropower dams may represent a major source of mortality to pre-spawning adults (Ritter et al 1997), but has received relatively little attention. Mortality rates for European eel are reported to range from 5-30% depending on turbine type and river flow (Haddingh 1994). The design of downstream passageways and the use of non-generating periods to reduce eel mortality is hindered by lack of knowledge of the downstream migration. For example, the environmental cues that trigger migration, the depth of migration, and the effects of light and water currents on eel behavior during migration, are all unknowns.

1.4.1.2.3.2. Fish passage

Fish passage is getting attention through the licensing or relicensing of dams for hydropower production and navigation. Upstream fish passage is usually a requirement but construction activities are mostly in the planning process. However, more than 90% of dams on the eastern seaboard are not hydroelectric facilities, and therefore have not been subject to continual relicensing and fish passage analysis.

Downstream passage of silver eel is a problem in streams with hydropower production facilities. Although the industry has been researching effective deterrence to passage mortality, turbine caused damage or mortality continues to be a problem.

1.4.1.2.3.3 Quantity-Stream Habitat

Busch et al (1998) used an ecosystem health assessment approach, developed for the Lake Ontario watershed (Busch and Lary 1996), to determine that Atlantic coastal streams from Maine to Florida have 15,115 dams that can hinder or prevent upstream and downstream fish movement. This results in a restriction or loss of access for fish to 84 percent of the stream habitat within this historic range. This is a potential reduction from 556,801 kilometers to 90,755 kilometers of stream habitat available for migratory and diadromous species such as American eel. The analyses were based upon the regional boundaries established by the USEPA database (Figure 8) and excluded obstruction caused by most natural barriers.

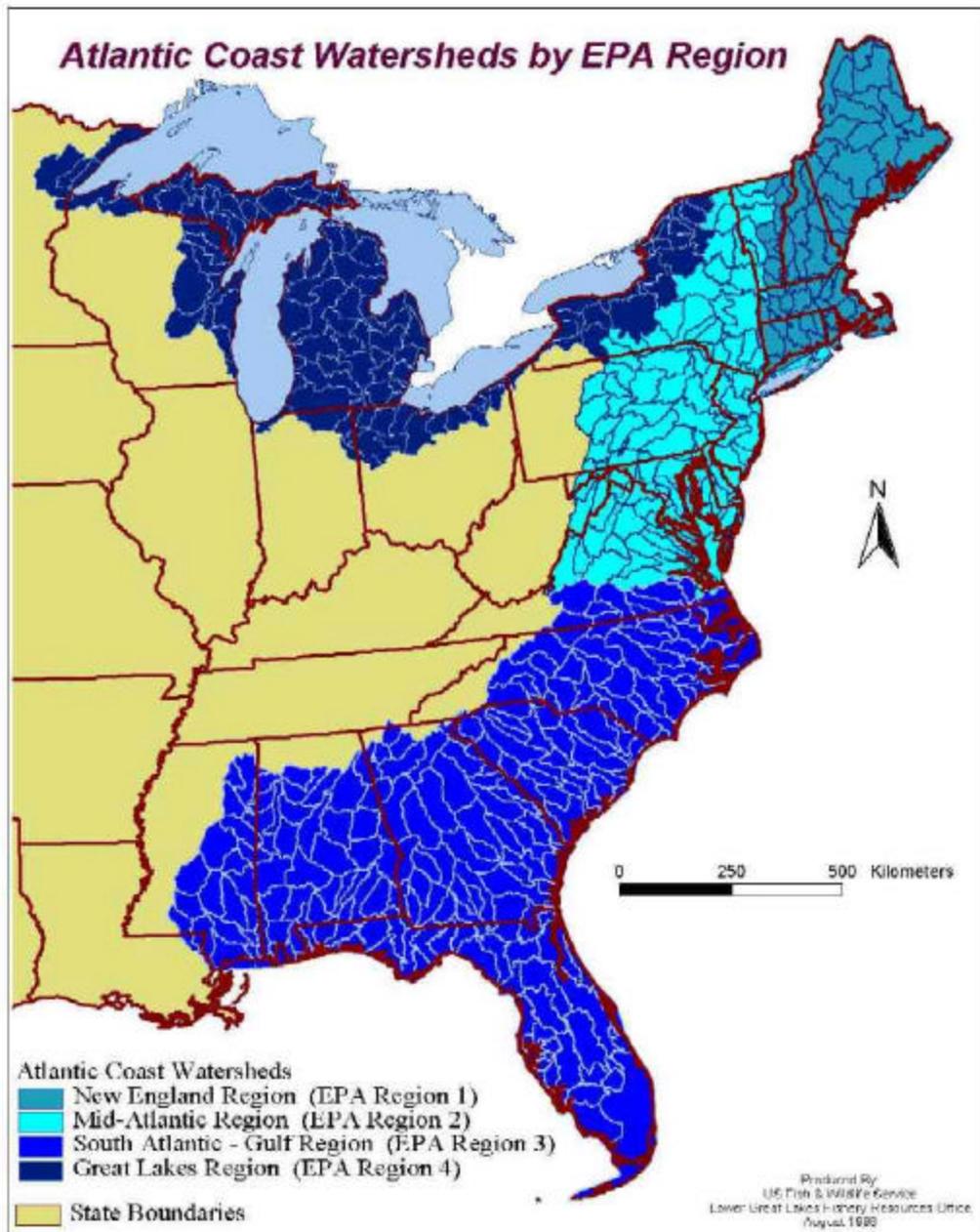


Figure 8. The regional boundaries from the USEPA database as used by Busch et al. (1998)

By region, the potential habitat loss was greatest (91%) in the North Atlantic region (Maine to Connecticut) where stream access is estimated to have been reduced from 111,482 kilometers to 10,349 unobstructed kilometers of stream length (Table 5). Stream habitat in the Mid Atlantic region (New York through Virginia) is estimated to have been reduced from 199,312 km to 24,534 km of unobstructed stream length (88% loss) (Table 6). The stream habitat in the South Atlantic region (North Carolina to Florida) is estimated to have decreased from 246,007 km to 55,872 km of unobstructed stream access, a 77% loss (Table 7).

Table 5. Eel habitat, North Atlantic region (Maine to Connecticut)

Huc4 Number and Watershed Name	Historical length (km)	Current Length (km)	Number of dams	Dams <10 ft.	Dams 10-24 ft.	Dams 25+ ft.	Hydro-Electric	Nav.
101 St. John River Basin	11,335	148	37	3	19	15	10	0
102 Penobscot River Basin	15,245	207	75	9	49	17	53	0
103 Kennebec River Basin	9,186	208	97	11	66	20	54	0
104 Androscoggin River Basin	4,467	195	95	15	57	23	54	0
105 Maine Coastal – St. Croix	10,884	5,166	98	22	69	7	34	0
106 Saco, ME, NH, MA	9,414	1,685	212	28	155	29	74	0
107 Merrimack River Basin	11,006	10	533	87	348	98	93	0
108 Connecticut River Basin	20,874	99	941	93	538	310	119	0
109 MA-RI Coastal Area	7,886	1,589	708	133	487	88	13	4
110 Connecticut Coastal	10,335	1,188	713	42	467	203	49	0
111 St. Francois Rriver Basin	850	1	13	5	5	3	8	0
Totals	111,482	10,348	3,522	448	2,260	813	561	4

Table 6. Eel habitat, Mid Atlantic region (New York through Virginia)

Huc4 Number and Watersheds Name	Historical length (km)	Current Length (km)	Number of dams	Dams <10 ft.	Dams 10-24 ft.	Dams 25+ ft.	Hydro-Electric	Nav.
201 Richelieu Basin including Lake Champlain drainage	9,126	1	235	24	125	83	68	1
202 Upper Hudson	22,389	1	660	91	373	194	64	17
203 Lower Hudson – Long Island	7,781	1,431	519	64	324	127	8	0
204 Delaware Coastal Area	26,934	5,148	1068	179	656	231	21	0
205 Susquehanna River Basin	52,331	251	684	75	324	285	19	2
206 Upper Chesapeake	14,884	8,862	157	13	93	51	3	0
207 Potomac River Basin	28,140	3,281	443	7	141	295	12	0
208 Lower Chesapeake	37,727	5,559	884	22	527	337	22	0
Totals	199,314	24,533	4650	475	2563	1603	217	20

Table 7. Eel habitat, South Atlantic region (North Carolina to Florida)

Huc4 Number and Watershed Name	Historical length (km)	Current Length (km)	No. of Dams	Dams <10 ft.	Dams 10-24 ft.	Dams 25+ ft.	Hydro Electric	Nav.
301 Chowan-Roanoke Coastal Dr.	36,775	3,632	371	3	257	230	15	0
302 Neuse-Pamlico Coastal Dr.	23,324	12,452	445	6	268	149	1	0
303 Cape Fear Coastal Dr.	20,471	5,990	626	5	385	226	9	3
304 Pee Dee Coastal Dr.	35,880	6,139	1034	58	637	333	10	0
305 Edisto-Santee Coastal Dr.	41,504	7,003	1942	52	1073	810	66	0
306 Ogeechee-Savannah Coastal Dr.	34,604	4,508	1028	33	546	447	30	1
307 Altamaha-St. Marys Coastal Dr.	37,172	4,673	1353	31	763	559	10	0
308 St. Johns Coastal Dr.	82,334	6,582	40		18	19	0	4
309 Southern Florida Coastal Dr.	8,044	4,893	105	6	46	45	0	0
Totals	246,008	55,872	6944	194	3993	2818	141	8

In the assessment of the Atlantic Coast watersheds, the St. Lawrence River - Lake Ontario watershed was included. However, data were incomplete because only the United States'

side of the Lake Ontario basin was assessed. Construction of the Moses Saunders Dam (1954-58) impeded upstream and downstream migration on the St. Lawrence River, restricting access by migratory fish from the Atlantic Ocean to Lake Ontario and the Finger Lakes system. In 1974, an eel ladder was constructed, which probably reduced the effects of the lack of upstream passage at the Moses Saunders Dam. The number of American eel ascending the ladder has decreased dramatically in recent years (see Figure 4).

While a number of American eel have utilized the Saunders eel ladder, an assessment of the percent passed to the total number of eel in the system has not been conducted. It is unknown whether the number currently passed is sufficient to sustain the Saint Lawrence River/Lake Ontario stock.

In the U.S. portion of the watershed, 455 dams result in 24,693 km of stream habitat lost or restricted from a total of 30,085 km (82% loss) to migratory fish originating in or having Lake Ontario as their destination (Table 8). Since dams on the St. Lawrence River hinder fish movement through the St. Lawrence River to and from the Atlantic Ocean, the total kilometers of stream access lost or restricted in the Lake Ontario and St. Lawrence River watershed is actually much larger.

Table 8. Eel habitat, Great Lakes region¹ (New York and Ontario to Quebec)

Huc4 Number and Watershed Name	Historical length (km)	Current Length (km)	Number of dams	Dams <10 ft.	Dams 10-24 ft.	Dams 25+ ft.	Hydro-Electric	Nav.
412 Eastern Lake Erie Drainage	113	66	4	0	1	3	3	0
413 Southwestern Lake Ontario Drainage	8,076	1,827	67	7	45	15	9	1
414 Southeastern Lake Ontario Drainage	16,156	2,877	159	33	74	52	19	15
415 Lake Ontario-St. Lawrence Drainage	5,740	622	225	24	118	83	150	2
Totals	30,085	5,392	455	64	238	153	181	18

The dam database used by Busch et al. (1998) included information on dam heights (Tables 5-8). It identified 3,512 dams in the North Atlantic Region of which 448 are less than 10 ft. high, 2,260 are between 10 and 24 ft. high, and 813 are higher than 25 ft. Of all the dams, 561 are used for hydropower production. The Mid-Atlantic Region has 4,650 dams of which 475 are less than 10 ft. high, 2,563 are between 10 and 24 ft. high, and 1,603 are higher than 25 ft. And, 217 dams are used for hydropower production. In the South Atlantic Region, the 6,944 dams identified included 194 that are less than 10 ft. high, 3,993 between 10 and 24 ft., and 2,818 higher than 25 ft. Of the dams in this region, 141 are used for hydropower production. Dams in the US Lake Ontario basin include 64 that are less than 10 ft. high, 238 that are 10-24 ft. high, and 153 that are 25 ft. or higher. Hydropower production was the use identified for 181 dams.

¹ No Canadian data were available, therefore, data presented are only from the U.S. side of Lake Ontario.

Various factors influence successful upstream or downstream migration of American eel past dams. Busch et al. (1998) evaluated fish migration restrictions due to dams by examining limited data on the presence or absence of American eel above and below dams. The preliminary results indicate that although height and use (purpose) for the facility appear to be important factors, other criteria need to be evaluated including slope, construction material, water flow, location of the dam in the watershed, and operational procedures.

Dams that require special licenses such as for hydropower production or navigation provide opportunities for fish passage if required by the resource management agencies. However, only 1,100 were identified for hydropower production and 50 for navigation out of the total number of 15,570 identified dams. Therefore, only 7% of these dams are covered by regulatory programs that could provide fish passage. The other specific uses for dams identified in the database include water-level control, water supply, and recreation.

Downstream passage to the American eel's historic habitat is just as important as successful upstream access. Therefore, turbine-induced mortality during downstream migration needs to be resolved since it impacts prespawning adult silver eel. Investigations have found turbine-induced mortality of eel to range from 5 to 60%, depending on the flow through the turbines and on the length of the fish (Hadderingh 1990; McCleave Person. Comm.). Experiments using lights to deflect American eel from water intakes into bypass areas have been successful at some hydroelectric power stations (Hadderingh 1990). The reduced numbers of American eel which currently utilize Lake Ontario tributaries, such as the Oswego River, presumably move upstream via the locks and require downstream passage in order to reach Lake Ontario. Haro (1996) also provides information on various methods of mitigating turbine entrainment and mortality by diverting eel around turbine intakes to bypass entrances during downstream migration. Experiments carried out using behavioral mitigation techniques such as strobe lighting have shown some success in diverting eel from turbine intakes. Other behavioral methods such as water and air jet curtains and weak electric fields have not shown similar success (Richkus and Whalen 1999). Research on mechanical mitigation devices such as angled bar racks, louvers, and screens has provided mostly inconclusive although insightful results that might warrant further research (Richkus and Whalen 1999).

1.4.1.2.3.4 Quality

Temperature: American eel are capable of tolerating a wide range of physiochemical conditions. Elvers have been found in waters as low as -0.8°C (Jeffries 1960). Yellow eel held at less than 5°C for over 5 weeks stopped feeding and reduced their oxygen consumption (Walsh et al. 1983). Yellow eel are known to hibernate in the mud during the winter (Fahay 1978). Preferred summer temperatures have been reported at $17.4 \pm 2^{\circ}\text{C}$ for yellow eel (Karlsson et al. 1984). American eel are apparently capable of surviving short-term thermal shocks. American eel have been reported to survive passage through a nuclear power plant, during which they were exposed to elevated temperatures for 1 to 1.5 h (Marcy 1973).

Salinity: Little work has been done on the salinity requirements of American eel. The leptocephali have been reported to be in near-ionic equilibrium with sea water (Hulet et al. 1972). Elvers are known to delay their upstream migration at the freshwater brackish interface which is believed to permit some physiological adjustments to the new freshwater regime (Sorensen and Bianchini 1986). Yellow eel occupy niches in freshwater and brackish regimes. Silver eel migrate from freshwater to the open ocean. From the above, postlarval American eel appear to be euryhaline.

1.4.1.3 HABITAT ISSUES

Habitat includes the physical, chemical and biological setting and requirements needed to support all life functions of American eel.

Spawning Areas

Spawning takes place in the Sargasso Sea. The specific location(s) and the specific habitat characteristics in this 5.2 million km² (2 million miles²) area have not been reported. Loss of spawning habitat would result in significant impacts on American eel. Threats to American eel populations and spawning habitat include sea level rise / land subsidence, and contaminants. Global warming and the subsequent rise in sea level could adversely affect American eel spawning activities. Sea level is predicted to rise above current levels by approximately 50 centimeters to 1 meter by the year 2100 (Oerlemans 1989, Titus et al 1991). The effects on this sea level rise on the currents and oceanic conditions that conduct larval migration are completely unknown. Land subsidence along the Atlantic Coast adds to the effect of sea level rise, resulting in an increase of 25-30 centimeters greater than the global average (Hull and Titus 1986). Such an increase could fundamentally alter current eel habitat. In addition, American eel accumulate significant amounts of contaminants in reproductive tissue. Thus, the potential to impair reproduction, if contaminants are not carefully monitored in important eel habitats.

Feeding and Growth Areas

Data from commercial harvest records for elvers/glass eel, yellow eel and stock assessments indicate that eel are found in most types of habitat including the offshore, mid-water and bottom areas of estuaries, embayments, rivers, streams, and lakes. However, eel are found to be most prevalent in the nearshore, shallow embayments and tributaries (Adams and Hankinson 1928; Facey and LaBar 1981; Helfman et al. 1983; GLFC 1996; NYSDEC 1997a & b).

American eel are classified as a warmwater species (Adams and Hankinson 1928) that are most abundant in relatively warm streams and shallow lakes or embayments (Ogden 1970), while relatively scarce in deep, steep gradient cold-water lakes (Smith and Saunders 1955). Limited work on preferred freshwater habitats indicates both lentic and lotic habitats are used and growth appears to be related to density and availability of food (Krueger and Oliveira 1999). Stream use appears to be important to elvers (Bigelow and Schroeder 1953) and yellow eel.

Issues and Concerns

Various habitat stresses and losses impact American eel abundance, health, distribution, and growth rates (Lary and Busch 1997; Richkus and Whalen 1999). These impacts have not been adequately described. Furthermore, since habitat management is also the responsibility of agencies other than the primary participants in the ASMFC, habitat issues need to be addressed through interagency coordination and other avenues (i.e., legislation, policy, enforcement, etc.).

Channel dredging and overboard spoil disposal are common throughout the Atlantic coast, but currently have unknown effects on American eel. Changes in salinity as a result of dredging projects could alter American eel distribution. Additionally, dredging associated with whelk and other fisheries may damage American eel benthic habitat; however, the significance of this impact also remains unknown.

Although pollution has the potential to adversely impact all the life stages of American eel, there are no data to suggest unusual sensitivity by American eel to urban or agricultural contaminants (e.g., pesticides and herbicides). However, due to their longevity and habitat use, high levels of contaminants have been reported in eel (Hodson et al. 1994). Additional information needs to be obtained to determine the impacts of contaminants on American eel. Also a new, specific area of concern deals with coastal wetlands and the potential impact caused by spraying insecticides for mosquito control at the time glass eel enter these areas. Potential impacts from contaminants include mortality, changes in behavior, and decreases in fecundity.

2.0 GOALS AND OBJECTIVES

2.1 SPECIFICATION OF MANAGEMENT UNIT

The specific “management unit” for this Fishery Management Plan is defined as that portion of the American eel population occurring in the territorial seas and inland waters along the Atlantic coast from Maine to Florida.

Significant numbers of eel use areas/habitats that are outside the jurisdictional boundaries of the state agencies participating in the ASMFC. These include watersheds in the Canadian Atlantic Provinces, upstream freshwater reaches that are managed by inland fish and wildlife agencies of ASMFC member states and regional institutions such as the Gulf States Marine Fisheries Commission, and those waters within Native American Reservations where Tribal Governments have jurisdiction. U.S. eel management needs to proactively include and coordinate the interests and approaches of the ASMFC with applicable jurisdictions/agencies in order to implement holistic management, including protection and enhancement of this species.

Since all eel reproduction occurs in the Sargasso Sea (Figure 2), the health and availability of this area to support reproduction is of significant importance. Activities impacting the health of the Sargasso Sea and reproductive success of eel, although outside direct management of the ASMFC, need to be addressed through other applicable authorities. The Secretary of Commerce and the National Marine Fisheries Service may take complementary management action in the Exclusive Economic Zone, as per the recommendations in Section 4.2.2.

The Goals of the Fishery Management Plan for American Eel are to:

1. 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 population; and
2. Provide for sustainable commercial, subsistence, and recreational fisheries by preventing overharvest of any eel life stage.

Primary Objectives

1. Improve knowledge of eel harvest at all life stages through mandatory reporting of harvest and effort by commercial fishers and dealers, and enhanced recreational fisheries monitoring;
2. Increase understanding of factors affecting eel population dynamics and life history through increased research and monitoring;
3. Protect and enhance American eel abundance in all watersheds where eel now occur;
4. Where practical, restore American eel to those waters where they had historical abundance but may now be absent by providing access to inland waters for glass eel, elvers, and yellow eel and adequate escapement to the ocean for pre-spawning adult eel; and
5. Investigate the abundance level of eel at the various life stages, necessary to provide adequate forage for natural predators and support ecosystem health and food chain structure.

Long-Term Objectives

- A Encourage protection of eel spawning, nursery and growth habitats with and/or through the agencies having jurisdiction over these areas;
- B Protect and enhance inland and coastal water quality to protect the health of the eel population and to reduce bioaccumulation of toxic substances; and
- C Coordinate harvest and abundance monitoring with resource management agencies outside the East Coast of the U.S.

3.0 MONITORING PROGRAM SPECIFICATIONS/ELEMENTS

The American Eel FMP encourages all state fishery management agencies to pursue full implementation of the Atlantic Coastal Cooperative Statistics Program (ACCSP), which will meet the monitoring and reporting requirements of this FMP. The American Eel FMP recommends a transition or phased-in approach be adopted to allow for full implementation of the ACCSP. Until such time as ACCSP is implemented, the American Eel FMP encourages state fishery management agencies to initiate implementation of specific ACCSP modules, and/or pursue pilot and evaluation studies to assist in development of reporting programs to meet the ACCSP standards (please refer to the ACCSP Program Design document for specific reporting requirements and standards; Contact - Joe Moran, ASMFC). The ACCSP partners are the 15 Atlantic coastal states (Maine – Florida), the District of Columbia, the Potomac River Fisheries Commission, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the three fishery management Councils, and the Atlantic States Marine Fisheries Commission. Participation by program partners in the ACCSP does not relieve states from their

responsibilities in collating and submitting harvest/monitoring reports to the Commission as may be required under this FMP.

Management of American eel will be based on scientific advice provided by the scientific community, as well as input from public hearings and from the Advisory Panel. Management will strive for a long-term viable population, supporting fisheries and inter-dependent wildlife populations. Effective management will require monitoring population abundance at various life stages, monitoring fishing mortality (harvest and incidental), preventing habitat degradation, restoring fish habitat, as well as identifying and supporting research. The measures outlined below are designed to facilitate the management process. As new data become available and new assessment data provide new perspective, management elements will adapt in order to most effectively reach the goals and objectives.

3.1 ASSESSING ANNUAL RECRUITMENT

Little is known about annual recruitment of American eel. Although maximum fecundity can be estimated, natural larval mortality is estimated to be substantial. The number of larvae that survive to reach the coastal areas each year and transform to glass eel is unknown. Also, the annual variation in recruitment to elvers or yellow eel is unknown, as is the number that survive to sexual maturity. Because American eel are slow maturing and long-lived, current juvenile indexing techniques have limited applicability in describing the annual abundance and variations in the abundance of respective cohorts. This is due to the variability in age/length relationships, and therefore similar size classes of eel will include a number of year classes. Resolution of the aging issue requires further investigation and validation of techniques used for age determination, as is mentioned in Section 6 “Information and Research Needs.” Additional information regarding larval and juvenile survival is essential to assessing annual recruitment. Monitoring abundance of American eel for each of the defined life stages will be necessary for the establishment of multiple recruitment indices.

3.1.1 Annual Young-of-Year Abundance Survey

The glass eel and elver (young-of-year) life stages provide the most unique opportunity to assess the annual recruitment of each year’s cohort since young-of-year result from the previous winter’s spawning activity, and hence are all the same age. Known age is an attractive feature of the young-of-year life stage, which has shown to be problematic with all older life stages. Therefore, a fishery independent young-of-year abundance survey is proposed in accordance with the options provided below.

Measurement of young-of-year abundance is considerably cost effective since the gear required is inexpensive to purchase or manufacture, requires no additional expense for bait, and may be operated by relatively few persons. Also, since the young-of-year life stage and period of recruitment onto the Atlantic coast is short in duration, each annual assessment of young-of-year abundance would not amount to a long commitment of staff time.

Data from a young-of-year abundance survey could provide a barometer with which to gauge the efficacy of management action, given due consideration to the factors which affect spawning, larval survival, transport, metamorphosis, and subsequent recruitment of young-of-year onto the Atlantic coast. Young-of-year abundance indices may also provide a basis of inference for the

future abundance of each year's cohort, similar to abundance indices validated for other fish species.

Accordingly, states/jurisdictions will conduct annual fishery-independent surveys for young-of-year American eel. Each participating jurisdiction shall deploy appropriate gear to capture young of the year at a minimum of two locations over a six-week period. A variety of gear types are available for use, and states should use the gear most suitable to the habitat and geography within their jurisdiction. The cost of most gear ranges from \$200 to \$400 per unit.

The timing and placement of the young-of-year sampling gear will coincide with those periods of peak onshore migration of young-of-year. The locations selected will be those previously shown to catch young-of-year American eel and should provide as wide a geographic distribution as possible. Initially, stock assessment biologists may need to alter the timing and placement of the sampling gear in order to determine peak migration period and locations for the annual survey. Thereafter, standard stations and procedures will remain fixed.

At a minimum, the gear will be set so that they are operational during periods of rising or flood tides occurring at nighttime hours. During these conditions, gear will be checked as often as possible and emptied of their catch. The catch will be sorted and all specimens identified to their lowest taxonomic order, measured, weighed and enumerated as appropriate. Species which appear to be predators of young-of-year will be denoted. The entire catch of young-of-year will be weighed and counted, and each individual measured for total length. The number of young-of-year per unit weight (gram) will be determined for each catch examined. Standard statistical techniques (sub-sampling) will be used in instances where the catch of young-of-year is too large (i.e., several hundred individuals or more) to warrant a complete census.

In addition to the catch and by-catch of young-of-year, various environmental and climatological data will be recorded for each catch. These will include date, water and air temperatures, salinity, tide stage, and soak time. Notation of wind speed, direction and precipitation will be recorded. Also, a subjective judgement of the condition of the gear at the time of sampling will be made on an ordinal scale of one to four, with one equal to good, two equal to fair, three equal to poor, and four equal to void or unsuitable for indexing. The judgement will relate to the condition the gear was found in relation to the condition it was left in the previous day. Young-of-the year captured at or near obstructions should be released upstream of these obstructions whenever possible.

All states/jurisdictions, except those exempted by the Management Board, are required to conduct an annual young-of-year abundance survey, beginning in the year 2000, as described above. The Technical Committee shall advise the Management Board on exemptions as necessary. Those states that are initially exempted will be required to conduct the annual young-of-year survey by the year 2001. States shall submit proposals for instituting their surveys as per Section 5.1.2.

3.1.2 Annual Report of Harvest or Catch Per Unit of Effort

A catch per unit effort (CPUE) reporting requirement will be initiated by every state, if not already required, in order to develop abundance indices for each life stage (see Section 3.4.1 for mandatory reporting requirements).

3.2 ASSESSING SPAWNING STOCK BIOMASS

The annual spawning stock biomass for American eel populations along the Atlantic Coast is unknown. NMFS landings data provide limited estimates of silver eel harvest: 423 tons to 1,813 tons were harvested between 1970 to 1995 from the Atlantic coast. The New England and Mid-Atlantic regions of the Atlantic Coast produce the majority of the American eel commercial harvest. However these data are of limited use due to inadequate sampling of inland harvest areas and dealer locations. Also, since the harvest data from a number of inland and marine agencies may include a number of species and an unknown ratio of mature (silver) and maturing (yellow) eel, the current fishery dependent data are inadequate to describe the annual abundance and variations in abundance between years. In short, any estimate of abundance or population trends based on existing harvest data is questionable because of inconsistent reporting requirements across jurisdictions. Furthermore, fishery independent abundance data are generally lacking.

3.2.1 Fishery-independent monitoring of adults/sub-adults.

The silver or migratory stage of American eel provides an opportunity to monitor the abundance of the spawning stock. Although these fish will be of various sizes and ages, they are on their way to reproduce and will jointly contribute to the abundance of the next cohort. Therefore, the fishery independent reporting of emigrant counts, should be maintained, standardized, and expanded. In addition, certain ongoing/recent state surveys for eel abundance and distribution may be useful for fishery-independent monitoring of silver and yellow eel populations.

3.3 ASSESSING MORTALITY

American eel mortality has three components: natural, fishing, and incidental. Natural mortality includes factors such as predation and disease; fishing mortality includes harvest and bycatch; incidental mortality includes anthropogenic impacts from fish passage (for example through hydroelectric turbines), chemical spills or hazardous chemical exposures.

A sustainable mortality rate will allow for a certain level of harvest and incidental losses while still maintaining a viable spawning stock biomass. This rate has not been calculated for eel because of the difficulty in obtaining abundance data (population and harvest) by age throughout the species' range. Combined mortality at all life stages in salt and fresh water is largely responsible for controlling the population size of American eel across its range.

3.3.1 Natural Mortality

Although not documented, natural mortality is presumed to be very high at the leptocephalus stage, glass eel and elver stages due to the high fecundity of the species. This notion is based on the high fecundity (Wenner and Musick 1974; Barbin and McCleave, 1997) of this species. Natural mortality for yellow and silver eel also lack documentation.

3.3.2 Fishing Mortality

Fishing mortality has two components: directed fishing mortality (e.g., intentional harvest) and non-directed mortality (e.g., by-catch). Although reported commercial landings data show a continuing decrease in harvest since the late 1970's, changes in fishing effort or mortality rates are not available. This situation will be addressed through the implementation of the harvest reporting requirements outlined in Section 3.4.1, and the ability to use consistent harvest data in future stock assessments.

The amount of American eel bycatch in commercial and recreational fisheries remains unknown. Additional information will be required to determine the impact of bycatch. It is likely that bycatch of American eel are commonly discarded in the recreational fishery and unreported in total harvest. Bycatch for American eel should be quantified within a bycatch-monitoring module of the Atlantic Coastal Cooperative Statistics Program (ACCSP).

3.3.3 Incidental Mortality

As defined in this FMP, incidental mortality is also caused by anthropogenic activities other than harvest. Activities include damming (e.g., impingement, entrainment, and turbine caused injury) navigation locks (e.g., impingement, entrainment), industrial/municipal water intakes (e.g., impingement, entrainment), and those caused by chemicals (drastic salinity changes, spills, point source releases, and non-point source releases such as the application of insecticides in glass eel nursery areas). Accumulated contaminants may impact individuals directly as well as egg viability and larval survival. Compression of range through habitat restrictions may increase the significance of predation mortality.

More research is needed on the extent and impact of incidental mortality in order to improve future stock assessments. See Section 6.3 for related research recommendations.

3.4 SUMMARY OF MONITORING PROGRAMS

Numerous state and federal agencies, universities, and private organizations are involved in data collection programs to directly determine American eel population status. While existing monitoring programs may be useful in identifying general trends within specific areas if consistent data have been collected, each is complicated by factors that may bias the data, such as sampling error, inappropriate equipment, or incomplete sampling effort. Most existing fishery dependent and independent monitoring programs lack a comprehensive data collection goal.

The goal of a comprehensive American eel monitoring program is to produce the data needed to obtain an accurate assessment of the American eel population for making management decisions. States must improve the reporting of eel harvest data by gear, season, and harvest effort and life stage, as well as fishery-independent data.

In order to collect information to support accurate management decisions, a comprehensive monitoring plan must be developed. Such monitoring efforts should be standardized and be conducted in each of the cooperating states within the ASMFC. Fishery-dependent reporting requirements will include pounds landed, harvest method, gear, season, effort, and life stage (see

Section 3.4.1). In addition, the NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) and state surveys should be utilized to collect catch, harvest, and biological information regarding recreational and subsistence fisheries for American eel. States/jurisdictions are encouraged to fund expansion of the survey inland, where significant recreational fisheries for catadromous and anadromous fish are reported to occur. Lack of such information could have serious consequences in the assessment of the American eel stock. Wherever practical, state harvest reporting requirements will coincide with the current and future mandates of the ACCSP. Reporting elements not covered by the ACCSP should be covered by annual reports submitted in conjunction with this FMP.

3.4.1 Annual State Report on Regulations, Harvest, Bycatch and Fishery-Independent Surveys for American Eel.

Each state/jurisdiction shall be required to submit an annual report (in accordance with Section 5.1.2) detailing that state's regulations, catch, harvest, bycatch, fishery dependent and independent surveys, and characterization of other losses for American eel. The report will address each of the topics listed below.

1. Commercial fishery
 - a. Synopsis of regulations in place
 - b. Estimates of directed harvest, by month, by region as defined by the states
 1. Pounds landed by life stage and gear type (defined in advance by ASMFC)
 2. Biological data taken from representative sub-samples to include sex ratio and age structure (for yellow/silver eels), length and weight if available
 3. Estimated percent of harvest going to food versus bait
 - c. Estimates of export by season (provided by dealers)
 - d. Harvest data provided as CPUE (by life stage and gear type)
 - e. Permitted catch for personal use, if available
2. Recreational fishery
 - a. Synopsis of regulations in place
 - b. Estimate of recreational harvest by season (if available)
 1. Biological data taken from representative sub-samples to include sex ratio, age structure, length and weight (if available)
3. Fishery-independent monitoring
 - a. Results of the Annual Young-of-Year Abundance Survey (unless exempt)
 - b. Description of other fishery-independent surveys performed (methods, location, etc.) and results (if required in FMP)
 - c. Projects planned for next five years
4. Characterization of Other Losses

To the extent possible states/jurisdictions should attempt to characterize the losses of American eel, in number and weight by life stage or age, due to factors other than commercial and recreational fisheries. Such losses may include, but are not limited to the following:

- a. Impingement/entrainment mortalities of eel at power generation facilities, water intakes, and navigation locks
- b. Bycatch mortalities in commercial and recreational fisheries
- c. Confiscated poundage from illegal or undocumented fisheries (i.e., poaching)

- d. Scientific losses (i.e., samples collected for contaminants analysis, other studies)
- e. Mass mortalities of eel due to disease, spills or other causes

Commercial Catch and Effort Data Collection Programs

The ACCSP commercial data collection program will be a mandatory, trip-based system with all fishermen and dealers required to report a minimum set of standard data elements (refer to the ACCSP Program Design document for details). Submission of commercial fishermen and dealer reports will be required after the 10th of each month.

Any marine fishery products landed in any state must be reported by a dealer or a marine resource harvester acting as a dealer in that state. Any marine resource harvester or aquaculturist who sells, consigns, transfers, or barter marine fishery products to anyone other than a dealer would themselves be acting as a dealer and would therefore be responsible for reporting as a dealer.

Recreational Catch and Effort Data Collection Programs

The ACCSP recreational data collection program for private/rental and shore modes of fishing will be conducted through a combination telephone and intercept survey. Recreational effort data will be collected through a telephone survey with random sampling of households until such time as a more comprehensive universal sampling frame is established. Recreational catch data will be collected through an access-site intercept survey. A minimum set of standard data elements will be collected in both the telephone and intercept surveys (refer to the ACCSP Program Design document for details). The ACCSP will implement research and evaluation studies to expand sampling and improve the estimates of recreational catch and effort.

For-Hire Catch Effort Data Collection Programs

The ACCSP is conducting an evaluation study to determine the best method(s) of data collection for for-hire fisheries. A minimum set of standard data elements will be collected in all for-hire catch/effort surveys (refer to the ACCSP Program Design document for details).

Discard, Release, and Protected Species Interactions Monitoring Program

The ACCSP will require a combination of quantitative and qualitative methods for monitoring discard, release, and protected species interactions in commercial, recreational, and for-hire fisheries. Commercial fisheries will be monitored through an at-sea observer program and several qualitative programs, including strandings, entanglements, trend analysis of logbook reported data, and port sampling. Recreational fisheries will be monitored through add-ons to existing intercept surveys and additional questions added to the telephone survey. For-hire fisheries will be monitored through an at-sea observer program and several qualitative programs (refer to the ACCSP Program Design document for details).

3.4.2 Biological Information

The ACCSP will require the collection of baseline biological data on commercial, for-hire, and recreational fisheries. Biological data for commercial fisheries will be collected through port

sampling programs and at-sea observers. Biological data for recreational fisheries will be collected in conjunction with the access-intercept survey. Biological data for for-hire fisheries will be collected through existing surveys and at-sea observer programs. A minimum set of standard data elements will be collected in all biological sampling programs (refer to the ACCSP Program Design document for details). Priorities and target sampling levels will be determined by the ACCSP Biological Review Panel, in coordination with the Discard/Release Prioritization Committee.

3.4.3 Social and Economic Information

Commercial Fisheries

The ACCSP will require the collection of baseline social and economic data on all commercial fisheries (refer to the ACCSP Program Design document for details). A minimum set of standard data elements will be collected by all social and economic surveys (refer to the ACCSP Program Design document for details).

Recreational Fisheries

The ACCSP will require the collection of baseline social and economic data on all recreational fisheries through add-ons to existing recreational catch/effort surveys (refer to the ACCSP Program Design document for details). A minimum set of standard data elements will be collected in all for-hire catch/effort surveys (refer to the ACCSP Program Design document for details).

3.4.4 At-Sea Observer Program

The ACCSP at-sea observer program is a mandatory program. As a condition of state and/or federal permitting, vessels should be required to carry at-sea observers when requested. A minimum set of standard data elements will be collected through the ACCSP at-sea observer program (refer to the ACCSP Program Design document for details). Specific fisheries priorities will be determined by the Discard/Release Prioritization Committee.

3.4.5 Vessel Registration System

The ACCSP has recommended the development of a standardized national fishing vessel registration system (VRS) through upgrades and expansions of the current Vessel Identification System (VIS). The VIS is an integration of the Coast Guard documentation and individual state registration systems. A minimum set of standard data elements will be collected through the VIS (refer to the ACCSP Program Design document for details).

4.0 MANAGEMENT PROGRAM IMPLEMENTATION

Management of American eel will be based on scientific advice provided by the Technical Committee, as well as input from public hearings and the Advisory Panel. In general, management will strive for a long-term sustainable population, with a surplus to support recreational, subsistence and commercial fisheries.

Each state must implement the required management measures and should protect American eel habitat within its jurisdiction to ensure the viability of the population segment residing within its boundaries. States must work with Native American tribal nations and other management jurisdictions within their boundaries in the management of American eel resources.

4.1 RECREATIONAL FISHERIES MANAGEMENT MEASURES

Currently there are observed but undocumented recreational fisheries for American eel. The harvest rate is unknown, as is the discard mortality rate of the bycatch of American eel from recreational fisheries for other species.

In order to minimize the chance of excessive recreational harvest, as well as circumvention of commercial eel regulations, the ASMFC member states/jurisdictions shall establish uniform possession limits for recreational fisheries of a six inch minimum size and a possession limit. Recreational anglers may possess no more than 50 eels per person, including crew members involved in party/charter (for-hire) employment, for bait purposes during fishing. Recreational fishermen will not be allowed to sell eel without a State license permitting such activity.

4.2 COMMERCIAL FISHERIES MANAGEMENT MEASURES

States shall institute licensing and reporting mechanisms to ensure that annual effort (including total units of gear deployed) and landings information by life stage (glass eel/elver, yellow eel, and silver eel) are provided by harvesters and/or dealers. In addition, the ACCSP will require a comprehensive permit/license system for all commercial dealers and fishermen.

4.2.1 Management Measures

States/jurisdictions shall maintain existing or more conservative American eel commercial fishery regulations, including gear specifications contained in Table 2, for all life stages. States with minimum size limits for commercial eel fisheries shall retain those minimum size limits, unless otherwise approved by the American Eel Management Board. The provisions listed within this paragraph are considered a compliance requirement and are effective immediately upon adoption of the FMP by the ASMFC.

Management measures include all mandatory monitoring and annual reporting requirements as described in Sections 3.4.1 and 5.1.2. Specifically, harvest, effort, and biological information shall be provided as per Section 3.4 for each life stage exploited in each jurisdiction. Wherever practical, monitoring requirements in Section 3.4.1 are consistent with current and future mandates of the Atlantic Coastal Cooperative Statistics Program (ACCSP). Monitoring elements not covered by ACCSP must still be covered by state agencies and reported as per Section 3.4.1. States may also propose alternative management programs as per Section 4.4.

4.3 HABITAT CONSERVATION AND RESTORATION

Protection of habitat such as nursery area is critical to the continued survival of American eel. Each state should identify, categorize, and prioritize important and historic American eel habitat within areas of its jurisdiction. Periodic monitoring should be designed and implemented to ensure the long-term viability of essential American eel habitat.

Barriers restrict or prevent migration into current and historical habitat, thereby, reducing total production. Successful upstream and downstream fish passage past barriers is essential to ensuring maximum spawning stock biomass of emigrating silver eels from the U.S. Atlantic coast (Lary and Busch, 1997).

In areas where residential and commercial development is adjacent to American eel habitat, state marine fisheries agencies should coordinate efforts with their inland fisheries/wildlife agencies and others (for example, state agencies with responsibility for soil and water conservation and water quality) to implement remedial actions to restore habitat. State marine fisheries agencies should also coordinate with their state water quality agencies responsible for developing and implementing river basin and wetland restoration plans, to ensure that American eel habitat is identified and considered in these plans, and that these plans are implemented. Also, state marine fisheries agencies should coordinate their concerns with the Army Corps of Engineers since they have authority to investigate, study, modify, and construct projects for habitat restoration, under Section 1135(b) of the Water Resources Development Act of 1986, and also under Section 206 of this same Act.

State marine fisheries agencies should coordinate with their state inland fisheries/wildlife agencies to identify migration times, through site-specific data collection and monitoring. This information should be used to provide comment to permitting agencies regarding seasonal restrictions on activities that may disturb or retard eel migration and feeding behaviors. Construction activities should be avoided in critical migration periods. However, the specific seasonal restriction dates for any particular area should be based on site-specific data and appropriate monitoring. States should consider obtaining land adjacent to critical migration corridors and staging areas to ensure their long-term protection. Protection of American eel habitat or areas of particular concern should be pursued through acquisition, deed restrictions, or conservation easements. State fisheries agencies should also work with their state soil and water conservation agencies and/or agricultural agencies to provide information on these habitats, to be used in their decisions regarding the state's riparian buffer program.

4.3.1 Preservation of Existing Habitat

Sargasso Sea

State marine fisheries agencies should be proactive in identifying opportunities to protect the health of the Sargasso Sea area through partnerships with NOAA and NMFS, including the implementation of the SAFMC's Fishery Management Plan for Pelagic *Sargassum* Habitat of the South Atlantic Region (SAFMC 1998).

4.3.2 Habitat Restoration, Improvement, and Enhancement

Reestablishment of Eel into Historic Habitats

ASMFC participating states/jurisdictions marine fisheries agencies are encouraged to collaborate with their sister inland management agencies, as well as with other Federal and State agencies, and Native American governments to mitigate to the extent possible the effects of various hazards to the upstream and downstream migration of American eel. Such mitigation should include, but not be limited to support of fish passage research, requirements for the construction of fish (eel) passage facilities upon construction of dams, power generating facilities and relicensing of same, and outright removal of identified hazards to eel passage.

Upstream passage

State marine fisheries agencies should cooperate with their inland fisheries/wildlife agencies and the USFWS to improve access to upstream reaches of streams currently restricted by dams with no ladders, helping to increase access to more habitat for feeding and growth. Although it is often assumed that navigation locks will provide unhindered upstream access for eel, this is not a proven, effective passageway due to the great fluctuations in water flow during lock operation (Lary and Busch 1997). Trap and truck methods have also been suggested as a process for eel passage. This has not been adequately evaluated as to effectiveness or the impact on the species, such as changes in the natural selection process. However, trap and transport of glass eels and elvers could be a cost effective, short-term method of upstream passage if it involved volunteers or harvesters who returned a portion of their glass eel/elver catch upstream of impassable blockages.

Downstream passage

State and federal agencies should investigate changes in turbine design to improve downstream fish passage and continue efforts to direct eel away from turbine passage to other higher survival passage opportunities. Investigations should also include feasibility of dam shut-downs during off-peak/night time hours to encourage passive escapement of migrating adult eels.

Monitor enhancement efforts

State and federal agencies should monitor and report on the amount of habitat opened through upstream passage projects and any associated changes in emigrating eel abundance. Passability of blockages for different size classes of eels should also be evaluated.

4.3.3 Avoidance of Incompatible Activities

Each state should establish windows of compatibility for activities known or suspected to adversely affect American eel life stages and their habitats (e.g. dredging, filling, aquatic construction) as well as notify the appropriate construction or regulatory agencies in writing.

Projects involving water withdrawal from important habitats (e.g. feeding grounds) should be scrutinized to ensure that adverse impacts resulting from impingement, entrainment, and/or

modification of flow, temperature and salinity regimes due to water removal will not adversely impact American eel in any life stage.

Each state which contains growth areas within its jurisdiction should develop water use and flow regime guidelines which are protective of American eel habitat and which will ensure to the extent possible the long-term health and sustainability of the stock. States should endeavor to ensure that proposed water diversions/withdrawals from rivers tributary to important habitats will not reduce or eliminate conditions favorable to American eel which make use of these areas.

4.3.3.1 Contaminants

American eel accumulate high concentrations of contaminants, potentially causing increased incidence of reproductive impairments. In the St. Lawrence River migrating silver eel, vertebral malformations and basophilic foci (lesions) in the liver were found to be most common in contaminated eel, while nematodes were present in American eel that were less contaminated (Couillard, et. el. 1997). Another study found that the highest concentrations of chemicals were found in the gonads (Hodson et.al. 1994).

Documentation of American eel being used as an indicator species for contaminant levels could not be found. Little work has been done on the effects of pollutants and the tolerance limits of American eel (Facey and Van Den Avyle 1987). Toxicity studies of aquacultural chemicals effects on the various life stages of the American eel suggest increased tolerance with size and age (Hinton and Eversole 1978, 1979, 1980). However, an accidental release of toxins into the Rhine River in 1986 killed hundreds of thousands of European eel (Facey and Van Den Avyle 1987). American eel tend to bioaccumulate heavy metals endemic to their freshwater habitat (Moreau and Barbeau 1982). Apparently, they also bioaccumulate other toxins as well. In 1976, New York's Departments of Health and Environmental Conservation banned the sale and possession of American eel taken from Lake Ontario and the Hudson River because of excessive polychlorobiphenyls (PCB) levels (greater than the legal limit of 2 ppm). Hudson River American eel were reported to have from 50 to 75 ppm and the Lake Ontario eel had 2.5 to 4.5 ppm of PCB's (Blake 1982). American eel are apparently sensitive to hypoxia and have been reported to select waters with high oxygen tensions (Hill 1969, Sheldon 1974). Tesch (1977) wrote, " the eel survives better in air than in poorly oxygenated or polluted water." American eel are especially susceptible to the accumulation of toxic compounds because of their long residence in aquatic habitats and their accumulation of lipids prior to migration. The impact of these toxic compounds on the American eel themselves has not been studied. However, these compounds can pass through the food chain and accumulate in human and wildlife consumers of American eel where they can increase the risk of cancer or interfere with normal reproduction. Furthermore, while clearly posing some risk to all consumers, the bioaccumulation of contaminants is a particularly critical issue to subsistence users of American eel, such as Native American tribes. This is because such user groups likely consume fish at far higher rates than either recreational fishers or individuals that purchase and consume American eels from commercial sources. Clearly, maintaining good water quality is important for maintaining the health of both humans and wildlife. Federal and state fishery management agencies should take steps to limit the introduction of compounds which pose a threat to human or American eel health.

American eel from the Kennebec River (Richmond) and the Penobscot River (Bangor) have been tested for dioxin (Mower 1996), and American eel from the west branch of the Piscataqua River (Falmouth) have been tested for heavy metals, PCBs, and organochloride pesticides (Sowles et al. 1996). Dioxin levels for Kennebec River and Penobscot River eel exceeded the maximum allowable concentrations recommended by the Department of Human Service's Bureau of Health. Eel from the Piscataqua River exceeded the Bureau's recommended Fish Consumption Advisory Threshold for mercury; had the highest levels of chromium, zinc, and chlordane of all the fish collected from the site; exceeded the EPA's Risk Based Consumption Limit (RBCL) and screening value (SV) for PCBs and coPCBs; and exceeded the RBCL for DDT. The RBCL is the highest concentration that allows for unlimited consumption for the most conservative exposure scenario (e.g. children versus adults), and the SV is a recommended safe concentration based on effects to the general population of adults.

Toxicological studies have indicated the American eel in certain areas bioaccumulate polychlorinated biphenols (PCBs) in levels above the food health standard (2.0 ppm) (Sowles et al, 1997). American eel have a high fat content and a bioaccumulation of many toxins occurs in the fat of the fish. Studies have also shown bioaccumulation of mercury and other heavy metals, dioxin and chlordane at levels warranting attention in some jurisdictions. Some states have issued health advisories regarding consumption of American eel. The impact of these chemicals on the health and reproductive capacity of American eel themselves is unknown.

4.3.4 Fisheries Practices

The use of any fishing gear or practice, which is documented by management agencies to have an unacceptable impact on American eel (e.g. habitat damage, or bycatch mortality), should be prohibited within the effected important habitats.

4.4 ALTERNATIVE STATE MANAGEMENT REGIMES

With approval of the American Eel Management Board, a state may vary its regulatory specifications listed in Section 4, so long as that state can show to the Board's satisfaction that the goals and objectives of this FMP will still be met.

4.4.1 Procedures

Procedures to modify state regulations include the following:

(a) A state may submit a proposal for a change to its regulatory program or any mandatory compliance measure under the Plan to the ASMFC. Changes shall be submitted to the ASMFC staff, who will distribute the proposal to the Management Board, the Plan Review Team, the Technical Committee, the Stock Assessment Committee, and the Advisory Panel.

(b) States must submit a proposal at least two weeks prior to the Technical Committee's spring or fall meeting.

(c) The Plan Review Team is responsible for gathering the comments of the Technical Committee, the Stock Assessment Committee, and the Advisory Panel, and presenting these comments to the Management Board for action.

(d) The Management Board will approve the state proposal for an alternative management program if it determines that the alternative management program is consistent with the goals and objectives of this Plan.

4.4.2 *De minimis* Status

The ASMFC Interstate Fisheries Management Fisheries Program Charter defines *de minimis* as "a situation in which, under existing condition of the stock and scope of the fishery, conservation, and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coast-wide conservation program required by a Fishery Management Plan or amendment."

Under this FMP, *de minimis* status would exempt a state from having to adopt the commercial and recreational fishery regulations for a particular life stage listed in Section 4 and any fishery-dependent monitoring elements for that life-stage listed in Section 3.4.1. States may apply for *de minimis* status for each life stage if (given the availability of data), for the preceding two years, their average commercial landings (by weight) of that life stage constitute less than one percent of coast wide commercial landings for that life stage for the same two-year period. States may petition the Board at any time for *de minimis* status, if their fishery falls below the threshold level. Once *de minimis* status is granted, designated States must submit annual reports to the Board justifying the continuance of *de minimis* status.

4.5. ADAPTIVE MANAGEMENT

Under adaptive management, the American Eel Management Board may vary the requirements specified in Sections 3 or 4 of this FMP. Such changes will be effective on January 1 (or on the first fishing day of the year), but may be put in place on an alternative date when deemed necessary by the Management Board.

Procedures to implement adaptive management are as follows:

- (a) The Plan Review Team (PRT) will continually monitor the status of the fishery and the resource, and report to the Management Board on or about October 1. The PRT will consult with the Technical Committee, the Stock Assessment Committee, and the Advisory Panel, in making their review and report. The report will contain recommendations concerning proposed adaptive revisions to the management program.
- (b) The Management Board will review the PRT report, and may consult independently with the Technical Committee, the Stock Assessment Committee, or the Advisory Panel. The Management Board may direct the PRT to prepare an addendum to effect changes it deems necessary. The addendum shall contain a schedule for the states to implement its provisions.

- (c) The PRT will prepare a draft addendum as directed by the Management Board, and shall distribute it to all states for review and comment. The Management Board shall, in coordination with each relevant state, utilizing that state's established public review process, ensure that the public has an opportunity to review and comment upon proposed adaptive management changes. The PRT will also request comment from federal agencies and the public at large. After a 30-day review period, the PRT will summarize the comments and prepare a final version of the addendum for the Management Board.
- (d) The Management Board shall review the final version of the addendum prepared by the PRT, and also shall consider the public comments received and the recommendations of the Technical Committee, the Stock Assessment Committee, and the Advisory Panel; it shall then decide whether to adopt or revise the addendum.
- (e) Upon adoption of an addendum, states shall prepare plans to carry out the addendum and submit them to the Management Board for approval, according to the schedule contained in the addendum.

4.6 EMERGENCY PROCEDURES

Emergency procedures may be used by the American eel Management Board to require any emergency action that is not covered by or is an exception or change to any provision in this fishery management plan. Procedures for implementation are addressed in the ASMFC Interstate Fisheries Management Program Charter, Section 6 (c) (10) (ASMFC 1998).

4.7 MANAGEMENT INSTITUTIONS

4.7.1. Atlantic States Marine Fisheries Commission and ISFMP Policy Board

The Atlantic States Marine Fisheries Commission (Commission) and the Interstate Fisheries Management Program (ISFMP) Policy Board are responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans and amendments thereto, and must make final determinations concerning state compliance or noncompliance. The ISFMP Policy Board reviews recommendations of the various Management Boards and, if it concurs, forwards them to the Commission for action.

4.7.2 American Eel Management Board

The American Eel Management Board is responsible for the development of a fishery management plan or amendment, and has voting representatives from Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Potomac River Fisheries Commission, District of Columbia, Virginia, North Carolina, South Carolina, Georgia, Florida, the USFWS, and the NMFS. The Board shall provide the ISFMP Policy Board with review and recommendations based on the fishery management plan. The Board may, after the necessary plan or amendment has been approved by the Commission, continue to monitor the implementation and enforcement of the fishery management plan or amendment, advise the ISFMP Policy Board of its effectiveness, or take other actions specified in the fishery management plan that are necessary to ensure its full and effective implementation.

The Board may directly consult with the chairs of the Technical Committee, Plan Review Team, Citizens' Advisory Panel and a representative from the ASMFC Law Enforcement Committee.

4.7.3 Plan Review Team

The Plan Review Team (PRT) is a small group whose responsibility is to provide staff support necessary to carry out and document the decisions of the Management Board. The PRT is directly responsible to the Management Board for providing information and documentation necessary to carry out the Board's decisions.

4.7.4 Technical Committee

The Technical Committee will consist of one representative from each jurisdiction and federal agency with an interest in the American eel fishery. Its role is to act as a liaison to the individual state agencies, providing information to the management process and review and recommendations concerning the management program. The Technical Committee will report to the Management Board, normally through the PRT.

4.7.5 Stock Assessment Subcommittee

The Stock Assessment Subcommittee (SASC) will consist of those scientists with expertise in stock assessment methods. Its role is to assess American eel populations and provide scientific advice concerning the implications of proposed management alternatives, or to respond to other scientific questions of the Management Board. The Stock Assessment Subcommittee membership will be proposed by the Technical Committee, and approved by the Management Board. The Stock Assessment Subcommittee will report to both the Plan Review Team and the Technical Committee.

4.7.6 Advisory Panel

The American Eel Advisory Panel is established according to the ASMFC Advisory Committee Charter. Members of the Advisory Panel are citizens who represent a cross-section of commercial and recreational fishing interests and others concerned about American eel conservation and management. The Advisory Panel provides the Management Board with advice directly concerning the Commission's American eel management program.

4.7.7 Departments of Commerce and Interior

The Commission has accorded NMFS (Department of Commerce) and the USFWS (Department of the Interior) voting status on the ISFMP Policy Board and the American Eel Management Board. These federal agencies may participate on the Plan Review Team, the Technical Committee, and the Stock Assessment Committee.

4.8 RECOMMENDATIONS TO THE SECRETARIES

Secretary of Commerce

The ASMFC recommends that the Secretary of Commerce address and initiate controls over harvest and use of American eel in federal waters (3-200 nautical miles offshore) that are not landed in states. Specifically, the ASMFC recommends that the Secretary of Commerce ban harvests of American eel at any life stage in the EEZ, but permits the possession of up to 50 eel per person as bait

Secretary of Interior

The U.S. Fish and Wildlife Service should provide an annual report, using the Service's new nationwide fish impediment database, documenting the progress made in alleviating barriers to passage for species managed by the Commission, including American eel.

In addition to existing channels for documenting exports, it is also recommended that the Secretary of the Interior proceed with listing American eel glass eel and elvers in Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). An Appendix III listing in no manner prohibits the harvest of American eel at any life stage. The Appendix III listing would improve law enforcement and shipment monitoring of glass eel and elvers in the lucrative but largely undocumented international trade. The listing provides for monitoring and inspection at the port of departure and also at the port of arrival of the importing country through the use of a permit system. A CITES Appendix III export permit indicates that a legal harvest has taken place in accordance with the permit issuing authority.

This listing has been recommended, in part, because of discrepancies in law enforcement reports that monitored only a portion of all live eel exports. In this limited number of inspected shipments, U.S. Customs Service records showed export weights that far exceeded National Marine Fisheries Service estimates of the east coast's entire American eel harvest. These data may indicate a need for better export tracking mechanisms through CITES permitting, but do not diminish the continuing need for state and local law enforcement in the field.

5.0 COMPLIANCE

5.1 MANDATORY COMPLIANCE ELEMENTS FOR STATES

Upon completion and approval of a management plan, Commission participating jurisdictions (ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, PRFC, DC, VA, NC, SC, GA, FL) are obliged to implement its requirements, unless exempted by *de minimis* status. If a state does not comply with the conservation measures of the Commission's fishery management plan, the law allows the U.S. Secretary of Commerce to impose a moratorium on that state's particular fishery. All Commission fishery management plans must include specific measurable standards to improve the status of the stocks and to determine if the states comply with the standards.

5.1.1 Mandatory Elements of State Programs

The following lists the mandatory program elements required for all participating states/jurisdictions to remain in compliance with this Fisheries Management Plan. Details of these compliance requirements are discussed in the identified sections.

1. Annual Young-of-Year Abundance Survey (Section 3.1.1)
2. Annual State Report on Regulations, Harvest, Effort, Bycatch, and Fishery Independent Surveys for American Eel (Section 3.4.1).
3. Recreational Fisheries Management Measures (Section 4.1).
4. Commercial Fisheries Management Measures (Section 4.2).

A state will be found out of compliance if:

- (a) The American Eel Management Board has not approved the regulatory and management programs for American eel.
- (b) It fails to meet any implementation schedule established in this FMP or any addendum prepared under adaptive management (see Section 4.5).
- (c) It fails to conduct an annual young-of-year abundance survey, unless otherwise exempted by the Management Board, beginning in the year 2000. If initially exempted states fail to conduct the young-of-year survey by the year 2001 (See Section 3.1.1).
- (d) It fails to implement a change to its program when determined necessary by the American Eel Management Board.
- (e) It fails to adequately enforce any aspect of its regulatory and management programs.

5.1.1.1 Regulatory Requirement

All state programs must include a regime of restrictions on recreational and commercial fisheries consistent with the requirements of Sections 4.1 and 4.2; except that a state may propose an alternative management program under Section 4.4. If approved by the American Eel Management Board, the state's proposal may be implemented as an alternative regulatory requirement for compliance under the law.

5.1.1.2 Monitoring Requirements

All state programs must include the mandatory monitoring requirements contained in Section 3.4.1 of the Plan. States must submit proposals to the Commission for any proposed changes to the required monitoring programs if the change may affect the quality of the data or the ability of the program to fulfill the needs of the fishery management plan. State proposals for modifications to required monitoring programs will be submitted to the Technical Committee at least two weeks prior to its spring or fall meetings. Proposals must be on a calendar year basis.

The Technical Committee will make recommendations to the American Eel Management Board concerning whether the proposals are consistent with the Plan.

If a state realizes it will be unable to fulfill its fishery monitoring requirements, it should immediately notify the Commission in writing. The Commission must be notified by the planned commencement date of the monitoring program.

The Commission will work with the state to develop a plan to secure funding or to plan an alternative program that will satisfy the needs outlined in this FMP (the Plan).

Each year, the ASMFC's Law Enforcement Committee (LEC) shall discuss new or chronic problems in enforcing eel regulations or prosecuting violators of these regulations. The LEC shall also make recommendations to improve enforcement and understanding of the regulations.

5.1.2 State Reporting and Compliance Schedule

Each state must submit an annual report concerning its American eel fisheries and management program on or before September 1 each year. The report shall cover:

(a) The previous calendar year's fishery and management program, including activity and results of monitoring (as identified in Section 3.4.1. of the Plan), regulations that were in effect, and harvest, including estimates of non-harvest losses and effort.

(b) The planned management program for the current calendar year (summarizing regulations that will be in effect and monitoring programs to be performed) highlighting any changes from the previous year.

States must implement this Plan according to the following schedule:

May 1, 2000: States must submit state programs to implement the Plan for approval by the Management Board. Programs, including monitoring programs, must be implemented upon approval by the Management Board.

January 1, 2001: States with approved management programs must begin implementing the Plan (or earlier if desired).

5.2 PROCEDURES FOR DETERMINING COMPLIANCE

A. The PRT will continually review the status of state implementation of the Plan, and advise the American Eel Management Board whenever a question arises concerning state compliance. The PRT will review state reports submitted under Section 5.1.2 and prepare a report for the American Eel Management Board, summarizing the status of the resource and fishery and the status of state compliance on a state-by-state basis.

B. Upon receipt of a report from the PRT, or at any time by request from a member of the American Eel Management Board, the Management Board will review the status of an individual state's compliance. If the Management Board finds that a state's regulatory and management

program fails to meet the requirements of this section, it may recommend that the state is out of compliance. The recommendation must include a specific list of the state's deficiencies in implementing and enforcing the Plan and the actions that the state must take in order to come back into compliance.

C. If the American Eel Management Board recommends that a state is out of compliance, as referred to in the preceding paragraph, it shall report that recommendation to the ISFMP Policy Board for further review according to the *ASMFC Charter for the Interstate Fisheries Management Program*.

D. A state that is out of compliance or subject to a recommendation by the American Eel Management Board under the preceding subsection may request at any time that the Management Board reevaluate its program. The state shall provide a written statement concerning its actions to justify a reevaluation. The Management Board shall promptly conduct such reevaluation (e.g., within 30 days), and if it agrees with the state, the Management Board shall recommend to the ISFMP Policy Board that the determination of noncompliance be withdrawn. The ISFMP Policy Board and the Commission shall address the Management Board's recommendation according to the *ASMFC Charter for the Interstate Fisheries Management Program*.

6.0 INFORMATION AND RESEARCH NEEDS

6.1 MANAGEMENT AND REGULATORY

Issues that have been identified as needed to support the management of American eel (order does not indicate importance). Information needed for regulations to manage harvest, include but not limited to:

- License fees, life stage, size, geographic area, and gear type.
- Design and implement an annual, fishery-independent, glass eel abundance survey.
- Assess American eel landing records for all life stages to determine their completeness and adequacy for evaluating the eel fishery; monitor population trends; commercial and recreational harvest; and, effects of gear type on harvest rates. If necessary, determine what data are needed to improve landing records.
- Evaluate the impact of American eel aquaculture on fish health, eel culture/hatcheries, and import and/or export concerns.
- Management of the species and its harvest by non-member jurisdictions (e.g., Vermont, West Virginia, Great Lakes States, Gulf Coast States and Canada).
- Quantify and qualify the economic considerations of exporting various American eel life stages.

- Quantify and qualify the economic considerations of the American eel bait fishery.

6.2 STOCK ASSESSMENT AND POPULATION DYNAMICS

To collect information to assist in future management decisions, a comprehensive monitoring plan must be developed throughout the Atlantic Coast as described in Section 3.4. In addition to the comprehensive monitoring plan, additional stock assessment and population dynamics information should be collected to assist in future management decisions including the following:

- Conduct additional stock assessments and determine harvest mortality rates. Use these data to develop a more reliable sustainable harvest rate.
- Further evaluate life history (table) information including sex ratio and population age structure.
- Formulate a coast wide sampling program for American eel using standardized and statistically robust methodologies.
- Contaminant effects on the fishery and effects of bioaccumulation with respect to harvest and sale prohibitions.
- Size-age-sex distributions within selected drainage containing different habitat types.
- Predator-prey relations: a) food habits of American eel in various habitats and b) predation on eel.
- Movements of American eel within a drainage during the yellow eel stage: a) degree of movement of eel between fresh waters and estuaries and b) degree of movements within fresh waters.

6.3 RESEARCH

Numerous additional data needs have been identified to improve the understanding of the life history of this species and the anthropogenic stresses that may influence its health and abundance.

- Stock assessment and determination of fishing mortality rates (F) to develop a sustainable harvest rate.
- Economic studies are necessary to determine the value of the fishery and the impact of regulatory management.
- Investigate: mechanism of sex determination; growth rates for males and females throughout their range; habitat preferences of males and females; predator-prey relationships; behavior and movement of American eel during their freshwater residency; oceanic behavior, movement and spawning location of mature adult American eel; and all information on the leptocephalus stage of the American eel.

- Evaluate contaminant effects on American eel and the effects of bioaccumulation with respect to impacts by age on survival and growth and effect on maturation and reproductive success.
- Investigate mode of nutrition of American eel leptocephali in the ocean.
- Determine growth rates of male and female American eel in different habitats.
- Determine if geographic sub-populations exist, which may have implications for management.
- Investigate larval and juvenile survival and mortality to assist in the assessment of annual recruitment. Such research could be aided by continuing and initiating new tagging programs within individual states.
- Determine food habits of glass eel while at sea.
- Investigate location and triggering mechanism for metamorphosis from leptocephalus to glass eel.
- Investigate mechanisms of exit from the Sargasso Sea and of transport across the continental shelf.
- Evaluate the impact, both upstream and downstream, of barriers on American eel with respect to population and distribution affects. Determine areas of extirpation and historical distribution.
- Investigate, develop, and improve technologies for American eel passage upstream and downstream.
- Evaluate the ecosystem importance of American eels as prey, predators, and mechanisms of transporting freshwater biomass to marine systems.
- Determine fecundity-length and fecundity-weight relations for female American eel from various parts of its geographic range.
- Determine mortality rates at different life history stages (leptocephalus, glass eel, yellow eel, and silver eel) and mortality rates with size within the yellow eel stage.
- Investigate mechanism of sex determination in American eel.
- Determine age at entry of glass eel into estuaries and fresh waters.
- Investigate migratory routes and guidance mechanisms for silver eel in the ocean.
- Investigate mechanisms of recognition of the spawning area by silver eel.

- Investigate mate location in the Sargasso Sea.
- Conduct studies on spawning behavior.
- Determine gonadal development in maturation.
- Conduct workshop on aging techniques.
- Sustainable fishing mortality rates (F) for American eel have not been examined. Researchers and fishery managers have not determined the best means to ensure the stability of the American eel populations
- Identification and understanding of American eel habitat needs for all life stages
- Model the effect of increased habitat availability and reductions in mortality at various freshwater lifestages on escapement.
- Research the impacts of elver fishing on the abundance and distribution of later lifestages within a watershed and what, if any, impacts there are on sexual determination and upstream migration.
- Research techniques (physical and behavioral) for providing upstream and downstream passage around dams
- Research the feasibility and ecological/genetic impacts of trap and truck programs for elvers
- Quantify and assess male eel habitat and male eel abundance
- Quantify and estimate the impact of the bait fishery for juvenile/bootstrap eels.

7.0 PROGRAM MANAGEMENT OPTIONS

7.1 IMPROVE IMPLEMENTATION EFFECTIVENESS

This FMP outlines a number of management actions addressing American eel (Section 3.1-3.3) and its habitats (Section 3.5). Since American eel are one population, management effectiveness would increase through focused coordination and standardization of most monitoring, assessment, and restoration activities throughout its range. This centralized approach could provide leverage for funding (internal and external), prioritization of research, and a central repository of information and data.

7.1.1 New Funding Options

New, dedicated funds would improve and expedite implementation of this FMP.

Recommendation by the American Eel Management Board to the ASMFC members requesting their active support is needed. The following options have been suggested:

- A. Advisory Panel member recommendation for a federal “migratory fish stamp,” similar to the migratory bird stamps, with the funds dedicated to habitat restoration and enhancement.
- B. A current effort underway by members of the hydropower industry to obtain funds from Congress to target multi-year American eel research and management enhancement.
- C. Improve coordination and partnerships with other agencies with complementary missions, such as USEPA and the USACOE, to assess the ecological health of coastal watersheds and to restore them.

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9.0 APPENDIX

ATTACHMENT 1: NMFS Commerical Landing for American Eel (pounds) for the Atlantic and gulf Coasts of the U.S. by jurisdiction (Personal Communication from the NMFS, Fisheries Statistics and Economics Division, 11-15-99).

State/Province	1950 - 1996 Total pounds	Percent of total	1987 - 1996 Total pounds	Percent of total
Virginia	21228939	26.01	4087675	29.93
Maryland	12021898	14.73	1975350	14.46
P.R.F.C.	9666343	11.84	2457555	18.00
North Carolina	8102355	9.93	859843	6.30
New Jersey	7313446	8.96	1855346	13.59
New York	7088810	8.68	344310	2.52
Delaware	3798000	4.65	1398200	10.24
Massachusetts	3580451	4.39	195251	1.43
Florida East Coast	3080542	3.77	6685	0.05
Maine	2318655	2.84	259971	1.90
Connecticut	949058	1.16	165758	1.21
Rhode Island	912300	1.12	6900	0.05
South Carolina	600200	0.74	0	0.00
Florida Inland Lakes	355400	0.44	0	0.00
Georgia	250436	0.31	9048	0.07
New Hampshire	206237	0.25	2379	0.02
Florida West Coast	108508	0.13	32188	0.24
Louisiana	50614	0.06	0	0.00
Texas	98	0.00	98	0.00
Total	81632290	100	13656557	100